HEALTHCARE SIMULATION AND ONLINE LEARNING

EDITED BY: Zaleha Abdullah Mahdy, Michelle A. Kelly, Ismail Mohd Saiboon and Dinker R. Pai

PUBLISHED IN: Frontiers in Surgery, Frontiers in Medicine, Frontiers in Pediatrics, Frontiers in Public Health and Frontiers in Oncology

frontiers Research Topics

ISSN 1664-8714
ISBN 978-2-88976-503-4
DOI 10.3389/978-2-88976-503-4

About Frontiers

Frontiers is more than just an open-access publisher of scholarly articles: it is a pioneering approach to the world of academia, radically improving the way scholarly research is managed. The grand vision of Frontiers is a world where all people have an equal opportunity to seek, share and generate knowledge. Frontiers provides immediate and permanent online open access to all its publications, but this alone is not enough to realize our grand goals.

Frontiers Journal Series

The Frontiers Journal Series is a multi-tier and interdisciplinary set of open-access, online journals, promising a paradigm shift from the current review, selection and dissemination processes in academic publishing. All Frontiers journals are driven by researchers for researchers; therefore, they constitute a service to the scholarly community. At the same time, the Frontiers Journal Series operates on a revolutionary invention, the tiered publishing system, initially addressing specific communities of scholars, and gradually climbing up to broader public understanding, thus serving the interests of the lay society, too.

Dedication to Quality

Each Frontiers article is a landmark of the highest quality, thanks to genuinely collaborative interactions between authors and review editors, who include some of the world's best academicians. Research must be certified by peers before entering a stream of knowledge that may eventually reach the public - and shape society; therefore, Frontiers only applies the most rigorous and unbiased reviews.
Frontiers revolutionizes research publishing by freely delivering the most outstanding research, evaluated with no bias from both the academic and social point of view. By applying the most advanced information technologies, Frontiers is catapulting scholarly publishing into a new generation.

What are Frontiers Research Topics?

Frontiers Research Topics are very popular trademarks of the Frontiers Journals Series: they are collections of at least ten articles, all centered on a particular subject. With their unique mix of varied contributions from Original Research to Review Articles, Frontiers Research Topics unify the most influential researchers, the latest key findings and historical advances in a hot research area! Find out more on how to host your own Frontiers Research Topic or contribute to one as an author by contacting the Frontiers Editorial Office: frontiersin.org/about/contact

HEALTHCARE SIMULATION AND ONLINE LEARNING

Topic Editors:
Zaleha Abdullah Mahdy, National University of Malaysia, Malaysia
Michelle A. Kelly, University of South Australia, Australia
Ismail Mohd Saiboon, National University of Malaysia, Malaysia
Dinker R. Pai, Sri Balaji Vidyapeeth University, India

Citation: Mahdy, Z. A., Kelly, M. A., Saiboon, I. M., Pai, D. R., eds. (2022). Healthcare Simulation and Online Learning. Lausanne: Frontiers Media SA.
doi: 10.3389/978-2-88976-503-4

Table of Contents

frontiers | Frontiers in Surgery

EDITORIAL
published: 10 June 2022
doi: 10.3389/fsurg.2022.944020

Editorial: Healthcare Simulation and Online Learning

Zaleha Abdullah Mahdy[1]*, *Ismail Mohd Saiboon*[2], *Dinker R. Pai*[3] *and Michelle A. Kelly*[4]

[1]Department of Obstetrics and Gynaecology, Faculty of Medicine, Universiti Kebangsaan Malaysia, Cheras, Malaysia, [2]Department of Emergency Medicine, Faculty of Medicine, Universiti Kebangsaan Malaysia, Cheras, Malaysia, [3]Medical Simulation Centre, Mahatma Gandhi Medical College and Research Institute, Sr Balaji Vidyapeeth, Puducherry, India, [4]School of Nursing, Curtin University, Perth, Western Australia

Keywords: healthcare simulation, online learning, research topic, technology in education, interprofessional education

OPEN ACCESS

Edited by:
Ferdinand Köckerling,
Vivantes Hospital, Germany

***Correspondence:**
Zaleha Abdullah Mahdy
zaleha@ppukm.ukm.edu.my

Specialty section:
This article was submitted to Visceral Surgery, a section of the journal Frontiers in Surgery

Received: 14 May 2022
Accepted: 23 May 2022
Published: 10 June 2022

Citation:
Mahdy ZA, Saiboon IM, Pai DR and Kelly MA (2022) Editorial: Healthcare Simulation and Online Learning. Front. Surg. 9:944020. doi: 10.3389/fsurg.2022.944020

Editorial on the Research Topic

Healthcare Simulation and Online Learning

Healthcare simulation, delivered in multiple formats inclusive of online learning, has become more important than ever with the changing perceptions among both healthcare professionals and patients about how healthcare training should be conducted, and the central focus on patient safety and clinical competence. The idea of a research topic on healthcare simulation and online learning was first mooted following the inaugural conference of the Malaysian Society for Simulation in Healthcare (MaSSH) in March 2018, seriously pursued after the second MaSSH Conference in July 2019, and submitted to Frontiers in Surgery in 2020. However, in 2020 the COVID-19 pandemic struck, hence lending more weight to virtual simulation-based training, as well as swinging the pendulum of teaching and learning in all fields towards the online platform. We were therefore curious to know how this has impacted healthcare training in various localities globally. In fact, it was pertinent to reflect on strategies that were emerging due to the COVID-19 pandemic.

An editorial team consisting of individuals from different countries was assembled. The team moved through the task and communicated online managing the different time zones, an approach that reflected the theme of this special issue. The research topic was open to all scholars and clinicians, and submissions from numerous professions were received. A total of 32 manuscript submissions were submitted, out of which 15 were finally accepted, hence the work is now available as an eBook. As of 14 May 2022, the number of online views has exceeded 33,900 inclusive of North America, United Kingdom, Europe, and Asia, clearly demonstrating the popularity and global interest in the topic [Healthcare Simulation and Online Learning | Frontiers Research Topic (frontiersin.org)].

The response to this research topic has been an eye opener, as seen from the statistics presented earlier. Even though we have received a record number of submissions and online views, what is especially encouraging has been the diversity of the submissions. This diversity is in the form of article content, and the geographical regions from where the submissions have arisen, mirroring the diverse backgrounds of the guest editors of this research topic. It is heartening to note that many submissions have come from the Asian continent, which is a step in the right direction to make the topic more inclusive. This is also likely to have a spin off effect for the other journals in the Frontiers stable.

To illustrate this point, in terms of geographical distribution there were eight articles from Asia, four from Europe and one each from the United States, Brazil and Australia. In terms of article content, topics ranged from healthcare education to patient education and technology in simulation. To highlight a few, Valentim and co-authors looked at the value of online educational strategies for educating healthcare workers on the specific issues which impacted the health of prisoners in Brazil's correctional system. Mohamad et al looked at how ontology could be used to explore the process of virtual reality (VR) simulator development and utilization. Mockrezecki and co-authors incorporated pharmacy faculty for training final year medical students, a classic example of interprofessional education (IPE), showcasing the benefits of learning together and sharing perspectives in order to understand and consolidate teamwork. The principle of building awareness of others' roles, specialty knowledge and contribution to patient care was explored through a pilot study, which demonstrated that through simulation role-play, medical students' prescribing skills improved significantly with pharmacist-led education. This represents a solid foundation for expanding such an approach to larger groups and highlights its potential to be formally included into future curricula. Another perspective was the utilization of simulation-based education (SBE) in conducting a low-fidelity low-cost in-situ neonatal resuscitation program (Pong et al). The approach was well received by major stakeholders, leading to funding of this type of training, which is well suited to low resource settings. From not knowing whether we would get enough articles for this research topic, to having the pleasure of such a broad tapestry of articles to review, has been a profoundly enriching experience. This reflects the growing uptake and broad applicability of contemporary technologies in health professions education and clinical training.

The sophisticated technologies described within this collection of publications are testament to the current trend in healthcare education. SBE through VR-based training (VRT) was the theme of two publications under this research topic (Mohamad et al, Favier et al), whilst another group described the use of augmented reality (AR) (Cofano et al) in a prospective case series that involved telementoring, hologram and 3D reconstruction in spinal surgery. The use of AR and VR was propagated during the pandemic that imposed huge limitations and obstacles to face-to-face physical classroom teaching-learning activities throughout 2020–2022. Adapting educational materials and adopting online or blended approaches to maintain training and certification during these clinically challenging times was imperative to ensure a sustainable workforce across the globe. Mohamad et al highlighted the development of VRT according to an effective ontology design, offering a different and useful perspective and direction for those wishing to incorporate VRT into the healthcare domain. The authors proposed a solid knowledge base be established to enable a comprehensive strategy for the development of VRT specifically the design of future VR applications especially in the healthcare domain.

Haptic technology in VRT improved the way in which surgical training could be delivered and was seen as a game-changer in surgical-based training, now and for decades to come (Favier et al). The introduction of haptics in VRT produced more immersive training opportunities in many surgical-based fields, compared with traditional training methods. Previously, most surgical training was conducted on patients, leaving very little room for error. The introduction of haptic technology in VRT allowed trainees to hone their surgical skills more quickly through repetitive, flexible and individualized training without fear of making mistakes, potentially shortening the learning curve of a surgeon.

During the COVID-19 pandemic, clinical teaching and the usual classroom-based continuing-medical-education (CME) sessions were significantly disrupted. Medical students in most countries could not access clinical areas such as wards, operating theatres, and emergency rooms, leading most clinician-educators to turn to online teaching approaches through telesimulation and video-based learning. Even though students still preferred the face-to-face approach (Saiboon et al), remote online learning became the lifeline to clinical teaching through an online CME approach (Schulte et al). For simple cognitive learning, like teaching disaster response medicine to preclinical undergraduate medical students, an asynchronous approach was successfully implemented through the **e**-**l**earning **i**n **t**eaching **e**mergency **d**isaster **r**esponse (ELITE DR) module (Saiboon et al). This module allowed flexibility for students to access the teaching material at any time from any place. Skills based teaching as in performing **f**ocused **a**ssessment with **s**onography in **t**rauma (FAST) was conducted successfully through the self-instructional-video (SIV) approach (Isa et al). The authors demonstrated that SIV teaching was not inferior to face-to-face classroom teaching. In fact, training of a more complex surgical procedure like sinus surgery was successfully conducted online using a combination of telesimulation, web-conferencing and task trainer (using 3-D printed sinus models) together with remote supervision and feedback from the subject matter expert (Suzuki et al). Apart from simple cognitive and psychomotor skills training, interactive video usage also promoted teaching of higher order thinking and teamwork, and enhanced the perception of authenticity during online training (Musa et al).

Another important point to emphasize in relation to online video-based learning was the benefit of preparatory educational video material to be viewed before the actual teaching session. This exposure promoted students' curiosity level and correlated positively with subsequent learning and understanding of the topic (Ho et al). In addition, educational videos played a vital role in patient education by reducing preoperative anxiety among parents and their children who were scheduled for surgery (Härter et al).

In summary, it has been a rewarding journey indeed for all four guest editors of this research topic. The project has reaffirmed our belief in simulation as a universally accepted educational modality; the included articles are proof that simulation is adaptable to online platforms and applies across geographical boundaries. Newer cutting-edge technologies offer added and flexible dimensions to the learning experience which, going forward, are likely to be adopted as a matter of routine, judging by the rapidity of development of applications for these modalities in SBE. The beginning has been great; it is now time to carry the journey forward where, based on the level of interest, an entire Frontiers journal on simulation and online learning may emerge, reflected by the level of interest from this current endeavour.

AUTHOR CONTRIBUTIONS

ZAM summarized the publications. MAK wrote the first draft. DRP, IMS and ZAM amended the draft. MAK finalized the draft. All authors contributed to the article and approved the submitted version.

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

frontiers in Pediatrics

PERSPECTIVE
published: 11 February 2021
doi: 10.3389/fped.2021.619035

Simulation-Based Education in the Training of Newborn Care Providers—A Malaysian Perspective

Kwai-Meng Pong [1], Jerrold Tze-Ren Teo [2] and Fook-Choe Cheah [2*]

[1] Pediatrics Department, Penang Adventist Hospital, Penang, Malaysia, [2] Department of Pediatrics, Faculty of Medicine, Universiti Kebangsaan Malaysia, Kuala Lumpur, Malaysia

Simulation-based education (SBE) is increasingly used as an education tool to improve learning for healthcare providers. In newborn care practice, SBE is used in the Neonatal Resuscitation Program (NRP) and training in procedural skills. The NRP is a mandatory course in Malaysia for all house officers (interns) and medical officers (residents) during their pediatric rotation. Almost 30,000 of NRP providers have been trained over the last 5 years. The recent establishment of the Allied Healthcare Center of Excellence (AHCoE), an organization dedicated to promoting SBE, and Malaysian Society for Simulation in Healthcare (MaSSH) aims to enhance the integration of SBE into the healthcare training curriculum and set up a local healthcare simulation educator training program. Our experience in implementing SBE necessitated that we made several important choices. As there was no strong evidence to favor high-fidelity over low-fidelity simulation, and because simulation centers can be very costly to set up with limited resources, we chose SBE mainly in the form of low-fidelity and *in situ* simulation. We also identified an important developmental goal to train Malaysian instructors on structured debriefing, a critical activity for learning in SBE. Currently, debriefing is often carried out in our centers at an *ad hoc* basis because of time limitation and the lack of personnel trained. Finally, we aim to implement SBE further in Malaysia, with two axes: (1) the credentialing and recertification of physicians and nurses, and (2) the education of lay caregivers of high-risk infants before discharge from the neonatal intensive care unit.

Keywords: simulation-based training, low-fidelity simulation, procedural skills, lay caregivers, debriefing, neonatal resuscitation, *in situ* simulation, interprofessional team

OPEN ACCESS

Edited by:
Michelle Ann Kelly, Curtin University, Australia

Reviewed by:
Lama Charafeddine, American University of Beirut, Lebanon
David Drummond, Universitary hospital Necker-Enfants Malades, France

***Correspondence:**
Fook-Choe Cheah
cheahfc@ppukm.edu.my

Specialty section:
This article was submitted to General Pediatrics and Pediatric Emergency Care, a section of the journal Frontiers in Pediatrics

Received: *19 October 2020*
Accepted: *14 January 2021*
Published: *11 February 2021*

Citation:
Pong K-M, Teo JT-R and Cheah F-C (2021) Simulation-Based Education in the Training of Newborn Care Providers—A Malaysian Perspective. Front. Pediatr. 9:619035. doi: 10.3389/fped.2021.619035

INTRODUCTION

In the past 10 years, simulation-based education (SBE) has been increasingly used as an educational tool to improve learning for healthcare providers. SBE is defined as an array of structured activities that represent actual or potential situations in education and practice. These activities allow participants to develop or enhance their knowledge, skills and attitudes, or to analyze and respond to realistic situations in a simulated environment (1, 2). Realistic scenarios in SBE aim to achieve "suspended disbelief" among trainees by replicating real-life situations with high fidelity (3). The anesthesia community first adopted SBE for medical training by using manikins in basic life support training (4, 5). Successful use of SBE has been reported subsequently in other specialties (e.g., emergency medicine, pediatrics, obstetrics and gynecology) (6–10). When SBE is implemented by experienced healthcare educators, it allows learning from mistakes, safe experimentation, deliberate practice, and standardized assessment of competency (11). With the increasingly higher number of medical graduates produced in countries such as Malaysia, there is as such, a declining opportunity for real-life neonatal resuscitation experiences for trainees[1]. Consequently, a new paradigm shift from the traditional "see one, do one, teach one" situations to using medical simulation in learning new skills and achieving competency has emerged.

This review discusses the application of simulation in teaching neonatal resuscitation and procedural skills as the core perspective in the development and promotion of SBE in neonatal practice in Malaysia.

THE INTRODUCTION AND DEVELOPMENT OF A NATIONAL NRP

In September 1996, the Department of Pediatrics of the Universiti Kebangsaan Malaysia (UKM), the Ministry of Health (MOH) of Malaysia and the Perinatal Society of Malaysia (PSM), officially introduced the Neonatal Resuscitation Program (NRP) in this country (12). To ensure a successful dissemination of the program nationwide, the NRP textbook, instructors' manual and test questions were translated into the local Malay language before the Malaysian NRP was launched. Professor Ronald Bloom from the USA was invited to Kuala Lumpur in 1996 to train the first batch of six core NRP instructors. These six instructors trained another 31 doctors and 6 nurses from all of the 13 states in Malaysia. Textbooks, instructor manuals, test questions, and manikins were then distributed to these core instructors for them to initiate the NRP training in their respective home states.

Dissemination of the NRP in Malaysia during the first 2 years was very encouraging. Of the first batch of 37 core instructors, 35 (94.6%) carried out training courses in their respective home states. This resulted in 513 new instructors and 2,256 providers who were trained and certified among health personnel from all over the country (13). Currently, there are 576 active instructors in Malaysia and a total of 29,152 NRP providers trained over the last 5 years (**Table 1**). The PSM is a professional non-governmental organization (NGO) that has taken the initiative to monitor the teaching activities of the NRP instructors as well as being engaged in the re-certification of providers (personal communication with Dr. See KC, director of NRP and affiliated to PSM).

This being a joint-venture effort by an NGO and the university, backed by a government agency (the MOH of Malaysia), showed that it is possible to successfully develop a locally customized NRP based on the original educational materials from an external source, in this case, the American Academy of Pediatrics. With the Malaysian NRP, it is encouraging to note that this SBE program goes in tandem with the improvement of health indicators of this country. The birth asphyxia-related mortality rate has declined to less than one in a million; perinatal mortality rate (PMR) and early neonatal mortality rate (NMR), have declined and stabilized to about eight and four in 1,000 live births, respectively, despite a rising preterm birth rate which doubled in 2013 and 2014. The Malaysian NRP is adjudged to have a positive impact on perinatal and neonatal care of this country (14). For the continuity of this quality improvement intervention, the NRP is a mandatory course funded by the government for all the pediatric house officers and medical officers in Malaysian public and teaching hospitals (15).

INTEGRATING SBE IN THE NRP TRAINING

The earlier versions of NRP training consisted of didactic lectures, videos and skill stations, at which trainees practiced procedural skills on manikins. With this approach, the retention of knowledge and skills among the trainees reportedly lasted for only 6 months (16). The latest version of NRP integrated SBE with emphasis on team performance and behaviors during neonatal resuscitation. It utilizes a multiple learning approach, i.e., online testing, online case-based simulations, practical case-based simulation and debriefing which focus on key behaviors such as communication, critical leadership, and team-work skills (12). Some groups further showed significant improvement in confidence and performance levels among the learners who had a combined traditional and simulation based NRP course compared with the traditional alone. There was apparent improved teamwork and technical skills among the team members in high-fidelity simulation neonatal resuscitation in the delivery suites (17–20). Of note, a study reported reduction in the incidence of hypoxic-ischemic encephalopathy from 37.3 to 13.6 per 10,000 births after a simulation-based training for the perinatal team (21). This highlights the potential benefit of simulation-based training on patient outcomes. Similarly, the Malaysian NRP is deemed to positively impact perinatal-neonatal health outcomes of this country. The Malaysian NRP follows closely the updated versions of its original predecessor.

HIGH-FIDELITY SIMULATION VS. LOW-FIDELITY SIMULATION

Fidelity is the principle of simulating a situation to realistically imitate true physiological realism. High-fidelity simulation (HFS), defined as simulation experiences that are extremely realistic and provide high level of interactivity and realism for the learner using technically sophisticated and computerized simulators manikins, has been used to enhance resuscitation education. On the other hand, low-fidelity simulation (LFS) is defined as simulation training that does not need to be controlled or programmed externally for the learner to participate; examples include case studies, role playing, or task trainers used to support students or professionals in learning a clinical situation or practice (2). The context of high- or low-fidelity may be viewed

[1]Government to resolve issue of housemen placement. Available online at: https://www.nst.com.my/news/nation/2018/06/378286/government-resolve-issue-housemen-placement (accessed June 19, 2020).

TABLE 1 | NRP-trained providers in relation to Malaysian annual live birth, perinatal mortality, and neonatal mortality rates during two different decades.

Year	Number of trained providers$^{\beta}$	Annual live birth^	Perinatal mortality rate^{+} (per 1,000 live birth)	Neonatal mortality rate^{+} (per 1,000 live birth)	Asphyxia mortality rate^{+} (per 1,000,000 live birth)	Preterm delivery$^{\#}$ (Percentage of total deliveries)
1996*	198	544,302	9.1	6.0	na	na
1997*	1,567	540,486	9.0	6.0	na	na
1998*	2,064	524,696	7.9	5.2	na	na
1999*	1,940	521,870	7.3	4.5	na	na
2010	na	491,239	7.7	4.3	4.4	8.1
2011	na	511,594	7.6	4.2	4.0	10.4
2012	na	508,774	7.3	4.0	1.9	11.3
2013	na	503,914	7.3	4.0	2.3	22.1
2014	na	511,865	7.2	3.9	2.0	21.9
2015	na	521,136	7.7	4.3	1.5	12.4
2016	4,362	508,203	8.3	4.2	1.1	11.7
2017	5,906	508,685	8.7	4.4	0.8	8.9

NRP, Neonatal Resuscitation Program; na, not available.
Data from Boo et al. (14).
$^{\beta}$*From the database of the Perinatal Society of Malaysia.*
^*Data from the Department of Statistics, Malaysia*[2].
$^{+}$*Data from the Ministry of Health, Malaysia*[3].
$^{\#}$*Data from the National Obstetrics Registry, Malaysia*[4].

critically as simulation environments may also influence the learning and behavior change of the student.

Residents trained with high-fidelity simulators in neonatal resuscitation performed better in written test scores and a shorter duration taken to achieve successful intubation (22). However, there was no difference between the high- and low-fidelity training in terms of NRP performance score and the resuscitation duration. A randomized trial further demonstrated that there was no significant difference in the performance scores between low-fidelity and high-fidelity in NRP training (23).

Based on these, there is no strong evidence as yet to recommend the use of HFS over LFS. The cost of HFS may be overbearing to many centers in the developing world. There are only a few institutions in Malaysia that have the resources and are equipped with high-fidelity simulators. In a recent survey conducted informally through a neonatal simulation network in Malaysia, only five out of 32 (15.6%) hospitals run HFS. These centers are SBE-dedicated establishments such as the Allied Healthcare Center of Excellence (AHCoE), and several academic teaching hospitals. Those centers that do not run HFS quoted financial constraint as the main obstacle and more than three-quarter would like to have HFS made available with the opinion that this modality may enhance outcomes. Even so, it is important to emphasize that low-fidelity training can be as effective as HFS and the focus should be on the learning objectives and choosing a simulation modality that best meets those needs. The majority of Malaysian centers are still opting for low-fidelity manikins in their resuscitation training programs.

IN SITU SIMULATION IN THE TRAINING OF PROVIDERS

Recently, *in situ* simulation has become a popular form of SBE. In contrast to a dedicated simulation center, *in situ* simulation is held in the actual patient care setting in an effort to achieve a high level of fidelity and realism; for example, in the NICU, ambulance, small aircraft, or catheterization lab. This training is valuable to assess, troubleshoot, or develop new system processes (2).

It allows team members to train in handling rare complex events, to evaluate their team dynamics, and to assess the hospital and departmental policies/procedures in real locations and in real time. It may help to reveal latent safety issues in their actual work environment for potential quality improvement (24–26).

A study has shown significant improvements in teamwork and technical skills of staff members in initial neonatal resuscitation in the labor room after an *in situ* session. The median technical score and the median team score were significantly higher for the scenarios run, with a significant reduction in the number of hazardous events and an improvement in achieving the targeted heart rate (20). Furthermore, an unannounced mock drill in an *in situ* simulation was reported to improve the observance and performance of adopted best practices and self-confidence among residents during neonatal resuscitation (27).

[2]Department of Statistics Malaysia Official Portal. Available online at: https://www.dosm.gov.my (accessed December 30, 2020).
[3]Petunjuk Kesihatan. Malaysia Ministry of Health. Available online at: https://www.moh.gov.my/index.php/pages/view/58 (accessed December 30, 2020).
[4]National Obstetrics Registry Annual Report. National Obstetrics Registry Malaysia. Available online at: http://www.acrm.org.my/nor/ (accessed December 30, 2020).

As the cost of setting up is relatively cheaper compared to that of a simulation center, *in situ* simulation is an attractive SBE model for Malaysia and other developing countries. In a recent poll of 32 Malaysian hospitals, almost 80% stated that SBE for newborn care providers was delivered *in situ* at the neonatal ward or NICU. Only six centers run their simulation in a simulation center (unpublished data).

PROCEDURAL SKILLS TRAINING

In neonatal practice, an important component of training is in procedural skills. This is essential in achieving competency prior to performing on the real patient especially when dealing with risky procedures (28–30). In recent years, unlike in resuscitation training programs, HFS has proved to be an effective tool in teaching the skills of airway management, and served as an assessment tool for competency in airway management among pediatric residents (31). Some researchers have shown that using an infant chest tube insertion model that they created, there is a significant improvement in skill scores, knowledge and confidence after SBE together with retention of skills even after 1 month (32). Moreover, the Accreditation Council for Graduate Medical Education (ACGME) has accepted competence level of trainees on certain procedural skills such as intraosseous and umbilical catheter placement which are done in a simulated setting (33).

Currently, the procedural training for medical and nursing students, pediatric residency trainees in Malaysia infrequently utilizes manikins. A few simulation centers in the country are in the process of organizing bootcamps/workshops for procedure skill training, especially for those in pediatric residency programs. The COVID-19 pandemic is also making many teaching institutions to re-strategize in investing more heavily in SBE, obtaining high-fidelity manikins and task trainers even for assessments.

INTER-PROFESSIONAL TEAM TRAINING

Neonatology is a very good example of crisis resource management (CRM) where obstetricians, neonatologists, midwives, neonatal nurses work together to provide the best possible care for the baby, usually in stressful situations. Moreover, with the exposure to CRM, there was an overall improved trainees' self-perception, which directly led to an improvement in the time taken to initiate critical steps in pediatric resuscitation (pulse check, calling for help, setting intravenous access and placement of chest leads) (34, 35). The above studies suggest that CRM training in SBE may be effective in promoting the behaviors that affect the outcomes in resuscitation.

The latest version of NRP has included emphasis on CRM by incorporating the 10 key behavioral skills and team performance into the revised syllabus (36). Local unpublished data indicated that almost half of the 32 Malaysian NICUs surveyed, run interprofessional team (IPT) training. Even so, up to three quarter of these centers still carried out SBE separately for a particular profession only, for example a NRP provider training course may be entirely subscribed by nurses. Although we are moving toward promoting more IPT in SBE, in many situations there may be a need to cater to a particular category of healthcare professional because of an overwhelming response. In some cultures, the lack of assertiveness in communicating may be an impediment to IPT training. Hence, there may be some necessary modifications to cater to the local context to enhance team involvement in the training for CRM.

DEBRIEFING

Debriefing is considered to be a crucial component of SBE. The learners will have the opportunity to recover from the stressful scenarios, make sense of the simulation activities, reflect and evaluate their performance to change the way they think and practice to consolidate their learning. A systematic review revealed that simulation with debriefing has a favorable effect on learning outcomes when compared with no intervention (37).

Neither video-assisted nor oral debriefing solely conferred any extra benefit. There was, however, significant improvement in the NRP performance scores in both groups after debriefing (38). A personal observation by the first author of this article, was that nurses in Malaysia were generally less communicative during the SBE sessions he conducted. Video-assisted debriefing may be useful in such situations, with trained simulation educators playing back the video to highlight some essential learning points.

In a recent local survey, only slightly more than half of the 32 centers hold a debriefing session after each SBE. Time limitation is also a factor in carrying out debriefing especially in centers that are busy with a heavy workload and lacking in staff. Of the 13 NICUs that organized "train-the-trainer" simulation educator course, only six hold a debriefer course. Effective debriefing needs simulation educators who have the skills and knowledge in conducting debriefing, such as those who are Certified Healthcare Simulation Educator® (CHSE®). Some reports indicated that structured debriefing after handling the management of cardiac arrest, accelerated the return of spontaneous circulation and improved neurologic outcome of real patients (39, 40). As such, there is immense potential of debriefing as a useful educational and quality improvement tool. There are currently three CHSE® trainers in Malaysia who plan to hold more local courses that focus on the training to perform structured debriefing.

SBE IN THE TRAINING OF PROFESSIONAL AND LAY PROVIDERS

The use of simulation-based training has been widely adopted in the USA, with 81% among the respondents of the Neonatal-Perinatal Medicine fellowship programs reportedly used simulation (41).

Simulation-based training/assessment is gradually incorporated into the pediatric residency training programs in Malaysia, as trainees are required to undergo successfully and be certified as providers in NRP and Pediatric Advanced Life Support (PALS), respectively.

In family-centered care, the involvement of parents or the caregiver is crucial before a high-risk neonate is discharged from the NICU[5]. The transition from NICU to home often results in much anxiety to the family. SBE may mitigate such a stressful period. Scenarios mimicking clinical conditions involving the infant can be simulated using various models and manikins. Family members are then encouraged to participate in multiple simulation sessions paced accordingly over a period of time, with them attending to various scenarios which include life-threatening conditions (42). With SBE, caregivers are more confident and prepared to handle emergency situations and resuscitation. Consequently, they feel more ready and confident in creating a safer environment for their infant (43). In Malaysia, more than half of the surveyed NICUs have healthcare providers entrusted to routinely educate caregivers regarding infant care and safety when at home (local unpublished data). Before discharge, important topics relating to responses to

[5]The Eight Principles of Patient-Centered Care Oneview. Available online at: https://www.oneviewhealthcare.com/the-eight-principles-of-patient-centered-care/ (accessed September 16, 2020).

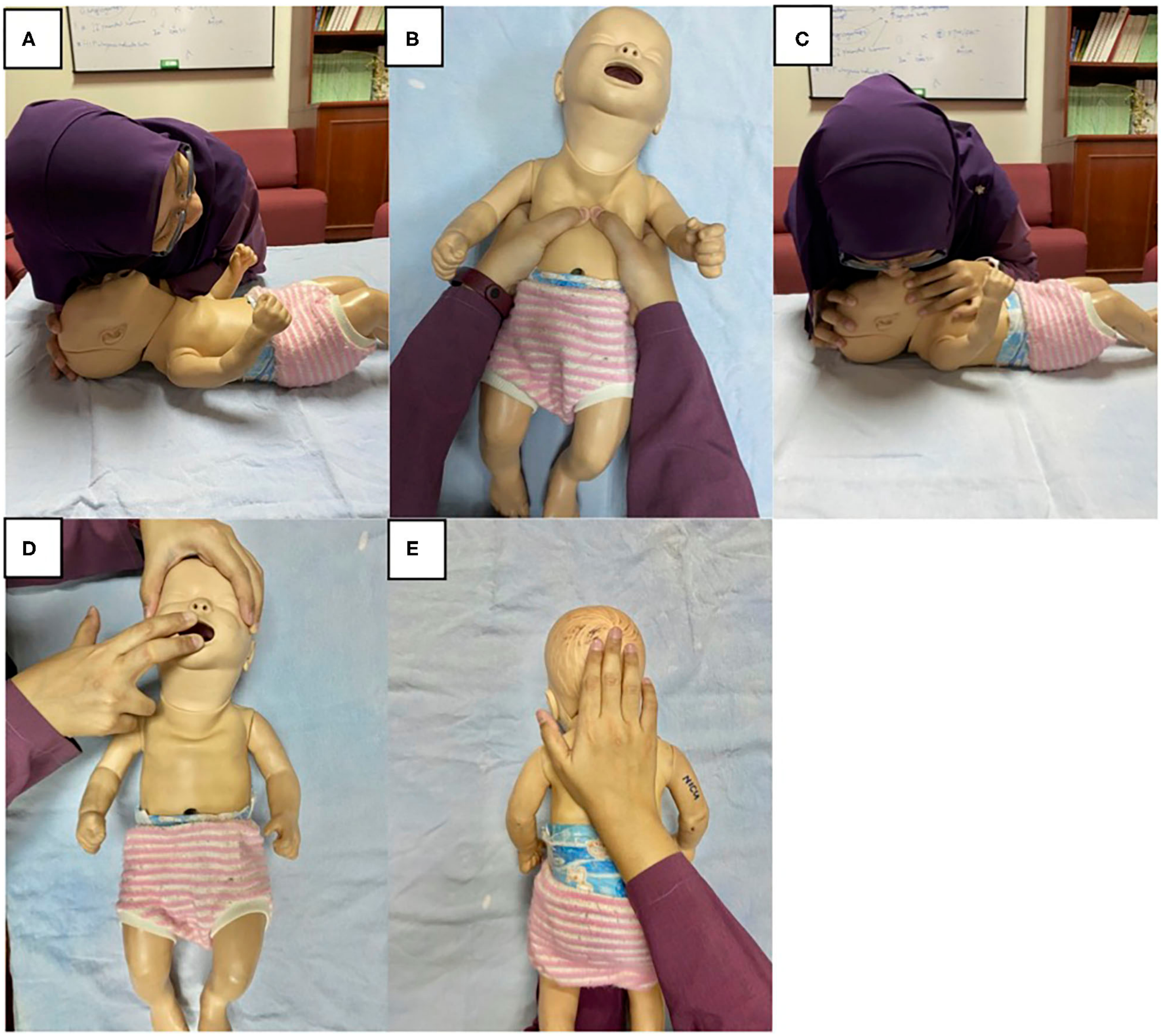


FIGURE 1 | Basic life support simulation training for lay caregivers of infants before discharge from the NICU. The step-by-step instruction when encountering an unresponsive infant includes, **(A)** listen for breathing, **(B)** perform chest compression, **(C)** give rescue breaths. In an infant suspected of choking, **(D)** opening mouth to look for and clear any foreign objects, **(E)** perform back blows. Written informed consent was obtained from the individual for the publication of any potentially identifiable images included in this article.

common emergencies and basic life support are relayed utilizing simulation with the appropriate models and manikins (**Figure 1**).

RECENT DEVELOPMENTS AND ADDRESSING CHALLENGES IN SBE

The SBE is faced with challenges that include limited resources and the lack of qualified or trained instructors. Trained healthcare simulation educators are mostly based in the university and tertiary referral hospitals. Recently, the UKM Medical Center in Kuala Lumpur has become a pacesetter when it became an authorized international training center for the AHA-sanctioned resuscitation programs. There is an increasing need for universities to lead in setting up simulation centers for training and assessment of competencies in resuscitation and procedural skills. A survey on the academic healthcare institutions in Malaysia identified the common challenges as financial support, insufficient of trained faculty and lack of available facilities. Most faculty staff had attended technical training, but there was still little training and development courses for educators opting for this career advancement pathway. Utilization of resources was also limited for research (44).

The AHCoE is an institution that originated as a not-for-profit organization. It was set up with a grant from the Malaysian Federal Government to create a regional shared network of educators dedicated to improve patient care[6]. Established in March 2010, the mission of the center includes effective integration of SBE. The establishment of the Malaysian Society for Simulation in Healthcare (MaSSH) signifies the country's further commitment to advance healthcare simulation training. The MaSSH was founded in 2016 and recently the society has collaborated with other healthcare simulation societies across the region, including the Society for Simulation in Healthcare (SSH) and Pan Asia Simulation Society in Healthcare (PASSH)[7]. In the pipeline is initiating the certification of healthcare simulation educators in Malaysia to ensure the provision of high-quality SBE. For a start, the SSH has just established a center for CHSE exam in Kuala Lumpur in 2020.

Collaborative efforts with NGOs also saw three neonatal emergency simulation (NESim), "train-the-trainers" workshops being organized by the MOH and PSM. NESim is a one-day simulation workshop with the participants handling real life neonatal emergency conditions and learning to perform optimally in stressful circumstances using manikins. The workshop comprised of interactive lectures and group learning activities, which include simulation scenarios and debriefing. A total of 54 participants were trained so far and these trainers were then to carry out training of their own staff in their respective hospitals. The AHCoE is also in the process of developing a Neonatal Simulation Educator (Train-the-Trainer) course in collaboration with the MaSSH. A mentorship program is also planned to guide the novice simulation educator who just qualified.

[6] Allied Healthcare Center of Excellence. Available online at: https://ahcoe.my/ (accessed June 22, 2020).

[7] About Us - MaSSH. Available online at: https://massh.org.my/about-us/ (accessed June 22, 2020).

CONCLUSION

Collaboration between the university and NGO created the impetus to initiate the NRP in Malaysia. Positive healthcare outcomes were seen consequently with major stakeholders commenced funding of simulation-based training in neonatal resuscitation, utilizing low-fidelity and *in situ* simulation for newborn care providers. SBE is increasingly becoming a tool for assessment of competency and a requirement for credentialing in specialist board registration and practice recertification.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

ETHICS STATEMENT

Written informed consent was obtained from the individual for the publication of any potentially identifiable images or data included in this article.

AUTHOR CONTRIBUTIONS

K-MP prepared the first draft of this manuscript, created the survey, analyzed and collated the data, and statistics from the Perinatal Society of Malaysia. JT-R contributed in the writing, created the table and figure, accessed the statistics from sources, ensured editorial accuracy of the manuscript, and reference compilation. F-CC steered the project, critically edited, primarily involved in re-structuring, and re-writing and re-formatting the manuscript into the final form. All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

ACKNOWLEDGMENTS

We would like to thank Drs. See Kwee Ching and Neoh Siew Hong of the Perinatal Society of Malaysia, and Dr. Amy Nur Diyana binti Mohamed Nasir of the Ministry of Health, who assisted in providing the statistics on trained providers in the NRP and the annual live birth, respectively. Our gratitude to all the participants of the survey on the status of SBE in Malaysia and a special thanks to Dr. Nor Hazirah binti Abidin for her help in the production of the images for the figure in this article.

REFERENCES

1. Pilcher J, Heather G, Jensen C, Huwe V, Jewell C, Reynolds R, et al. Simulation-based learning: It's not just for NRP. *Neonatal Netw.* (2012) 31:281–7. doi: 10.1891/0730-0832.31.5.281
2. Healthcare Simulation Dictionary. Available online at: https://www.ssih.org/Dictionary [accessed December 23, 2020].
3. Halamek LP, Kaegi DM, Gaba DM, Sowb YA, Smith BC, Smith BE, et al. Time for a new paradigm in pediatric medical education: teaching neonatal resuscitation in a simulated delivery room environment. *Pediatrics.* (2000) 106:E45. doi: 10.1542/peds.106.4.e45
4. Abrahamson S, Denson JS, Wolf RM. Effectiveness of a simulator in training anesthesiology residents. *J Med Educ.* (1969) 44:515–9. doi: 10.1097/00001888-196906000-00006
5. Berden HJJM, Pijls NHJ, Willems FF, Hendrick JMA, Crul JF. A scoring system for basic cardiac life support skills in training situations. *Resuscitation.* (1992) 23:21–31. doi: 10.1016/0300-9572(92)90159-A
6. Ellis C, Hughes G. Use of human patient simulation to teach emergency medicine trainees advanced airway skills. *J Accid Emerg Med.* (1999) 16:395–9. doi: 10.1136/emj.16.6.395
7. Cohen ER, Feinglass J, Barsuk JH, Barnard C, O'Donnell A, McGaghie WC, et al. Cost savings from reduced catheter-related bloodstream infection after simulation-based education for residents in a medical intensive care unit. *Simul Healthc.* (2010) 5:98–102. doi: 10.1097/SIH.0b013e3181bc8304
8. Okuda Y, Bryson EO, Jacobson L, DeMaria Jr S, Quinones J, Shen B. No title. What Is Evidence? *Util Simul Med Educ.* (2009) 76:330–43. doi: 10.1002/msj.20127
9. Issenberg SB, McGaghie WC, Petrusa ER, Gordon DL, Scalese RJ. Features and uses of high-fidelity medical simulations that lead to effective learning: A BEME systematic review. *Med Teach.* (2005) 27:10–28. doi: 10.1080/01421590500046924
10. Paige JT, Kozmenko V, Yang T, Paragi Gururaja R, Hilton CW, Cohn I, et al. High-fidelity, simulation-based, interdisciplinary operating room team training at the point of care. *Surgery.* (2009) 145:138–46. doi: 10.1016/j.surg.2008.09.010
11. Brett-Fleegler MB, Vinci RJ, Weiner DL, Harris SK, Shih MC, Kleinman ME. A simulator-based tool that assesses pediatric resident resuscitation competency. *Pediatrics.* (2008) 121:e597–603. doi: 10.1542/peds.2005-1259
12. Wyckoff MH, Aziz K, Escobedo MB, Kapadia VS, Kattwinkel J, Perlman JM, et al. Part 13: Neonatal resuscitation: (2015). American Heart Association guidelines update for cardiopulmonary resuscitation and emergency cardiovascular care. *Circulation.* (2015) 132:S543–60. doi: 10.1161/CIR.0000000000000267
13. Boo NY, Pong KM. Neonatal resuscitation training program in Malaysia: results of the first 2 years. *J Paediatr Child Health.* (2001) 37:118–24. doi: 10.1046/j.1440-1754.2001.00597.x
14. Boo NY. Neonatal resuscitation programme in Malaysia: An eight-year experience. *Singapore Med J.* (2009) 50:152–9.
15. Perinatal Society of Malaysia - PSM Bulletin. Available online at: http://www.perinatal-malaysia.org/index.cfm?&menuid=121&lang=EN (accessecd June 20, 2020).
16. Kaczorowski J, Levitt C, Hammond M, Outerbridge E, Grad R, Rothman A. Retention of neonatal resuscitation skills and knowledge: a randomized controlled trial. *Fam Med.* (1998) 30:705–11.
17. Cavaleiro A, Guimarães H, Calheiros F. Training neonatal skills with simulators? *Acta Paediatr Int J Paediatr.* (2009) 98:636–9. doi: 10.1111/j.1651-2227.2008.01176.x
18. Lee MO, Brown LL, Bender J, MacHan JT, Overly FL. A medical simulation-based educational intervention for emergency medicine residents in neonatal resuscitation. *Acad Emerg Med.* (2012) 19:577–85. doi: 10.1111/j.1553-2712.2012.01361.x
19. Curran VR, Aziz K. Evaluation of the effect of a computerized training simulator (ANAKIN) on the retention of neonatal resuscitation skills. *Teach Learn Med.* (2004) 16:157–64. doi: 10.1207/s15328015tlm1602_7
20. Rubio-Gurung S, Putet G, Touzet S, Gauthier-Moulinier H, Jordan I, Beissel A, et al. *In situ* simulation training for neonatal resuscitation: An RCT. *Pediatrics.* (2014) 134:e790–7. doi: 10.1542/peds.2013-3988
21. Draycott T, Sibanda T, Owen L, Akande V, Winter C, Reading S, et al. Does training in obstetric emergencies improve neonatal outcome? *BJOG An Int J Obstet Gynaecol.* (2006) 113:177–82. doi: 10.1111/j.1471-0528.2006.00800.x
22. Campbell DM, Barozzino T, Farrugia M, Sgro M. High-fidelity simulation in neonatal resuscitation. *Paediatr Child Health (Oxford).* (2009) 14:19–23. doi: 10.1093/pch/14.1.19
23. Finan E, Bismilla Z, Whyte HE, LeBlanc V, McNamara PJ. High-fidelity simulator technology may not be superior to traditional low-fidelity equipment for neonatal resuscitation training. *J Perinatol.* (2012) 32:287–92. doi: 10.1038/jp.2011.96
24. Guise JM, Mladenovic J. *In situ* simulation: identification of systems issues. *Semin Perinatol.* (2013) 37:161–5. doi: 10.1053/j.semperi.2013.02.007
25. Guise JM, Lowe NK, Deering S, Lewis PO, O'Haire C, Irwin LK, et al. Mobile *in situ* obstetric emergency simulation and teamwork training to improve maternal-fetal safety in hospitals. *Jt Comm J Qual Patient Saf.* (2010) 36:443–53. doi: 10.1016/S1553-7250(10)36066-1
26. Patterson MD, Geis GL, Falcone RA, LeMaster T, Wears RL. *In situ* simulation: Detection of safety threats and teamwork training in a high risk emergency department. *BMJ Qual Saf.* (2013) 22:468–77. doi: 10.1136/bmjqs-2012-000942
27. Surcouf JW, Chauvin SW, Ferry J, Yang T, Barkemeyer B. Enhancing residents' neonatal resuscitation competency through unannounced simulation-based training. *Med Educ Online.* (2013) 18:1–8. doi: 10.3402/meo.v18i0.18726
28. Sharara-Chami R, Taher S, Kaddoum R, Charafeddine L. Simulation training in endotracheal intubation in a paediatric residency. *Middle East J Anaesthesiol.* (2014) 22:477–85.
29. Gaies MG, Morris SA, Hafler JP, Graham DA, Capraro AJ, Zhou J, et al. Reforming procedural skills training for pediatric residents: A randomized, interventional trial. *Pediatrics.* (2009) 124:610–9. doi: 10.1542/peds.2008-2658
30. Al-Qadhi SA, Pirie JR, Constas N, Corrin MSC, Ali M. An innovative pediatric chest tube insertion task trainer simulation: a technical report and pilot study. *Simul Healthc.* (2014) 9:319–24. doi: 10.1097/SIH.0000000000000033
31. Overly FL, Sudikoff SN, Shapiro MJ. High-fidelity medical simulation as an assessment tool for pediatric residents' airway management skills. *Pediatr Emerg Care.* (2007) 23:11–5. doi: 10.1097/PEC.0b013e31802c61d5
32. Gupta AO, Ramasethu J. An innovative nonanimal simulation trainer for chest tube insertion in neonates. *Pediatrics.* (2014) 134:e798–805. doi: 10.1542/peds.2014-0753
33. Mills DM, Williams DC, Dobson J V. Simulation training as a mechanism for procedural and resuscitation education for pediatric residents: a systematic review. *Hosp Pediatr.* (2013) 3:167–76. doi: 10.1542/hpeds.2012-0041
34. Bank I, Snell L, Bhanji F. Pediatric crisis resource management training improves emergency medicine trainees' perceived ability to manage emergencies and ability to identify teamwork errors. *Pediatr Emerg Care.* (2014) 30:879–83. doi: 10.1097/PEC.0000000000000302
35. Blackwood J, Duff JP, Nettel-Aguirre A, Djogovic D, Joynt C. Does teaching crisis resource management skills improve resuscitation performance in pediatric residents? *Pediatr Crit Care Med.* (2014) 15(4). doi: 10.1097/PCC.0000000000000100
36. Weighner G, Zaichkin J. *Textbook of Neonatal Resuscitation*. 7th ed. Elk Grove Village, IL: American Academy of Pediatrics and American Heart Association (2016).
37. Cheng A, Eppich W, Grant V, Sherbino J, Zendejas B, Cook DA. Debriefing for technology-enhanced simulation: a systematic review and meta-analysis. *Med Educ.* (2014) 48:657–66. doi: 10.1111/medu.12432
38. Sawyer T, Sierocka-Castaneda A, Chan D, Berg B, Lustik M, Thompson M. The effectiveness of video-assisted debriefing versus oral debriefing alone at improving neonatal resuscitation performance a randomized trial. *Simul Healthc.* (2012) 7:213–21. doi: 10.1097/SIH.0b013e3182578eae
39. Edelson DP, Litzinger B, Arora V, Walsh D, Kim S, Lauderdale DS, et al. Improving in-hospital cardiac arrest process and outcomes with performance debriefing. *Arch Intern Med.* (2008) 168:1063–9. doi: 10.1001/archinte.168.10.1063
40. Wolfe H, Zebuhr C, Topjian AA, Nishisaki A, Niles DE, Meaney PA, et al. Interdisciplinary ICU cardiac arrest debriefing improves survival

outcomes. *Crit Care Med.* (2014) 42:1688–95. doi: 10.1097/CCM.0000000000000327

41. Eppich WJ, Nypaver MM, Mahajan P, Denmark KT, Kennedy C, Joseph MM, et al. The role of high-fidelity simulation in training pediatric emergency medicine fellows in the United States and Canada. *Pediatr Emerg Care.* (2013) 29:1–7. doi: 10.1097/PEC.0b013e31827b20d0
42. Arnold J, Diaz MCG. Simulation training for primary caregivers in the neonatal intensive care unit. *Semin Perinatol.* (2016) 40:466–72. doi: 10.1053/j.semperi.2016.08.007
43. Raines DA. Simulation as part of discharge teaching. *MCN Am J Matern Nurs.* (2017) 42:95–100. doi: 10.1097/NMC.0000000000000312
44. Ismail M, Johar M, Siraj H, Arif K, Jalina K, Iva M, et al. Influence of simulation in malaysian healthcare education and research (ISIM-HERE): a two- decade experience. *Med Health.* (2019) 14:53–67. doi: 10.17576/MH.2019.1401.05

Conflict of Interest: K-MP received honorarium for teaching activities in workshops conducted by the Allied Healthcare Centre of Excellence, (AHCoE), Penang, Malaysia.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Surgery

METHODS
published: 30 March 2021
doi: 10.3389/fsurg.2021.657901

Augmented Reality in Medical Practice: From Spine Surgery to Remote Assistance

Fabio Cofano[1,2], Giuseppe Di Perna[1], Marco Bozzaro[2], Alessandro Longo[3], Nicola Marengo[1], Francesco Zenga[1], Nicola Zullo[4], Matteo Cavalieri[5], Luca Damiani[5,6], Daniya J. Boges[5,7], Marco Agus[8], Diego Garbossa[1] and Corrado Calì[9,10]*

[1] Neurosurgery Unit, Department of Neuroscience "Rita Levi Montalcini," University of Torino, Turin, Italy, [2] Spine Surgery Unit, Humanitas Gradenigo, Turin, Italy, [3] Spine Surgery Unit, Humanitas Cellini, Turin, Italy, [4] Spine Surgery Unit, Casa di Cura Città di Bra, Bra, Italy, [5] Intravides SRL, Palazzo degli Istituti Anatomici, Turin, Italy, [6] LD Consulting, Chiavari, Italy, [7] BESE Division, King Abdullah University of Science and Technology, Thuwal, Saudi Arabia, [8] College of Science and Engineering, Hamad Bin Khalifa University, Doha, Qatar, [9] Neuroscience Institute Cavalieri Ottolenghi, Orbassano, Italy, [10] Department of Neuroscience "Rita Levi Montalcini," University of Torino, Turin, Italy

OPEN ACCESS

Edited by:
Ismail Mohd Saiboon, National University of Malaysia, Malaysia

Reviewed by:
Gregory Fabrice Jost, University of Basel, Switzerland
Prashanth J. Rao, University of New South Wales, Australia

***Correspondence:**
Corrado Calì
corrado.cali@unito.it

Specialty section:
This article was submitted to Neurosurgery, a section of the journal Frontiers in Surgery

Received: *24 January 2021*
Accepted: *08 March 2021*
Published: *30 March 2021*

Citation:
Cofano F, Di Perna G, Bozzaro M, Longo A, Marengo N, Zenga F, Zullo N, Cavalieri M, Damiani L, Boges DJ, Agus M, Garbossa D and Calì C (2021) Augmented Reality in Medical Practice: From Spine Surgery to Remote Assistance. Front. Surg. 8:657901. doi: 10.3389/fsurg.2021.657901

Background: While performing surgeries in the OR, surgeons and assistants often need to access several information regarding surgical planning and/or procedures related to the surgery itself, or the accessory equipment to perform certain operations. The accessibility of this information often relies on the physical presence of technical and medical specialists in the OR, which is increasingly difficult due to the number of limitations imposed by the COVID emergency to avoid overcrowded environments or external personnel. Here, we analyze several scenarios where we equipped OR personnel with augmented reality (AR) glasses, allowing a remote specialist to guide OR operations through voice and *ad-hoc* visuals, superimposed to the field of view of the operator wearing them.

Methods: This study is a preliminary case series of prospective collected data about the use of AR-assistance in spine surgery from January to July 2020. The technology has been used on a cohort of 12 patients affected by degenerative lumbar spine disease with lumbar sciatica co-morbidities. Surgeons and OR specialists were equipped with AR devices, customized with P2P videoconference commercial apps, or customized holographic apps. The devices were tested during surgeries for lumbar arthrodesis in a multicenter experience involving author's Institutions.

Findings: A total number of 12 lumbar arthrodesis have been performed while using the described AR technology, with application spanning from telementoring (3), teaching (2), surgical planning superimposition and interaction with the hologram using a custom application for Microsoft hololens (1). Surgeons wearing the AR goggles reported a positive feedback as for the ergonomy, wearability and comfort during the procedure; being able to visualize a 3D reconstruction during surgery was perceived as a straightforward benefit, allowing to speed-up procedures, thus limiting post-operational complications. The possibility of remotely interacting with a specialist on the glasses was a potent added value during COVID emergency, due to limited access of non-resident personnel in the OR.

Interpretation: By allowing surgeons to overlay digital medical content on actual surroundings, augmented reality surgery can be exploited easily in multiple scenarios by adapting commercially available or custom-made apps to several use cases. The possibility to observe directly the operatory theater through the eyes of the surgeon might be a game-changer, giving the chance to unexperienced surgeons to be virtually at the site of the operation, or allowing a remote experienced operator to guide wisely the unexperienced surgeon during a procedure.

Keywords: augmented reality, telementoring and surgery, spine surgery, hologram 3D display, remote assistance, COVID emergency, AR surgery, remote proctor

INTRODUCTION

The challenges of learning, planning and performing procedures in spine surgery have been enriched by the recent development of new technological tools and instrumentations, able to assist surgeons and reducing surgical invasiveness (Minimally-Invasive Surgery, MIS) but maintaining a valuable profile of safety (1–5). One of the most promising applications of advancements in visual/haptic display technologies and computational power is represented by augmented reality (AR) (6), an emerging technological field. After the developments and further drops of prices for the Virtual Reality (VR) headsets, few companies have started the development of AR glasses. First commercial AR headsets available on market were the Epson Moverio BT-200, allowing imaging superimposition thanks to an integrated camera and tracking systems. The advantage of this system, now updated and evolved with better sensors, is to be able to interface with Unity, a game engine that can be used to create custom tools for 3D visualization and tracking and that became popular thanks to VR and gaming industry. Also, the possibility of stereoscopic vision allows projection of three-dimensional objects on the user eyesight; superimposition of digital content to the real field of view creates a digital hologram, which can be informative of the observed reality.

While performing surgeries in the operating room (OR), surgeons and assistants often need to access several information regarding surgical planning and/or procedures related to the surgery itself, or the accessory equipment to perform a wide spectrum of operations (7). Furthermore, as known, the shape and timing of surgical learning curve for surgeons strictly relies on the possibility to physically access the OR and learn procedures from other experienced colleagues in a space/time-dependent and limited manner; all these processes could be eased by AR.

Interactions with such digital objects were something considered science fiction, as seen in movies projecting us in the future; nevertheless, recently Microsoft implemented this technology with the "hololens," an AR visor with a tracking system able to recognize hand motion thus allowing interactions with holograms. Most likely this technology will access the general consumer market within the next 10 years. Our group has already large experience with mixed reality, having worked on one of the first large-scale setups for AR interactions "CAVE" (8), which was at the basis of the idea of engineering a portable system projecting hologram to assist neurosurgery.

Generating 3D models from medical images does not imply similar challenges compared to electron micrographs (8–12) (segmentation of the latter type requires knowledge from the user of the observed image, and generation of masks could take longer, although semi-automated or fully automated techniques can speed up the process) (12). On the contrary, medical images such as CT scans or MRI are often black and white images, that could be easily binarized and hence used to generate directly a three-dimensional object. Here, we propose to use techniques used for segmentation of microscopy images to clinical medical images, in order to generate 3D dimensional models that could be used as holograms to be projected on stereoscopic AR glasses, allowing the visualization of models with integrated surgical planning.

Another practical case for the use of the AR was to face the number of limitations imposed by the COVID emergency. Indeed, during months of hard lockdown, until recently, access to OR was limited, with strict regulations regarding personnel allowed to enter surgical theater. For several procedures, external experts or consultants were needed to assist for specific procedure, like setting up special equipment, or assist during surgery for the implant of new devices. Since access to the OR was not free to specialists, AR came in handy by allowing these experts to pilot these particular operations directly.

In this paper several scenarios of AR-assisted spinal procedures are presented, in order to show and describe all the potential benefits and caveats in the processes of mentoring, coaching and assistance to the surgical staff. We were able to demonstrate how AR is beneficial during special surgical procedures. The flexibility and easiness to use of the software platform makes the system suitable for multiple devices; AR have the potential to make this setup a standard equipment in the OR, such as surgical scissors and scalpels.

METHODS

This study is a preliminary case series of prospective collected data about the use of AR-assistance in spine surgery from January to July 2020. The technology has been used during surgeries for lumbar arthrodesis in a multicenter experience involving author's Institutions.

COHORT

We selected a cohort of 12 patients that required lumbar arthrodesis surgery for degenerative lumbar spine disease.

IMAGING AND 3D RECONSTRUCTION

CT Scans used to classify and plan surgery were acquired carefully using a z spacing allowing smooth 3D reconstructions without visible artifacts during the renderings. Image segmentations and 3D reconstructions were obtained either using a pipeline developed for electron microscopy stacks at nanometer resolution (11, 13) or with the Horos software, available for free.

AUGMENTED REALITY HEADSETS

In order to visualize digital content, or participate to an interactive session using augmented reality (AR), we took advantage of four different state of the art AR goggles: the Epson BT-300 and BT-350, both allowing HD projection, with a 5 MPx camera on board, and the Vuzix Blade, also allowing HD projection (**Figure 1**). The latter is equipped though with a 8 Mpx camera on board, allowing higher resolution video streaming, which is then better suited to visualize surgical details provided by the first operator. All these systems are wearable with ease, and can be used with TeamPilot app, allowing to send the audio-video stream to a remote user running the TeamViewer app on a pc, smartphone or tablet (**Figure 1**). Remote users can take snapshots and create visual clues such as arrows or doodles on a still frame that can be visualized on the eye of the user wearing the goggles (**Supplementary Video 1**). Despite the use of different headsets, powered by different head-mounted display (HMD) technology, all of them were running the same software tool (see next section Software Tools). This allowed us to assess the use

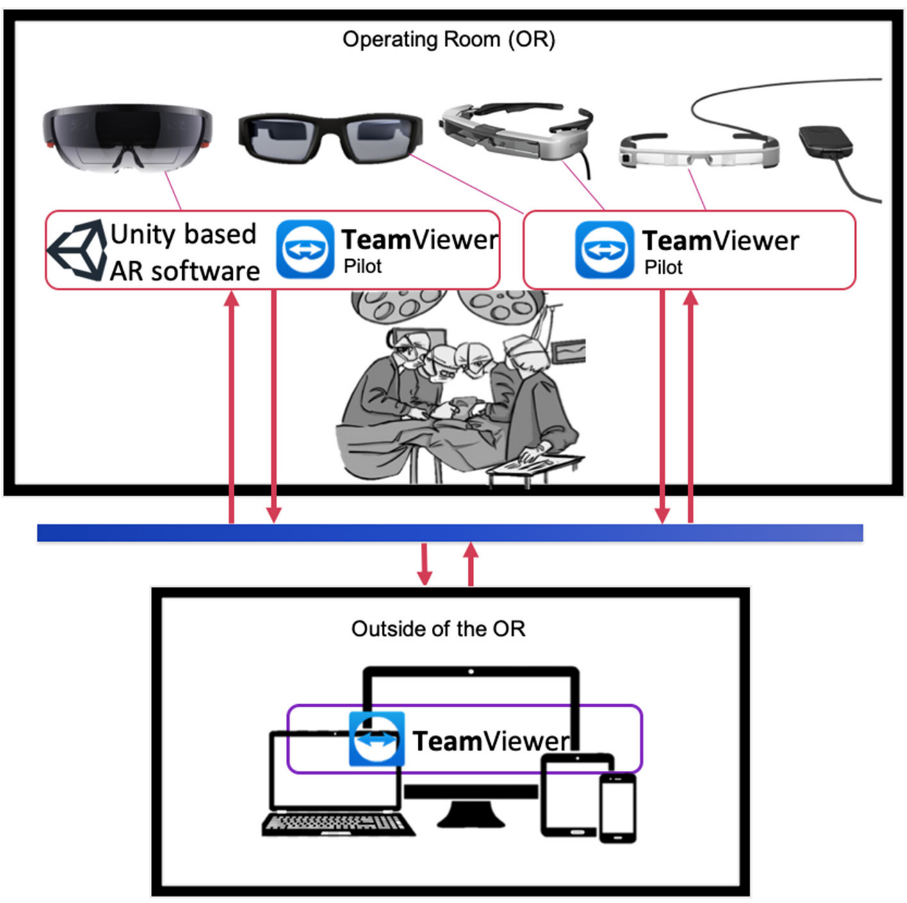


FIGURE 1 | Graphical representation of AR information flow between OR and remote users. Top panel: key personnel in the OR (i.e., physician, technical specialists, surgeons) wearing AR goggles equipped with software for digital content superimposition (Unity custom tool) and/or video streaming and interaction (e.g., Teamviewer Pilot) from the OR. Goggles models from the left: Microsoft Hololens, Vuzix Blade, Epson BT-350, Epson BT-300. Bottom panel: personnel outside the OR can visualize the video streaming from goggles equipped with Teamviewer Pilot via TeamViewer app on laptops, tablets or smartphones.

of the technique, rather than the headset technology *per se*. For one case we have used Microsoft Hololens 1, which are equipped with a 8MPx camera and HD stereoscopic projection. To take full advantage of the stereoscopic view of the system, we developed a custom-made app using Unity.

SOFTWARE TOOLS

TeamViewer pilot is a cross platform remote assistance software that was developed and enhanced for the purpose of exploiting AR and AI features combined (**Figure 1**). Key personnel wearing the AR goggles operate with TeamViewer Pilot at one end, interacting with other users equipped with a TeamViewer remote client at another one, running on a laptop or tablet. Both software applications require fast connections in order to perform relatively smooth. As part of the routinely preparations of the OR, it is recommended to check on any updates that may occur to the OR access link to its Internet Service Provider (ISP) to limit the occurrence of technical issues during the operation. A dedicated connection link is also desired. Our setup has tested an average bandwidth and delay values of 60 Mbps downstream, 90 Mbps upstream and a ping value of 50 ms. Other parameters that need to be adjusted within the TeamViewer software involves hardware acceleration options in the case of systems with weak GPUs. TeamViewer will automatically attempt to optimize its performance based on balancing between connection and image quality. This can be solely controlled by the enduser as well.

Another in-house Unity-based software tool customized specifically for the HoloLens goggles is the Holosurgery app. This piece of software holds features that enable more convenient input methods such as hand gestures and voice commands. Summoning optimized pre-processed imaging data such as 3D models of a patient's spine is achieved with simple key vocal inputs, e.g., "Show 3D Model." In addition, the 3D model is manipulated using hands and fingers motions and that achieves re-scaling, movement, and rotating of the 3D model. There is also more complex geometry operations such arbitrarily clipping planes which neatly visualizes a clipped region of interest within the displayed 3D model.

All three state of the art software tools along with the implemented AR goggles empowers the OR staff to perform normally in non-normal and challenging times similarly in the case of global pandemics.

SYSTEM USABILITY SCALE

System Usability Scale is an industry standard used to give a gross but reliable evaluation of the usability of a product. It is a questionnaire that can be customized to a certain extent, based on individual needs. Each answer requires an answer on a scale from 1 (strongly disagree) to 5 (strongly agree). A 9 questions questionnaire reported in **Table 1** was administered to $n = 5$ expert who have used to devices in the OR.

TABLE 1 | System usability scale (SUS).

System usability scale (SUS)	*N* (1–5)
I think I would like to use the Augmented Reality (AR) system frequently	
I found the AR application unnecessarily complex	
I think that I would need technical support for using AR goggles	
I like using the AR interface	
I think that most people would learn to use this system quickly	
I felt very confident using the AR system	
I needed to train a lot before I could use the AR system	
The information provided by the interfact was clear and helpful	
I felt is difficult to interact and control the system	

CASE STUDIES

Telementoring

AR goggles allowed to stream videos and transmit still images from the surgical field to different specialists (**Figure 2**). Processes of supervision and coaching have been performed to verify the possibility of an effective and interactive remote-assistance in the OR without requiring a physical presence. The use of AR googles goes beyond simple video-conferencing, since remote users can interact with the video stream and make drawings or create arrows that the user wearing the device can visualize live. This gives the possibility to not only give audio, but also visual clues to the operator in the OR. AR goggles have been used also to face physical limitations during the COVID emergency to allow OR technicians and technical consultants from spinal devices companies supervise—before and during the procedures—surgeons, nurses, and neurophysiologists without accessing the OR (**Figure 3**). Spinal instrumented procedures require specific surgical instruments, both for the positioning of implants (e.g., screws, rods, or cages) and to allow surgeons to approach the spinal canal and/or during the decompressive step (**Figure 3**). Neuronavigation could be used to improve the accuracy of screw positioning if compared with the free-hand technique (14). Furthermore, intraoperative neuromonitoring during spinal procedures has become one of the most important tools to preserve the integrity of the nervous structures, especially for MIS techniques (15).

Surgical Planning

Surgeons had the possibility to get a live visualization of the CT reconstruction and of the planned trajectories (**Figure 2**) (7) of the screws while maintaining the view on the surgical field. Moreover, Microsoft hololens allow interactions with gesture by hand tracking, which allows to keep the surgical theater sterile.

Teaching

The ability to obtain an ergonomic live-sharing of surgeons view, together with the possibility to overlay images or videos offered the opportunity to involve a group of young residents and medical students for a remote step-by-step interactive learning of the surgical procedure (**Figures 2**, **3**).

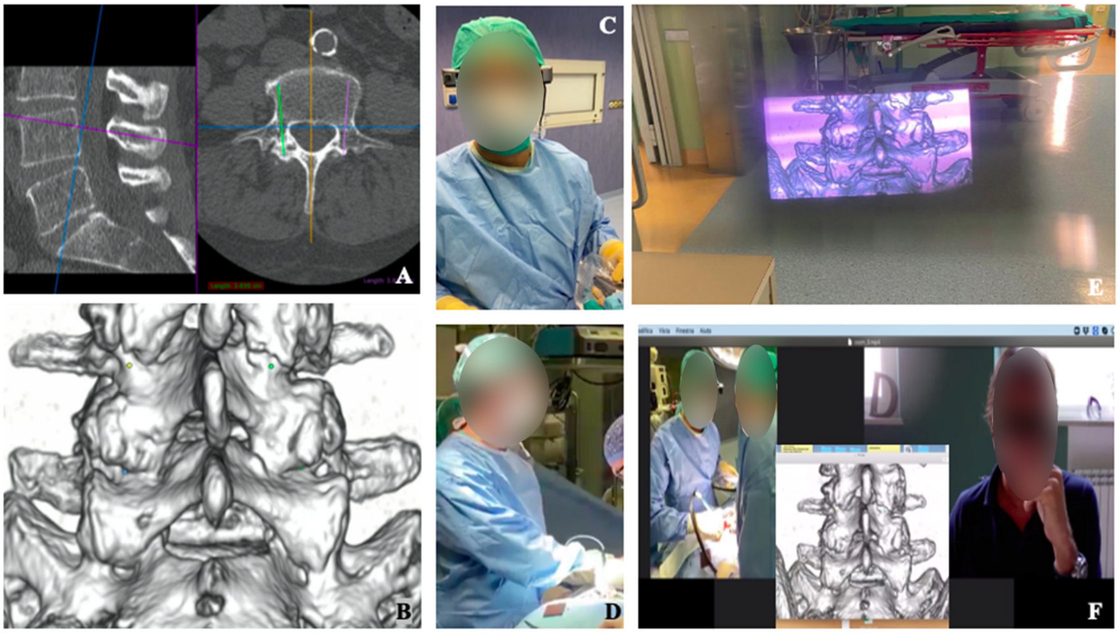


FIGURE 2 | Visualization of intra-operative 3D-model planning **(A–D)**. Surgical planning of screws positioning for lumbar spine fusion is shown **(A)**, with 3D reconstructed model highlighting the screws' entry points **(B)**. Surgeon wore smart glass during surgery **(C,D)** and, with augmented reality, was able to see the 3D model wherever He preferred into the space **(E)**. The enhanced videoconference function with smart glasses' screen sharing allowed participants to see through the eyes of the surgeon and communicate with him **(F)**.

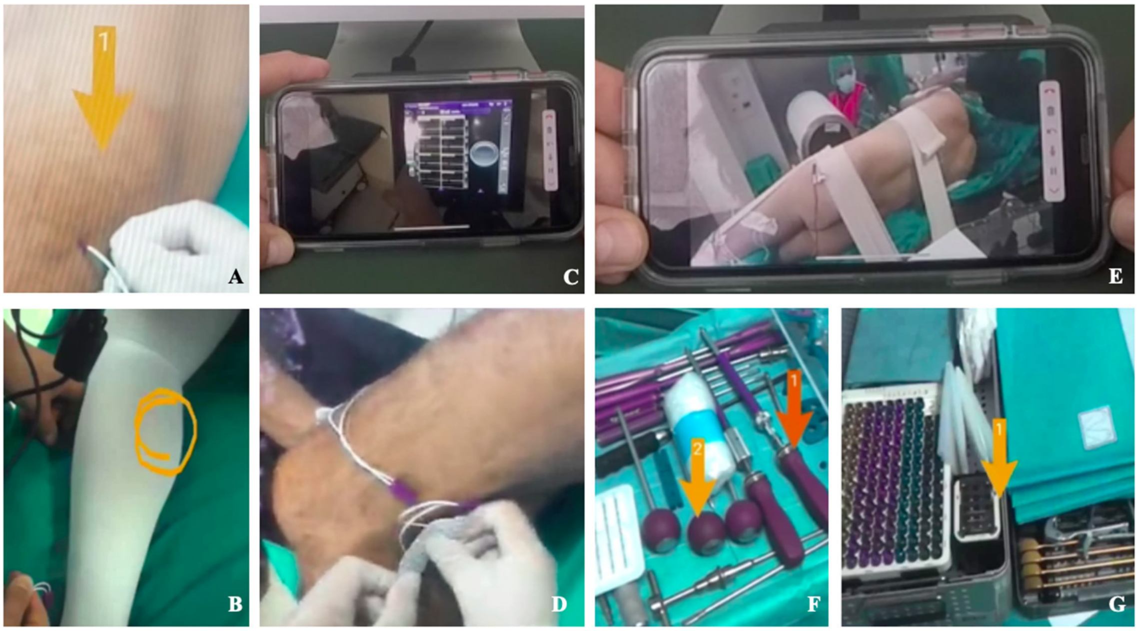


FIGURE 3 | Remote operative Room setup with Epson smart glasses **(A–G)**. Remote vision of the operative room showing neuromonitoring electrodes positioning **(A,B,D)** and enhanced videoconference function that allowed to avoid the physical presence of specialists consultants in the OR **(A–D)**. Remote vision of patient positioning and instrumentation setting in the OR using enhanced videoconference function **(E–G)**.

RESULTS

A total number of 12 lumbar arthrodesis have been performed while using the described AR technology. Five cases of Lateral Lumbar Interbody Fusion (LLIF) and 7 Transforaminal Lumbar Interbody Fusion (TLIF) were performed with posteriore screwing through Standard (5 pts, PT) or Cortical Bone Trajectory (2 pts, CBT). Intraoperative neuromonitoring was used in all the cases. Neuronavigation was used in two TLIF procedures.

Telementoring

In three cases (2 CBT-TLIF, 1 LLIF) surgical procedures have been shared through enhanced videoconferences among three experienced surgeons. The surgeon in the OR discussed the case while showing the screw entry-point and the trajectory, with the aid of the fluoroscopy and neuromonitoring. In the LLIF case, the discussion about the procedure involved the lateral positioning, the trans-psoas approach and the cage placement. In seven cases (5 LLIF and 2 TLIF procedures) the positioning of neuromonitoring electrodes on patients skin and the wires connection to the central monitoring platform and display was made by surgeons wearing AR goggles with the remote assistance from specialized technicians. Similarly, the remote assistance allowed the surgeon to set neuronavigation in two cases. In all the procedures, companies ensured a live support for nurses assisting surgeons with regard to the devices and surgical instrumentations needed.

Surgical Planning

In three cases AR goggles allowed the surgeon to access to the surgical planning of patients that underwent CBT fixation in real time while maintaining the view on the operator field.

Teaching

In two cases (1 LLIF, 1 TLIF) a group of four residents belonging to their first year of the Residency program and two medical students got access to the procedure with a remote connection, with the possibility to interact with the surgeons. Surgeries were performed in a step-by-step manner.

No complications potentially linked to the use of AR were registered, such as malfunction of the neuromonitoring and of the neuronavigation system, or infections. Surgeons reported a positive feedback as for the ergonomy, wearability and comfort during the procedure, as confirmed by the results shown on the graphs in **Figure 4** after SUS questionnaires.

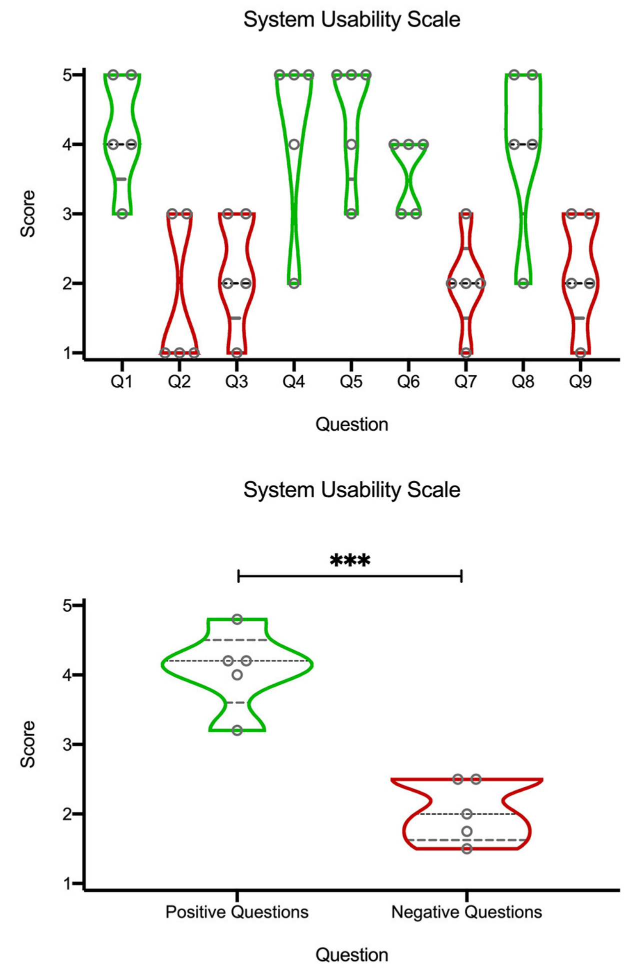


FIGURE 4 | Violin plots of quantification of the SUS questionnaire (**Table 1**) on a Likert scale (1 corresponding to "strongly disagree," and 5 to "strongly agree"). Black dashed line represents the median, the gray dashed lines represents the quartiles, and width of the violin corresponds to the number of points at a certain height. The top graph are the scores from individual questions. Bottom graph is an average from "positive" (green) or "negative" (red) questions. ***p < 0.01, unpaired t-test.

INTERPRETATION

AR represents the possibility to create a useful and real-time interaction between multiple environments and/or images/videos of interest (16). AR systems have been conceived and developed during the last decades and their applications for medicine have been described for different specialties such as neurosurgery, radiotherapy, orthopedics or plastic surgery. First examples of application and implementation of AR in neurosurgery were described by Roberts et al. in 1986 which proposed the projection of CT images in a surgical microscope. In 1998 the same principles were used to project vascular structures with fluoroscopy while in 2002 AR was applied in a neurosurgical endoscope (17).

In this case series a simple, ergonomic and successful use of AR goggles is presented. In addition, the unfortunate conjunction with the COVID-19 pandemic has led to the chance of facing physical restrictions adding further applications of this technology.

These tools, indeed, allow surgeons to view images and use apps anywhere and anytime they like overlaying digital content on their real field of view. Moreover, images, videos or screens shared by other devices could be watched on these see-through lenses, through an enhanced videoconference app (**Supplementary Video 1**). Considering this last feature, different preliminary applications of EPSON ECC in surgery have already been described and the idea of telementoring with augmented reality took place. Recently, Roja-Munoz et al. published their experience with the STAR (System for Telementoring with Augmented Reality) system, analyzing different results of two different groups that performed leg fasciotomies. Participants were unexperienced surgeons (surgical residents and medical students) and were divided into two different groups: the former receiving remote instructions provided by an expert surgeon, directly on their field of view, using the STAR system; the latter receiving no external guidance beyond initial consultation of the Advanced Surgical Skills for Exposure in Trauma course manual. Results showed fewer mistakes and better performances among mentees belonging to the group that received guidance trough the STAR system (18).

Another important advantage offered by this AR system, is the real-time visual feedback of the operative field that allows the mentor to provide a better coaching, as reported in other previous papers (19, 20). Davis et al. described an interesting experience using the Virtual Interactive Presence and Augmented Reality (VIPAR) system that allows a remote surgeon to communicate visual and verbal information in real time to a local surgeon performing a procedure; namely neurosurgeons based in Birmingham, Alabama, successfully assisted neurosurgeons in Ho Chi Minh City, Vietnam, in fifteen cases of endoscopic third ventriculostomy with choroid plexus coagulation. Neurosurgeons using the system reported a good feedback and concluded it was useful for safer procedures compared to standard operations (21). In this experience, the use of AR goggles allowed remote surgeons to follow and discuss the procedures in their crucial steps, during the approach and the device positioning phase.

These examples could represent a starting point to better investigate the potential development of AR for the teaching/supervision of surgical techniques, reducing the need for physical presence of experienced surgeon and consequently its related constraints on time and budgets.

The remote mentoring could also be considered to coordinate the setting up of the operative room for newer procedures or to help surgeons with the use of new instrumentations, even when specialist consultants could not physically enter the operative room. It is well-known that many traditional neurosurgical procedures often required the use of intraoperative neuromonitoring (IONM) in order to guarantee the best result, both in terms of extent of resection and neurological safeguarding. With the advent of new emerging minimal invasive techniques for spinal degenerative disease (e.g., CBT or LLIF), this need has spread further. Consequently, the great spread of the use of these techniques has increased the need for IONM (15, 22), with an augmented request for specialist consultants and technicians helping surgeons during the operative room set up. Thus, the other advantages of using an AR device described in this series was represented by the remote interaction between specialist consultants, surgeons and nurses, allowing the right setting of the operative room, even when advanced instrumentations are used.

Finally, and as already mentioned, although the remote mentoring and specialist counseling with the AR seemed, until few months ago, only a window on the future of the operative rooms and surgical activities, the recent dramatic experience of lockdown due to COVID-19 pandemic spread has changed the perspective, making it an everyday tool for the OR.

Another important application of AR for surgery is represented by its role in surgical planning. In this series CBT planning was visualized by the surgeon while maintaining the view on the surgical field and obtaining a real time feedback of the planned screw entry points. During the past few decades, several tools have been developed to improve pre-operative surgical planning both for spine and cranial surgery (7, 23).

The 3D printing era brought most surgical fields to an advanced new level, where even minimal differences from standard anatomy are detected, helping surgeons during the pre-operative planning and during the procedure, and then, leading to a customized surgical management. Nowadays, the so-called image guidance surgery is widely used in different surgical specialties (e.g., plastic free flap surgery, colon-rectal surgery) but recently, due to reached high accuracy, have been widely implemented in neurosurgery for cranial, spinal and skull base procedures (24). Penner et al. described their experiences with 3D model for surgical planning of cortical bone trajectory (CBT) screws positioning (7). Creating a customized spine CT scan-based 3D model, indeed, significantly improved the accuracy of screws positioning with the free hands technique, compared with the standard technique (7). The proposed methodology shares various similarities with virtual reality systems for surgical simulation, popularized in last two decades, and nowadays routinely employed for training specific interventions involving specific skills and eye-hand coordination (25).

To this end, systems incorporating haptic feedback for realistic rendering of contact forces experienced during the interaction with tissues are considered of fundamental importance for speeding up the learning curve (26). On the other side, according to the surgical specialty considered, these systems can make trainees deal with various complex hazards, rarely occurring in practice in OR, but potentially very dangerous if not carefully faced. This is especially the case of specialties involving drilling or burring, like mastoidectomy (27), orthognathic (28) and dental implantation (29), and orthopedic surgery (30).

For these tasks, haptic rendering is required to provide realistic forces and torques created by the complex interactions between the surgical tools and tissues involving tool penetration, tissue removal, rotational speed and vibrations (31). The accurate simulation of these interactions is technically challenging, since the frequency requirement for providing an adequate real time haptic feedback is above 500 Hz, corresponding to the generation of a force/torque sample every 2 ms, and the haptic simulation needs to be synchronized with visual rendering and other physical simulations eventually involving fluids and soft tissues (32).

Apart of these considerations, the proposed system can be used for gathering data related to surgical tool trajectories that can be used for fitting haptic models describing the tool-tissue dynamics that can be derived through contact models (33) or more modern machine learning methods (34). This represents a challenging and interesting research avenue that we plan to explore in the future.

Masciatelli et al. and Cabrilo et al. firstly described the application of AR in neurovascular surgery showing optimized workflow by providing essential anatomical information (35, 36). In another study by Cabrilo et al., virtual segmentations of the patient's vessels, the aneurysms, the aneurysms necks, were injected into the eyepiece of the operating microscope (37). The EPSON smart glasses could represent an innovative tool in order to integrate the production of pre-operative 3D model with the augmented reality. Once prepared, indeed, the virtual 3D model object could be loaded on the smart glasses; then, it could be scaled and positioned everywhere inside the surgeon's field of view. This way, the need to looking away from the operative field could be reduced and the neurosurgeon could be facilitated by the immediate availability of the patient's 3D model.

Resident training in surgical specialties is based on the apprenticeship model developed by Dr. William Halsted in 1980s and the training paradigm of "see one, do one, teach one" have been the pivotal concept until nowadays (38). Different authors have underlined the growing importance of introducing simulation into residents' formations and skills assessment (39). According to this picture, integrating AR into resident education could represent a renovation of the aforementioned educational model (16).

The operating theater has been the main classroom for many surgeons and is well-known that acquisition of surgical skills requires repeated occasions for hands-on practice. However, the limited number of people that can access to the OR and the large number of residents that need to learn surgical procedures often represent an issue, especially for small surgical centers and less developed countries.

Thus, the application of new technologies to increase residents' exposure to surgical procedures could play a key role for the learning curve. Thanks to its integrated camera and the previous described videoconference function, the EPSON glasses gives to the surgeon the possibility to record all the procedure and to create a live streaming that could be shared with residents and medical students, reducing the need for physical presence in the operative room. Moreover, the possibility to watch the pre-operative planning and reconstructed 3D models superimposed on the surgical field through the EPSON glasses, provide a double advantage; on one hand, indeed, surgeon has the possibility to see the model without taking eyes off of the operative field, while on the other hand, the simultaneous view of the real surgical field and of the 3D model could improve and speed up the residents' learning process.

Henssen et al. reported interesting results with their experience with AR comparing two different methods to study neuroanatomy; the classic method of studying cross sections of the brain and the one based on an AR-based neuroanatomy learning app (40). Hence, AR could represent a great instrument to improve education, especially in that fields of surgery that are particularly challenging. In neurosurgery, for example, surgeons constantly have to face with small anatomical corridors and critical neural and vascular structures that often lie within millimeters of their surgical instruments.

Understanding the true usability of the system, in order to assess whether it is not merely a technical exercise but rather a potential "everyday use tool" was key to us. In order to quantify how specialists perceived the use of the devices in the OR, they filled a SUS questionnaire (**Table 1**) and rated each question from 1 to 5, using a Likert scale where 1 correspond to "strongly disagree," and 5 to "strongly agree" (**Figure 4**). SUS questionnaires are commonly used to rate usability of hardware or software setups (41), and their use to rate mixed reality applications is common (10). From the top violin plots we noticed a bimodal trend, around the values 4 and 2, by looking at the scores from individual questions (Top graph). Since the bimodal trend seemed to correspond to questions with a rather "positive" or "negative" meaning, we visually divided them into green (positive) and red (negative). Indeed, the positive questions (Bottom graph), related to a likeness and appreciation of the application and the devices, had higher score (around the "agree" side of the graph), while the negative questions, related to a general dislike, discomfort or unease in using the system had a general lower score ("disagree"). This semi-quantitative assessment indicated a propension of the physicians in willing to use the system as it is.

Therefore, providing a precise and reliable 3D virtual and interactive environment, AR may become an extremely valuable tool for education of neurosurgical procedures, due to their intricate and complex nature.

DATA AVAILABILITY STATEMENT

The data analyzed in this study is subject to the following licenses/restrictions: Ethical. Requests to access these datasets should be directed to Fabio Cofano, fabio.cofano@gmail.com.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

CC wrote the first proof of the paper, with inputs from LD and MC. FC retrieved all the relevant literature, put together all qualitative/quantitative contributions from all authors and other users, and wrote the whole manuscript. MA contributed with a critical review of the manuscript and significant inputs during the rebuttal phase. GD, AL, MB, NM, FZ, and NZ tested the AR setup on field and gave their feedbacks to the technical team. DB was responsible for the technical support of the system and coordinated the work on the Unity code for the Microsoft hololens setup, together with MC. LD and DG coordinated the operations in OR with the AR setup. DG and CC coordinated the study. All authors contributed to the article and approved the submitted version.

FUNDING

This work was supported by the Kaust Innovation Fund POC grant to CC.

ACKNOWLEDGMENTS

We acknowledge Prof. Alessandro Vercelli (Department of Neuroscience, Università di Torino) for critical review of the manuscript.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsurg.2021.657901/full#supplementary-material

REFERENCES

1. Meng B, Bunch J, Burton D, Wang J. Lumbar interbody fusion: recent advances in surgical techniques and bone healing strategies. *Eur Spine J.* (2021) 30:22–33. doi: 10.1007/s00586-020-06596-0
2. Cofano F, Marengo N, Ajello M, Penner F, Mammi M, Petrone S, et al. The era of cortical bone trajectory screws in spine surgery: a qualitative review with rating of evidence. *World Neurosurg.* (2020) 134:14–24. doi: 10.1016/j.wneu.2019.10.079
3. Marengo N, Ajello M, Cofano F, Santonio FV, Monticelli M, Di Perna G, et al. A tailored approach to cortical bone track for spine fixation surgery: 3-dimensional printed custom made guides for screws placement: 2-dimensional operative video. *Oper Neurosurg.* (2020) 19:E600–1. doi: 10.1093/ons/opaa219
4. Cofano F, Di Perna G, Marengo N, Ajello M, Melcarne A, Zenga F, et al. Transpedicular 3D endoscope-assisted thoracic corpectomy for separation surgery in spinal metastases: feasibility of the technique and preliminary results of a promising experience. *Neurosurg Rev.* (2020) 43:351–60. doi: 10.1007/s10143-019-01204-2
5. Mao JZ, Agyei JO, Khan A, Hess RM, Jowdy PK, Mullin JP, et al. Technologic evolution of navigation and robotics in spine surgery: a historical perspective. *World Neurosurg.* (2020) 145:159–67. doi: 10.1016/j.wneu.2020.08.224
6. Contreras López WO, Navarro PA, Crispin S. Intraoperative clinical application of augmented reality in neurosurgery: a systematic review. *Clin Neurol Neurosurg.* (2019) 177:6–11. doi: 10.1016/j.clineuro.2018.11.018
7. Penner F, Marengo N, Ajello M, Petrone S, Cofano F, Santonio FV, et al. Preoperative 3D CT planning for cortical bone trajectory screws: a retrospective radiological cohort study. *World Neurosurg.* (2019) 126:e1468–74. doi: 10.1016/j.wneu.2019.03.121
8. Calì C, Baghabra J, Boges DJ, Holst GR, Kreshuk A, Hamprecht FA, et al. Three-dimensional immersive virtual reality for studying cellular compartments in 3D models from EM preparations of neural tissues. *J Comp Neurol.* (2016) 524:23–38. doi: 10.1002/cne.23852
9. Coggan JS, Calì C, Keller D, Agus M, Boges D, Abdellah M, et al. A process for digitizing and simulating biologically realistic oligocellular networks demonstrated for the neuro-glio-vascular ensemble. *Front Neurosci.* (2018) 12:664. doi: 10.3389/fnins.2018.00664
10. Agus M, Boges DJ, Gagnon N, Magistretti PJ, Hadwiger M, Cali C. GLAM: glycogen-derived lactate absorption map for visual analysis of dense and sparse surface reconstructions of rodent brain structures on desktop systems and virtual environments. *Comput Graph.* (2018) 74:85–98. doi: 10.1016/j.cag.2018.04.007
11. Calì C, Kare K, Agus M, Veloz Castillo MF, Boges D, Hadwiger M, et al. A method for 3D reconstruction and virtual reality analysis of glial and neuronal cells. *J Vis Exp.* (2019). doi: 10.3791/59444
12. Boges DJ, Agus M, Magistretti PJ, Calì C. Forget about electron micrographs: a novel guide for using 3D models for quantitative analysis of dense reconstructions. *Volume Microscopy.* (2020) 155:263–304. doi: 10.1007/978-1-0716-0691-9_14
13. Mohammed H, Al-Awami AK, Beyer J, Cali C, Magistretti PJ, Pfister H, et al. Abstractocyte: A visual tool for exploring nanoscale astroglial cells. *IEEE Trans Vis Comput Graph.* (2018) 24:853–61. doi: 10.1109/TVCG.2017.2744278
14. Dennler C, Jaberg L, Spirig J, Agten C, Götschi T, Fürnstahl P, et al. Augmented reality-based navigation increases precision of pedicle screw insertion. *J Orthop Surg Res.* (2020) 15:174. doi: 10.1186/s13018-020-01690-x
15. Cofano F, Zenga F, Mammi M, Altieri R, Marengo N, Ajello M, et al. Intraoperative neurophysiological monitoring during spinal surgery: technical review in open and minimally invasive approaches. *Neurosurg Rev.* (2019) 42:297–307. doi: 10.1007/s10143-017-0939-4
16. Pelargos PE, Nagasawa DT, Lagman C, Tenn S, Demos JV, Lee SJ, et al. Utilizing virtual and augmented reality for educational and clinical enhancements in neurosurgery. *J Clin Neurosci.* (2017) 35:1–4. doi: 10.1016/j.jocn.2016.09.002
17. Lee C, Wong GK. Virtual reality and augmented reality in the management of intracranial tumors: a review. *J Clin Neurosci.* (2019) 62:14–20. doi: 10.1016/j.jocn.2018.12.036
18. Rojas-Muñoz E, Cabrera ME, Lin C, Andersen D, Popescu V, Anderson K, et al. The system for telementoring with augmented reality (STAR): a head-mounted display to improve surgical coaching and confidence in remote areas. *Surgery.* (2020) 167:724–31. doi: 10.1016/j.surg.2019.11.008
19. Green JL, Suresh V, Bittar P, Ledbetter L, Mithani SK, Allori A. The utilization of video technology in surgical education: a systematic review. *J Surg Res.* (2019) 235:171–80. doi: 10.1016/j.jss.2018.09.015
20. Carrera JF, Wang CC, Clark W, Southerland AM. A systematic review of the use of google glass in graduate medical education. *J Grad Med Educ.* (2019) 11:637–48. doi: 10.4300/JGME-D-19-00148.1
21. Davis MC, Can DD, Pindrik J, Rocque BG, Johnston JM. Virtual interactive presence in global surgical education: international collaboration through augmented reality. *World Neurosurg.* (2016) 86:103–11. doi: 10.1016/j.wneu.2015.08.053
22. Altieri R, Zenga F, Fontanella MM, Cofano F, Agnoletti A, Spena G, et al. Glioma surgery: technological advances to achieve a maximal safe resection. *Surg Technol Int.* (2015) 27:297–302.
23. Rengier F, Mehndiratta A, Von Tengg-Kobligk H, Zechmann CM, Unterhinninghofen R, Kauczor HU, et al. 3D printing based on imaging data: Review of medical applications. *Int J Comput Assist Radiol Surg.* (2010) 5:335–41. doi: 10.1007/s11548-010-0476-x
24. Meulstee JW, Nijsink J, Schreurs R, Verhamme LM, Xi T, Delye HH, et al. Toward holographic-guided surgery. *Surg Innovat.* (2019) 26:86–94. doi: 10.1177/1553350618799552
25. Lungu AJ, Swinkels W, Claesen L, Tu P, Egger J, Chen X. A review on the applications of virtual reality, augmented reality and mixed reality in surgical simulation: an extension to different kinds of surgery. *Expert Rev Med Dev.* (2021) 18:47–62. doi: 10.1080/17434440.2021.1860750
26. Rangarajan K, Davis H, Pucher PH. Systematic review of virtual haptics in surgical simulation: a valid educational tool? *J Surg Educ.* (2020) 77:337–47. doi: 10.1016/j.jsurg.2019.09.006
27. Agus M, Giachetti A, Gobbetti E, Zanetti G, Zorcolo A, John NW, et al.. Mastoidectomy simulation with combined visual and haptic feedback. *Stud Health Technol Inform.* (2002) 85:17–23. doi: 10.3233/978-1-60750-929-5-17
28. Medellin-Castillo HI, Zaragoza-Siqueiros J, Govea-Valladares EH, de la Garza-Camargo H, Lim T, Ritchie JM. Haptic-enabled virtual training in orthognathic surgery. *Virtual Reality.* (2020) 2020:1–15. doi: 10.1007/s10055-020-00438-6

29. Zhao X, Zhu Z, Cong Y, Zhao Y, Zhang Y, Wang D. Haptic rendering of diverse tool-tissue contact constraints during dental implantation procedures. *Front Robot.* (2020) AI 7:35. doi: 10.3389/frobt.2020.00035
30. Faieghi M, Atashzar SF, Tutunea-Fatan OR, Eagleson R. parallel haptic rendering for orthopedic surgery simulators. *IEEE Robot Automat Lett.* (2020) 5:6388–95. doi: 10.1109/LRA.2020.3013891
31. Agus M, Giachetti A, Gobbetti E, Zanetti G, Zorcolo A. Real-time haptic and visual simulation of bone dissection. *Presence Teleoperat Virtual Environ.* (2003) 12:110–22. doi: 10.1162/105474603763835378
32. Agus M, Giachetti A, Gobbetti E, Zanetti G, Zorcolo A. A multiprocessor decoupled system for the simulation of temporal bone surgery. *Comput Visual Sci.* (2002) 5:35–43. doi: 10.1007/s00791-002-0085-5
33. Agus M, Brelstaff GJ, Giachetti A, Gobbetti E, Zanetti G, Zorcolo A, et al. Physics-based burr haptic simulation: tuning and evaluation. In: *12th International Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems HAPTICS'04 Proceedings IEEE.* (2004). p. 128–35. doi: 10.1109/HAPTIC.2004.1287187
34. Sun H., Martius G. Machine learning for haptics: inferring multi-contact stimulation from sparse sensor configuration. *Front Neurorobot.* (2019) 13:51. doi: 10.3389/fnbot.2019.00051
35. Mascitelli JR, Schlachter L, Chartrain AG, Oemke H, Gilligan J, Costa AB, et al. Navigation-linked heads-up display in intracranial surgery: early experience. *Operat Neurosurg.* (2018) 15:184–93. doi: 10.1093/ons/opx205
36. Cabrilo I, Schaller K, Bijlenga P. Augmented reality-assisted bypass surgery: embracing minimal invasiveness. *World Neurosurg.* (2015) 83:596–602. doi: 10.1016/j.wneu.2014.12.020
37. Cabrilo I, Bijlenga P, Schaller K. Augmented reality in the surgery of cerebral aneurysms: a technical report. *Neurosurgery.* (1982) 10:252–61. doi: 10.1227/NEU.0000000000000328
38. Chaer RA, DeRubertis BG, Lin SC, Bush HL, Karwowski JK, Birk D, et al. Simulation improves resident performance in catheter-based intervention: results of a randomized, controlled study. *Ann Surg.* (2006) 244:343. doi: 10.1097/01.sla.0000234932.88487.75
39. Gorman PJ, Meier AH, Krummel TM. Simulation and virtual reality in surgical education: real or unreal? *Arch Surg.* (1999) 134:1203–8. doi: 10.1001/archsurg.134.11.1203
40. Henssen DJ, van den Heuvel L, De Jong G, Vorstenbosch MA, van Cappellen van Walsum AM, Van den Hurk MM, et al. Neuroanatomy learning: augmented reality vs. cross-sections. *Anat Sci Educ.* (2020) 13:353–65. doi: 10.1002/ase.1912
41. Brooke, J. SUS: A "quick and dirty" usability scale. In: Jordan PW, Werdmeester BA, McClelland AL, editors. *Usability Evaluation in Industry*. London: Taylor & Francis (1996). p. 189–94.

Conflict of Interest: LD is the owner of the company LD Consulting.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Public Health

ORIGINAL RESEARCH
published: 29 April 2021
doi: 10.3389/fpubh.2021.628178

E-Learning in Teaching Emergency Disaster Response Among Undergraduate Medical Students in Malaysia

Ismail M. Saiboon[1*], *Fareena Zahari*[1], *Hisham M. Isa*[1], *Dazlin M. Sabardin*[1] and *Colin E. Robertson*[2]

[1] *Department of Emergency Medicine, Faculty of Medicine, Universiti Kebangsaan Malaysia, Cheras, Malaysia,* [2] *Accident and Emergency Medicine, University of Edinburgh, Edinburgh, United Kingdom*

Introduction: Teaching disaster response medicine (DRM) to medical students requires considerable resources. We evaluate the effectiveness of e-learning in teaching emergency disaster response (ELITE-DR), a novel initiative, in educating medical students of the cognitive aspect of DRM.

Methods: A prospective cross-sectional study among pre-clinical year medical students was carried out to determine their knowledge on DRM and perception regarding the ELITE-DR initiative using a validated online questionnaire. A three-part self-learning video covering the principles and medical management of DRM were distributed before answering the questionnaire served as the training.

Results: A total of 168 students participated in the study. Their overall knowledge showed a significant increase in between pre-and-post-interventions. Recall and simple decision-making knowledge aspects were better than complex decision-making knowledge. It appeared that participants assimilate knowledge better from visual rather than audio stimuli. Participants with high perception-scores demonstrated better knowledge-scores. However, e-learning was not preferred as a substitute for face-to-face (F2F) teaching.

Conclusion: ELITE-DR shows promise in teaching DRM. Simple recall and comprehension levels of knowledge were well-served through this technique. However, for more complex decision-making knowledge, a different approach might be required. ELITE-DR offers flexibility, accessibility, and personalized learning. The content presentation is improved by using several different visual stimuli. This approach is useful for cognitive aspect learning, but it should not replace standard F2F teaching.

Keywords: education training, e-learning, disaster medicine, medical students, self-learning video

Edited by:
Francesco Della Corte, University of Eastern Piedmont, Italy

Reviewed by:
Pertti Juhani Hakkinen, National Center for Biotechnology Information (NLM), United States
Che-Wei Lin, Taipei Medical University, Taiwan

****Correspondence:***
Ismail M. Saiboon
fadzmail69@yahoo.com.my;
ismail@ppukm.ukm.edu.my

Specialty section:
This article was submitted to Disaster and Emergency Medicine, a section of the journal Frontiers in Public Health

Received: *11 November 2020*
Accepted: *29 March 2021*
Published: *29 April 2021*

Citation:
Saiboon IM, Zahari F, Isa HM, Sabardin DM and Robertson CE (2021) E-Learning in Teaching Emergency Disaster Response Among Undergraduate Medical Students in Malaysia. Front. Public Health 9:628178. doi: 10.3389/fpubh.2021.628178

INTRODUCTION

Globally, disaster medicine is inadequately represented in the undergraduate medical curriculum (1). Even though more medical schools have incorporated disaster medicine into their curriculum lately, it is believed that medical undergraduates still do not possess adequate knowledge and skill in this area (2). Teaching disaster response medicine (DRM) to undergraduate (UG) medical students is challenging, and not all medical schools include DRM as part of their curriculum (3–5). DRM teaching has many facets or components. Apart from knowledge, there are elements of planning, decision-making (both clinical and operative), simple or complex treatment strategies, clinical procedures, protocols, etc. (6–8). These are usually taught at the post-graduate level or as a subspecialty (9). However, as the recent COVID-19 pandemic has shown, UG education of disaster medicine is vital and should include some basic knowledge, simple procedures, and basic decision-making elements.

Disaster response is traditionally delivered using face-to-face (F2F) training, simulation, and role play (10, 11). This is a challenge for many academic institutions, as simulation role-play requires significant teaching manpower (12). Other difficulties include restrictions on teaching time within the 5- or 6-year curriculum (12, 13), difficulty gathering students in a single, suitable educational setting, and lack of direct access to experts (10).

In 2020, the COVID-19 pandemic has highlighted the difficulties in delivering UG curricula, especially for DRM (14–17). In Malaysia, as many parts of the world, this difficulty is brought about the government-imposed limitation to social interaction with the introduction of the Movement Control Order Act (18) that included suspending primary, secondary, and tertiary education. Since the majority of activities in DRM teaching involve gathering and close interactions, the implementation of the Movement Control Order Act posed a greater challenge to teaching DRM to UG medical students, as traditional methods of teaching become prohibited during the pandemic. Faced with these challenges, e-learning has been suggested as a promising alternative instead of traditional F2F methods (19–21).

In our institution, the Emergency Medicine module is taught in Year-5 over 1 credit hour (1 credit-hour = 40 notional hours). Presently DRM, which is part of this module, is taught in the form of face-to-face classroom method with field simulation exercise. This study attempts to experiment with deliverance of the cognitive aspect of teaching and learning contents of DRM as an online learning rather than face-to-face among the undergraduates in the pre-clinical years (Year-1 and Year-2), who are not normally students of this module. This study, e-learning in teaching emergency disaster response (ELITE DR), focused only on the cognitive aspect of DRM, uses a one-way asynchronous online video teaching. As outcomes of the study, we set out to evaluate the effectiveness of this novel initiative and the medical students' perception of it. The hypothesis was that the cognitive aspect of DRM could be taught effectively and acceptably using the ELITE-DR approach.

METHODOLOGY

Study Design

This was a prospective, cross-sectional, interventional study involving pre-clinical year students at Faculty of Medicine Universiti Kebangsaan Malaysia (UKM), looking at pre- and post-intervention outcomes. Enrolment for the study was performed using convenience sampling. Pre-clinical year medical students, from the first and second year of the program, were invited to participate in this study since DRM was not part of the pre-clinical year curriculum. Therefore, it removed the bias of doing this intervention by excluding students who had prior exposure to disaster management teaching or training. To further minimize potential confounders such as referring to other printed or online materials and discussion among the participants, it was emphasized to the participants that the marks in the questionnaires would not affect their curriculum assessment. This was to alleviate further stress among the participants and to promote compliance with the methodology. Each participant was required to watch a set of the self-learning-video (SLV) completely at least once.

The study was conducted between 2nd April 2019 and 31st March 2020. Approval was obtained from the Medical Research and Ethics Committee of UKM and funding was provided by the Faculty of Medicine as a Fundamental Research grant (approval number FF-2019-087).

Development of the Self Learning Video (SLV)

The SLV consisted of three video lectures of 8–10 min duration to maintain participants' focus and attention. The three videos covered the Principles of DRM and Disaster Medical management were covered. The video was developed using the Screencast-O-Matic application (version 0.2.2.3, Screencast-O-Matic, Seattle, WA, USA) as there were no available videos from the internet that adequately cover the principles of DRM. The Principles of DRM include definition, classification, phases, aims, activation process, and staging, while Disaster Medical management topics included: decontamination, triage, treatment, and transport. Screenshots from the videos showing the activation process, principles of disaster response (CoSCADTTT), disaster stages and triage are shown in **Figures 1A–D**.

The SLV content was validated by a panels of local emergency physicians who specialized in disaster medicine. They viewed the SLVs several times and made valuable remarks that contributed to the validity of the video. The recommended changes were made to the videos following comments from the panelists, and the process repeated until all panelists were satisfied with its content and arrangement. The study materials were then uploaded onto an online platform that was accessible to all participants.

Questionnaire Development

The study collected quantitative data which included the participants' knowledge and perceptions. Respondents were invited to answer a self-administered questionnaire. Twenty questions assessed knowledge, while 26 questions assessed perceptions. Questions assessing knowledge were divided into principles and medical management of DRM. The knowledge-based questions were multiple-choice questions with a single best answer, and each question carried one (1) mark. The 26 items on the perceptions comprised the self-gain, presentability,

Abbreviations: DRM, disaster response medicine; ELITE DR, e-learning in teaching emergency disaster response; F2F, face-to-face; PS, perception score; SLV, self-learning-video; UG, undergraduate.

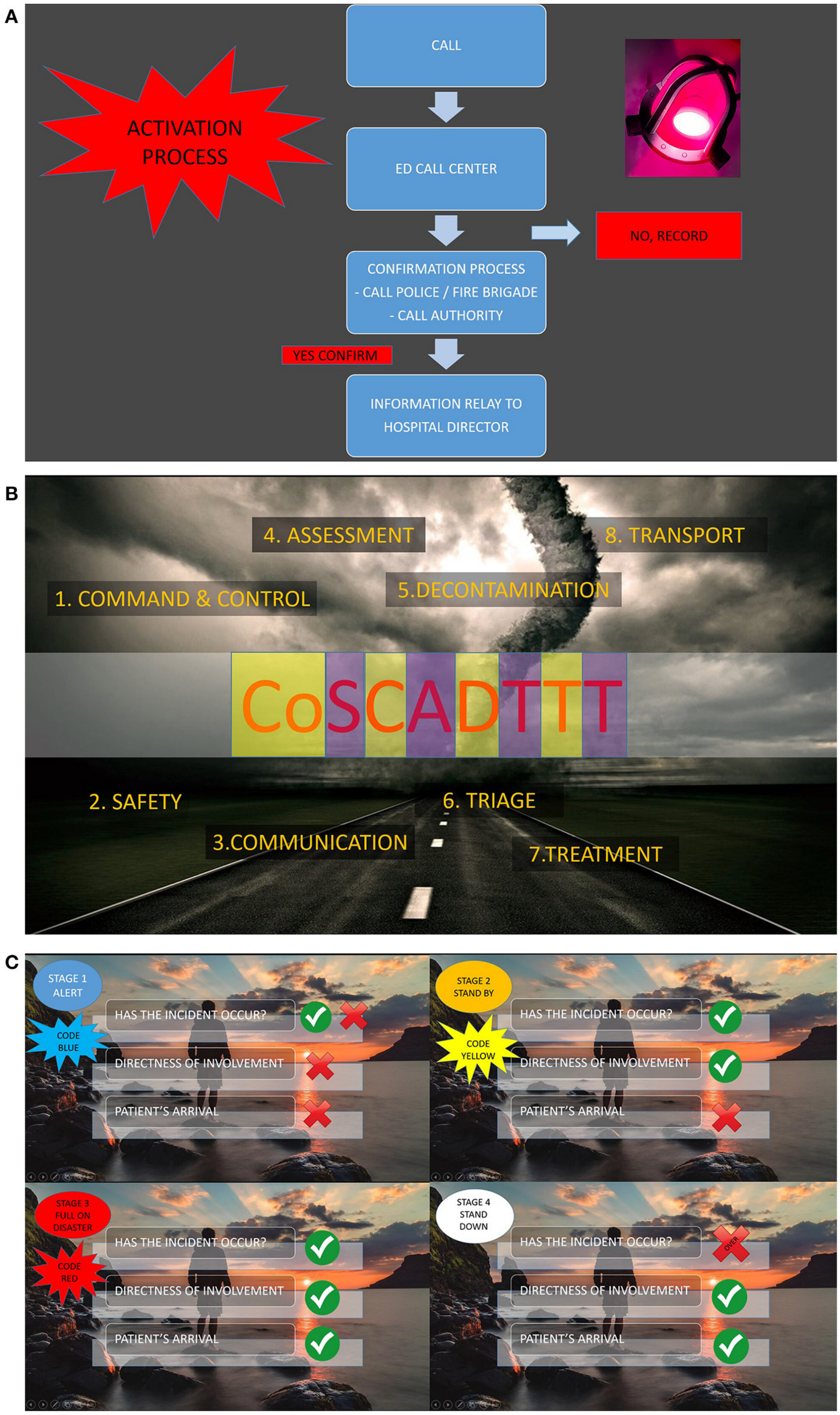


FIGURE 1 | Continued

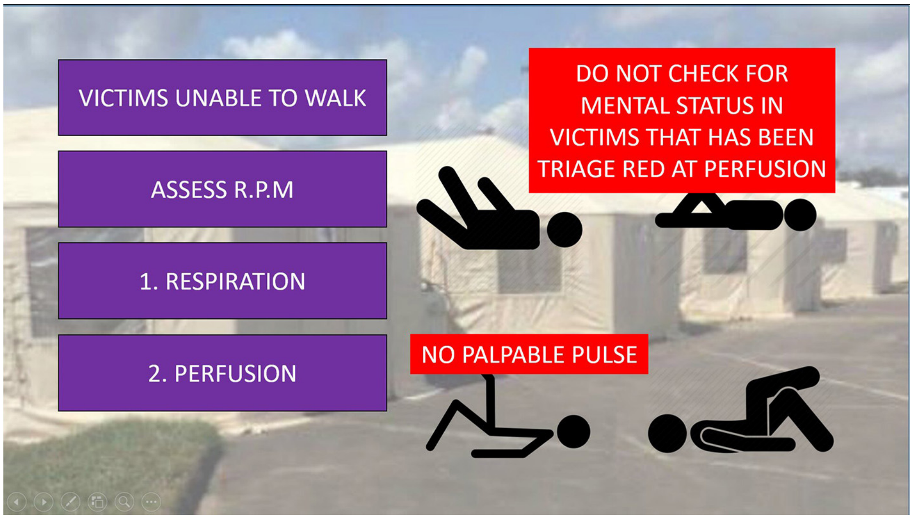
D


FIGURE 1 | (A–D) Screen-shots from the ELITE-DR video. **(A)** Activation process of disaster response, **(B)** all-hazards principles of disaster response, **(C)** stages of disaster activation, and **(D)** triage process.

and e-learning in the medical curriculum. These questions were developed by a group of three expert panels from among the local emergency physicians who specialized in DRM. The Delphi technique was used to develop the questionnaires. All questions were validated by expert panels of DRM to ensure those questions are clinically relevance. Further validation of the questionnaire was performed with a group of medical students from another institution that was not involved in this study.

Self-gain referred to the elements of that bring direct benefits to the participants and their preference, such as knowledge gained, flexibility, personalized learning, usefulness, ease of use, and familiarity of using online material or application in completing their task. In terms of presentability, the participants' preference for the SLV was evaluated. For e-learning in teaching DRM, those elements such as the use of e-learning as a standard teaching modality, substituting standard teaching with SLV, and recommendation of the SLV to fellow students were covered.

Perception was measured by using a 4-point Likert scale instrument. Participants were asked to rank their agreeability to the statements given based on a 4-graded scale. Marks were given for each scale from −2 for strongly disagree; −1 for disagree; +1 for agree; and +2 for strongly agree. The total score was then calculated and divided by the number of participants to give the perception score (PS). The mean PS score was used to categorize the perception of the participants ranging from strongly disagree to strongly agree according to the scale shown in **Table 1**.

TABLE 1 | Perception's score (PS) scale.

PS	Agreeability
<-1 to −2	Strongly disagree
<0 to −1	Disagree
0 to +1	Agree
> +1 to +2	Strongly agree

Study Protocol

The SLVs and the validated questionnaire were given to the eligible participants after briefing and consenting. A pre-test questionnaire was given to establish the baseline DRM knowledge among the participants. Each participant then received the three-part SLVs via web-links as below:

(Part 1) https://youtu.be/DAdVnFLozww
(Part 2) https://youtu.be/ySWylU-1xmI
(Part 3) https://youtu.be/3LiH0kS2brs.

The participants were given 7 consecutive days of access to the SLVs from the pre-test date. None of the participants received any teaching from facilitators during the learning session, as the intention was to simulate a self-instructional, unsupervised learning situation. Participants were strictly advised against referring to other resources of DRM either through printed materials or online or to discuss with each other in order to limit the potential confounding factors.

Post-intervention assessment (post-test) on knowledge and perception was conducted using a self-administered questionnaire after the participants had completed their dedicated 7 consecutive days of learning. A flow diagram detailing the study is given in **Figure 2**.

Statistical Analysis

There were 274 medical students in the pre-clinical years in the Faculty of Medicine UKM. Using the Krejcie and Morgan table (22), it was considered that a minimum of 155 participants was required to achieve a statistical power of 80% at a confidence

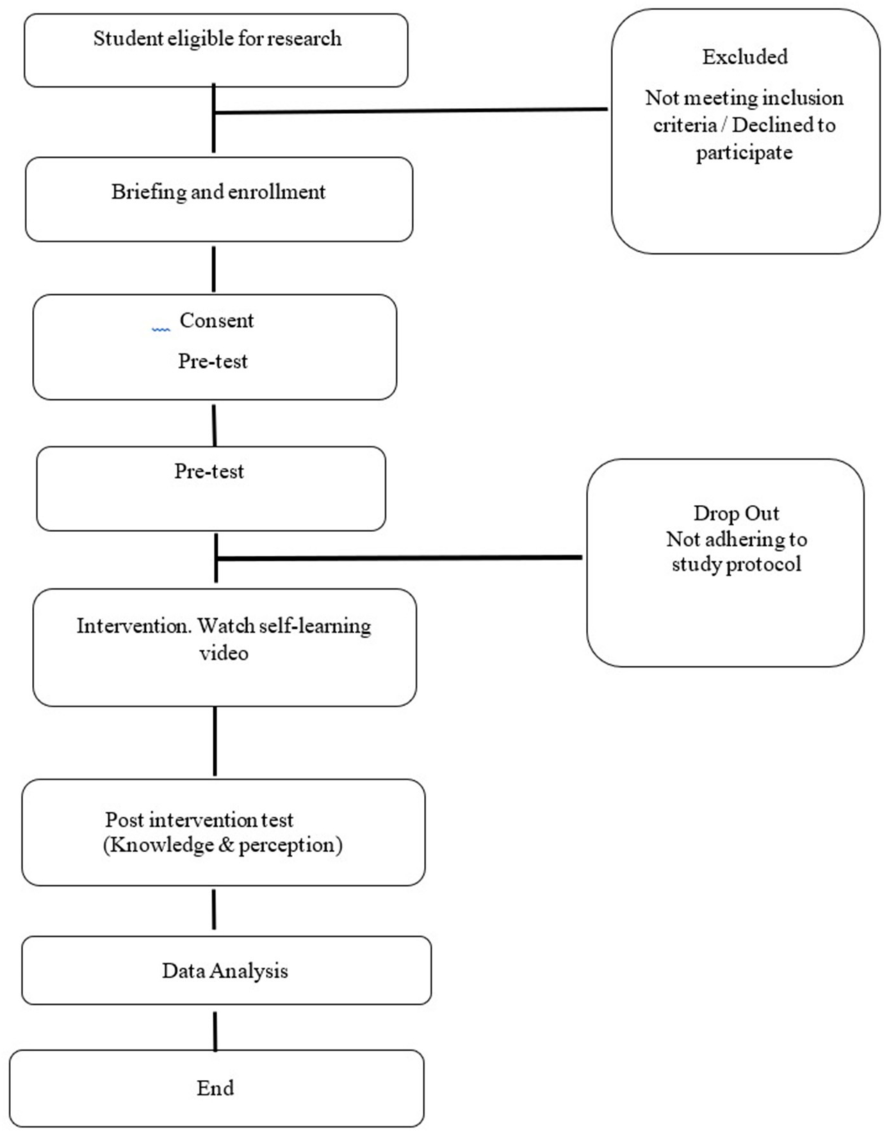


FIGURE 2 | Study flow diagram.

interval of 95%. For the internal consistency measurement of the questionnaire, Cronbach's alpha score was 0.83.

Statistical analyses were performed using Minitab Statistical Software (version 19, Pennsylvania State University, PA, USA). Demographic characteristics of the participants were obtained by descriptive analysis. Data were summarized using mean and standard deviation for continuous variables, frequency, and percentages for categorical variables. The 99% confidence interval was calculated for the mean scores. A paired t-test was used to assess the mean differences between the two groups (knowledge between pre- and post-test), and one-way ANOVA was used to compare the PS achieve among the four groups of PS. All differences were considered statistically significant if $p < 0.01$.

RESULTS

From a total of 274 undergraduate medical students in the pre-clinical year eligible for this study, 261 participants consented and were enrolled into the study. Thirteen were excluded from the study, 12 were because they had attended a disaster response medicine course prior this and one declined to participate. A total of 93 participants did not complete the study; a final total of 168 participants completed the study (**Figure 3**).

Of the 168 participants, the majority were females from the first year ($N = 135$; 80.4%). Most of the participants (86.3%) watched the SLVs only once. The demographic details of the participants are shown in **Table 2**.

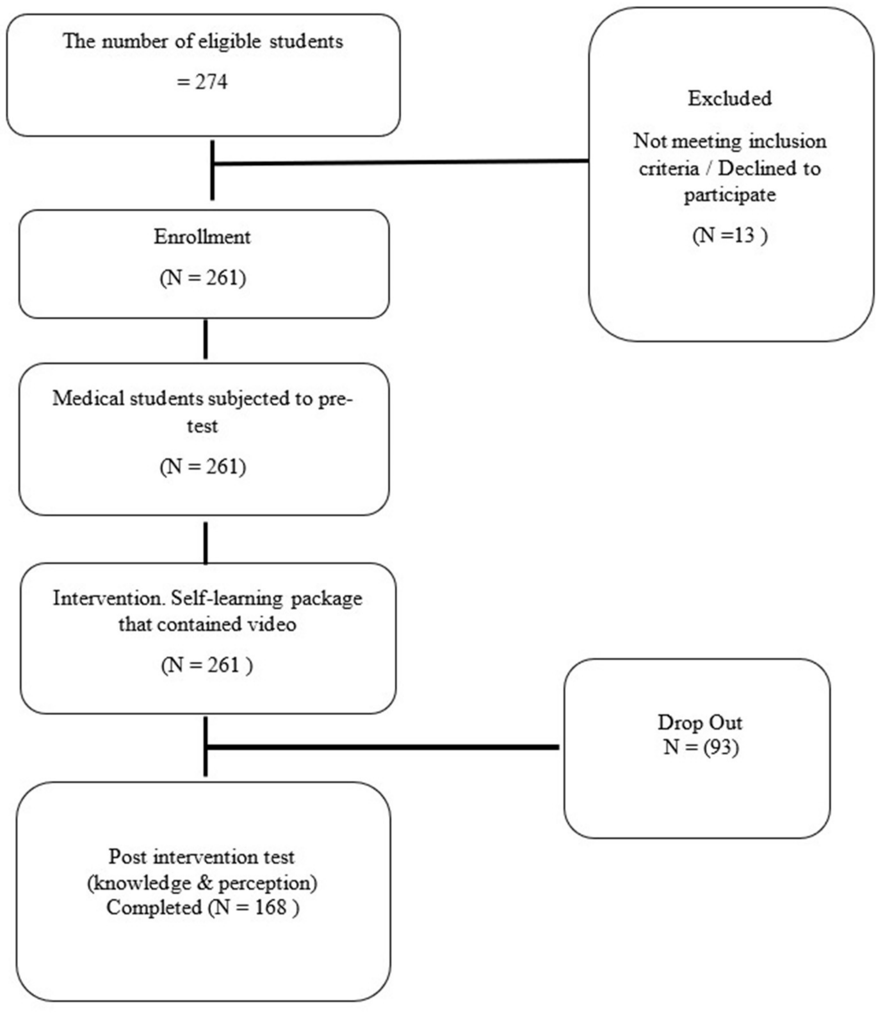


FIGURE 3 | CONSORT flowchart of the study on E-Learning in Teaching Emergency Disaster Response (ELITE DR).

Table 3 shows the pre- and post-test data for knowledge on the principles, and medical management of DRM and their respective sub-components. The mean pre- and post-test marks for knowledge of DRM were 6.99 ± 2.65 and 13.31 ± 5.21, respectively ($p < 0.001$). On sub-analysis there was significant improvement in knowledge on the principles and medical management of DRM ($p < 0.001$).

The medical management components like triage and decontamination also significantly improved between pre- and post-test (all $p < 0.001$) but not in the areas of treatment and transport with $p = 0.029$ and $p = 0.180$, respectively.

Table 4 shows the responses and mean score on perception for self-gain. Self-gain questions revealed that the participants "strongly agree" that e-learning is highly flexible, useful, easy to handle, and improved their knowledge. However, for familiarity with e-learning, such as finding the technique easier to use for revision, and allowing them to accomplish more work, the participants only scored "agree."

Table 5 displays the result and mean score on SLV Presentability. The majority of the participants agreed or strongly agreed with the eye-catching visual stimuli of the videos (PS = +1.05 to +1.27). Animation, highlighted and enlarged words, and pictures were the preferred visual stimuli and helped participants retain facts (PS = +1.27). The participants scored "agree" (PS = +0.77 to +0.83) for audio stimuli, e.g., music, that had been incorporated in the videos.

Table 6 shows the result and mean score on perception of the e-learning medical curriculum. Most of the participants would strongly recommend this video to others to enhance their learning ability of DRM (PS = +1.26 to +1.38). Most of the participants "agree" that DRM taught through e-learning, should be incorporated into the medical curriculum (PS = +0.71 to +0.99) in the form of adjunct material (PS = +1.12). However, they "disagree" (PS = −0.36) that DRM through e-learning could, or should, completely replace F2F sessions.

TABLE 2 | Demographic data of the participants.

Demographic data of the participants		
Gender	Frequency (*N* = 168)	Percentage (%)
Male	33	19.6
Female	135	80.4
Year		
1	120	71.4
2	48	28.6
Race		
Malay	96	57.1
Chinese	30	17.9
Indian	25	14.9
Others	17	10.1
Frequency of watching the SLP		
1	145	86.3
2–4	22	13.1
>4	1	0.6

TABLE 3 | The mean score on pre-test and post-test for overall Knowledge, Principles, and Medical Management of Disaster Response.

	Knowledge scores		
	Pre-test (*N* = 168)	**Post-test (*N* = 168)**	***p*-value**
Knowledge on Disaster Response (overall)/20	6.99 ± 2.65	13.31 ± 5.21	<0.001
Knowledge on Principles of Disaster Response/9	2.91 ± 1.43	6.24 ± 2.53	<0.001
I. Definition	0.37 ± 0.48	0.76 ± 0.43	<0.001
II. Classification	0.1 ± 0.3	0.43 ± 0.5	<0.001
III. Phases	0.59 ± 0.49	0.88 ± 0.33	<0.001
IV. Stage	1.1 ± 0.82	1.64 ± 0.68	<0.001
V. Activation	0.06 ± 0.23	0.67 ± 0.47	<0.001
VI. Command and control	0.26 ± 0.54	1.37 ± 0.79	<0.001
VII. Safety	0.18 ± 0.38	0.68 ± 0.47	<0.001
Knowledge on Medical Management of Disaster Response/11	4.08 ± 1.97	7.06 ± 3.05	<0.001
I. Decontamination	0.01 ± 0.08	0.7 ± 0.46	<0.001
II. Triage	2.78 ± 1.58	5.39 ± 2.22	<0.001
III. Treatment	0.46 ± 0.49	0.58 ± 0.49	0.029
IV. Transport	0.58 ± 0.49	0.65 ± 0.47	0.18

Analysis of participants' knowledge and their PS revealed that those who graded higher PS could obtained a better knowledge score. One-way ANOVA analysis also revealed a significant difference between the PS groups' knowledge score ($p < 0.001$) as shown in **Table 7**.

DISCUSSION

This study has demonstrated that a novel e-learning package can successfully be used to teach DRM to UG medical students. Previous studies have been shown that e-learning can be as effective as F2F teaching when it comes to understanding knowledge aspects such as simple recall and comprehension (23–26). In contrast to the higher levels of learning outline in the Bloom's taxonomy, such as analysis, application, synthesis, and assessment, recall, and comprehension levels of learning are particularly well-served by e-learning. The participants, however, did not score well for medical management aspects, especially for the treatment and transport components. This was expected because the participants were pre-clinical students, and these subjects would have been unfamiliar to them where a deeper clinical understanding, further appraisal, and decision-making skills were required.

Feedback and debriefing have been shown to be important to enhance understanding in these areas (27). We may improve these skills if the feedback can be provided while viewing the video. An e-learning video platform that can assess the participants' understanding and collect their immediate feedback (28), such as ED-Puzzle or Common Ground (CG) scholar, may be one approach to this. The CG scholar platform has been shown to support critical thinking and promote a higher-order of thinking skills (29). It incorporates active knowledge production, ubiquitous learning, and recursive feedback, which involved receiving and giving reviews from peers and instructors to allow learners to reflect on their work. Our study used Screencast-O-Matic, a one-way directed video application that could not provide or create these higher-order thinking skills for the participants.

Participants did particularly well on the triage topic. This could be related to the structured algorithm, which was available in the video and hence required only simple decision-making (lower-order thinking). The structured algorithm directed the participants to follow the signs or symptoms elicited before deciding.

Perceptions were categorized according to the PS scale in **Table 1**. In self-gain, the participants agreed on most of the learning items, especially those involving knowledge improvement, flexibility, personalization, usefulness, and ease of handling. They found e-learning easier to use and convenient. Having a flexible and personalized e-learning environment is important to encourage an active and inclusive learning environment (30). However, in terms of familiarity, such as revising using digital materials alone or using technologies in accomplishing more work, the PS score was much lower. Therefore, while participants find e-learning helpful, they need to be familiarized with e-learning tools, especially when searching for new data or knowledge.

Limitations in the familiarity with usage of digital technology can lead to difficulties for students to accomplish their goals. Consequently, the effort they need to invest to generate the expected outcomes tends to be higher than that of students better familiarized with online technologies (31). In terms of presentability, the participants awarded high scores for visual inputs compared to audio inputs. This is coherent with a previous study where visual computer-based learning did not show any significant difference with or without an auditory narrative (32).

TABLE 4 | Result and mean score on perception for self-gain.

	Self-gain (*N* = 168)								
	Strongly disagree (-2)		Disagree (−1)		Agree (+1)		Strongly agree (+2)		Mean PS (a + b + c + d)/ 168
	n	a	*n*	b	*n*	c	*n*	d	
Knowledge of disaster response has improved	1	−2	1	−1	95	+95	71	+142	+1.36
Content of the e-learning useful in my career	0	0	2	−2	95	+95	71	+142	+1.40
Able to watch at own pace	2	−4	6	−6	84	+84	76	+152	+1.35
I can learn at home, at work, at college, library or café (i.e., mobile)	2	−4	2	−2	81	+81	83	+166	+1.43
The knowledge presented in the e-learning is easy to understand	1	−2	2	−4	101	+101	62	+124	+1.31
Easier to revise electronic educational materials than printed material	7	−14	25	+25	95	+95	41	+82	+0.86
E-learning technologies allow accomplishing more work	4	−8	12	−12	117	+117	35	+70	+0.99
E-learning provides better learning opportunities (i.e.: accessibility to all without physical attendance)	3	−6	15	−15	101	+101	49	+98	+1.06
E-learning improves the quality of my studies	1	−2	4	−4	112	+112	51	+102	+1.24

N = total number of respondents.
n = total respondent to each Likert Scale.
a = n × (−2); b = n × (−1); c = n × (+1); d = n × (+2).
a, b, c, d = the total score for each category of Likert scale.

TABLE 5 | Result and mean score on SLV presentability.

	SLV presentability (*N* = 168)								
	Strongly disagree (−2)		Disagree (−1)		Agree (+1)		Strongly agree (+2)		Mean PS (a + b + c + d)/ 168
	n	a	*n*	b	*n*	c	*n*	d	
The animation used able to sustain my focus	2	−4	11	−11	119	+119	36	+72	+1.05
The pictures used able to catch my attention	1	−2	11	−11	121	+121	35	+70	+1.06
The music helped to sustain my attention	2	−4	21	−21	126	+126	19	+38	+0.83
The music uplift my mood	3	−6	24	−24	123	+123	18	+36	+0.77
The bolded words attract my attention	2	−4	5	−5	105	+105	56	+112	+1.24
The enlarged words attract my attention	1	−2	3	−3	101	+101	63	+126	+1.26
The animation, pictures, and visual stimulus help me to remember the content better	2	−4	3	−3	105	+105	58	+116	+1.27

N = total number of respondents.
n = total respondent to each Likert Scale.
a = n × (−2); b = n × (−1); c = n × (+1); d = n × (+2).
a, b, c, d = the total score for each category of Likert scale.

TABLE 6 | Result and mean score on perception for e-learning in the medical curriculum.

E-learning in the medical curriculum ($N = 168$)									
	Strongly disagree (-2)		Disagree (−1)		Agree (+1)		Strongly agree (+2)		Mean PS (a + b + c + d)/168
	n	a	*n*	b	*n*	c	*n*	d	
Incorporate e-learning in the current medical curricular	2	−4	17	−17	110	+110	39	+78	+0.99
Medical curricular can be taught through e-learning	7	−14	31	−31	96	+96	34	+68	+0.71
E-learning should act as a supplementary to the F2F teaching	2	−4	9	−9	113	+113	44	+88	+1.12
E-learning substitute F2F lecture	42	−84	58	−58	55	+55	13	+26	−0.36
Recommend video to other medical students	1	−2	0	0	101	+101	66	+132	+1.38
Recommend the video for general public viewing	1	−2	6	−6	100	+100	61	+122	+1.27
Recommend this video to non-medical students	1	−2	6	−6	103	+103	58	+116	+1.26
Recommend this video to post-graduate students	1	−2	1	−1	109	+109	57	+114	+1.31
Recommend this video to general practitioners	1	−2	3	−3	107	+107	57	+114	+1.29
Would not recommend this video to be put on YouTube for free access	44	−88	68	−68	40	+40	16	+32	−0.5

N = total number of respondents.
n = total respondent to each Likert Scale.
a = n × (−2); b = n × (−1); c = n × (+1); d = n × (+2).
a, b, c, d = the total score for each category of Likert scale.

It appeared that visual stimuli were preferred to audio stimuli for factual learning and knowledge retention.

In terms of e-learning incorporation in the DRM, the participants agreed with most of the statements, except the statement that e-learning could replace F2F teaching totally. Presumably, this is because, in F2F teaching, students receive not just visual stimuli but also audio, emotional, tactile, and feedback stimuli that make a more immersive, powerful, and retentive learning experience. Furthermore, psychomotor skills could not be adequately covered with e-learning. However, participants agreed that e-learning is greatly beneficial, but not up to the level of replacing the current format of DRM teaching.

It is interesting to note that most of our participants in this study were females as shown in **Table 2**. This is generally due to there are more female students in medical school throughout Malaysia with a ratio of about 60:40 (female:male) (33). Another reason why there were more female participants was due to larger dropout rate among male participants (48%, $n = 30$) as compared to females (36%, $n = 76$) who did not complete the study.

TABLE 7 | One-way ANOVA for the mean total score in four groups PS Strongly Agree, Agree, Disagree, and Strongly Disagree in Self-gain.

Sample	Sample size	Total score mean	Standard deviation	*p*-value
Strongly agree	136	14.25	4.81	$p < 0.001$
Agree	30	11.77	5.33	
Disagree	2	7.5	0.71	
Strongly disagree	0	0	0	

STUDY LIMITATIONS

The number of questions in the questionnaires is relatively low and might not be adequate in assessing some topics. Nevertheless, our study gives a general idea of the capability of video teaching in acquiring factual knowledge and decision making in DRM. Future studies may target decision-making topics with more emphasis on assessing higher-order thinking skills.

This study did not explore or evaluate the psychomotor skills that students would usually perform during F2F simulation exercises of DRM, including Airway, Breathing, Circulation, and Immobilization procedures. These include standard first aid procedures (bleeding and wound management, splinting, and bandaging), invasive procedural skills (airway and ventilation management, intravenous cannulation), carrying and lifting of victims, etc. Generally, an online platform always has difficulties in teaching and assessing procedural skills. A further study in assessing teaching and learning procedural skills could be conducted in the future.

We did not evaluate the relative time spent by the participants in watching the three videos. This might help reveal whether the duration of the video watching relates to the effectiveness of learning and knowledge retention.

The videos in our study do not have "closed-captioning" since we felt that all the important facts have been spelled out in the videos. However, having closed captioning might have had positive influence on the participants' understanding. This will constitute further improvement in our future educational material or research using video for e-learning. Another limitation of our video was the lack of features for printing key points or summary from the video. Providing the viewers the ability to print key points or a summary of the videos might help in learning. This feature allows key frames of the segment to be converted to textual annotation using segmental encoding and decoding deep learning models (34).

The study also did not compare synchronous (real-time interaction using any online application like Zoom, Microsoft Teams, etc.) with asynchronous teaching (not real-time interaction) of DRM. This study employed an asynchronous one-way video teaching rather than synchronous e-learning with feedback incorporated. Future research should explore the impact of synchronous and asynchronous e-learning with and without incorporated feedback to determine the best way of delivering DRM to UG medical students.

Our study did not compare with the other technique of disaster response medicine teaching because most of the time this subject were taught using a classroom medium either as a face-to-face immersive simulation, table-top exercise or hybrid simulation of approach combining e-learning with classroom immersive simulation. Therefore, we felt it was not appropriate to compare our study that utilize a full asynchronous online approach with the current established methods. Furthermore, we did not evaluate the psychomotor skills in our study.

Finally, this study did not incorporate debriefing even though debriefing is a very powerful learning tool because debriefing was not suitable for an asynchronous methods of teaching. Furthermore, debriefing after watching the video would disrupt the findings of the study. We wanted to determine the effect of a pure asynchronous online teaching on disaster response medicine topics. However, in the future study, we are going to include the element of debriefing with the synchronous mode of teaching.

CONCLUSION

Our study revealed that ELITE-DR, a novel e-learning platform is beneficial in teaching-learning of emergency DRM among UG medical students. Recall of knowledge comprehension and simple analysis-application for basic decision-making was particularly well-served through ELITE-DR, whereas complex decision-making knowledge aspects such as treatment and transport decisions were likely to require a different approach, perhaps one that incorporates feedback. Higher flexibility, usefulness, ease of access, and personalized learning were some of the benefits that make e-learning an acceptable approach for DRM teaching. In e-learning, UG students preferred visual stimuli compared to audio stimuli. The majority of UG students agreed that e-learning could provide as an adjunct but should not replace F2F teaching.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Medical Research and Ethics Committee of Universiti Kebangsaan Malaysia. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

IS, FZ, HI, DS, and CR provided the study concept and performed data analysis. FZ and IS performed data collection. IS, FZ, and CR interpreted the data. All authors were involved in writing and critically reviewing the final manuscript.

FUNDING

This study was from the fundamental research grant of the Faculty of Medicine UKM. Research and ethical permission was obtained for carrying out the study from the university research and ethical committee (UKM-REC Approval Number FF-2019-08).

ACKNOWLEDGMENTS

This study would not be possible without the help of Prof. Roslina Abdul Manap, Deputy Dean of Undergraduate Studies and Alumni, Faculty of Medicine of UKM, Associate Prof. Dr. Mohd Johar Jaafar, the Head of Emergency Medicine Department, and all their staff for allowing us to conduct this study. We are grateful to the Faculty of Medicine UKM for providing the Fundamental Research Grant in support of this study. Special thanks also go to Dr. Amirudin Sanip and the Research Unit of the Emergency Department for helping in the data preparation and analysis.

REFERENCES

1. Kasselmann N, Bickelmayer J, Peters H, Wesemann U, Oestmann JW, Willy C, et al. Relevance of disaster and deployment medicine for medical students: a pilot study based on an interdisciplinary lecture series. *Unfallchirurg.* (2020) 123:464–72. doi: 10.1007/s00113-019-00738-w
2. Tsai YD, Tsai SH, Chen SJ, Chen YC, Wang JC, Hsu CC, et al. Pilot study of a longitudinal integrated disaster and military medicine education

program for undergraduate medical students. *Medicine*. (2020). 99:e20230 doi: 10.1097/MD.0000000000020230
3. Sinha A, Pal DK, Kasar PK, Tiwari R, Sharma A. Knowledge, attitude and practice of disaster preparedness and mitigation among medical students. *Disaster Prev Manag An Int J*. (2008) 17:503–7. doi: 10.1108/09653560810901746
4. Saiboon IM, Jaafar JM, Nasarudin NMA, Md Jamal S, Ahmad Z, Harunarashid H, et al. Development of web-based learning packages for emergency skills. *Proc Soc Behav Sci*. (2012) 60:426–9. doi: 10.1016/j.sbspro.2012.09.401
5. Alexander AJ, Bandiera GW, Mazurik L. A multiphase disaster training exercise for emergency medicine residents: opportunity knocks. *Acad Emerg Med*. (2005) 12:404–9. doi: 10.1111/j.1553-2712.2005.tb01538.x
6. Bajow N, Djalali A, Ingrassia PL, Ageely H, Bani I, Corte FD. Proposal for a community-based disaster management curriculum for medical school undergraduates in Saudi Arabia. *Am J Disaster Med*. (2015). 10:145–52. doi: 10.5055/ajdm.2015.0197
7. Back DA, Lembke V, Fellmer F, Kaiser D, Kasselmann N, Bickelmayer J, et al. Deployment and disaster medicine in an undergraduate teaching module. *Mil Med*. (2019). 184:e284–9. doi: 10.1093/milmed/usy250
8. Saiboon IM, Jaafar MJ, Harunarashid H, Jamal SM. The effectiveness of simulation based medical education in teaching concepts of major incident response. *Proc Soc Behav Sci*. (2011) 18:372–8. doi: 10.1016/j.sbspro.2011.05.053
9. Algaali KY, Djalali A, Della Corte F, Ismail MA, Ingrassia PL. Postgraduate education in disaster health and medicine. *Front Public Health*. (2015) 3:185. doi: 10.3389/fpubh.2015.00185
10. Curtis HA, Trang K, Chason KW, Biddinger PD. Video-based learning vs. traditional lecture for instructing emergency medicine residents in disaster medicine principles of mass triage, decontamination, and personal protective equipment. *Prehosp Disaster Med*. (2018) 33:7–12. doi: 10.1017/S1049023X1700718X
11. Wiesner L, Kappler S, Shuster A, DeLuca M, Ott J, Glasser E. Disaster training in 24 hours: evaluation of a novel medical student curriculum in disaster medicine. *J Emerg Med*. (2018) 54:348–53. doi: 10.1016/j.jemermed.2017.12.008
12. Saiboon IM, Jaafar MJ, Ahmad NS, Ahmad Z, Hamzah FA, Jamal SM. Simulation based education in delivering emergency medicine module. *Proced Soc Behav Sci*. (2011) 18:388–93. doi: 10.1016/j.sbspro.2011.05.056
13. Bajow N, Djalali A, Ingrassia PL, Ragazzoni L, Ageely H, Bani I, et al. Evaluation of a new community-based curriculum in disaster medicine for undergraduates. *BMC Med Educ*. (2016) 16:225. doi: 10.1186/s12909-016-0746-6
14. McCloskey B, Zumla A, Ippolito G, Blumberg L, Arbon P, Cicero A, et al. Mass gathering events and reducing further global spread of COVID-19: a political and public health dilemma. *Lancet*. (2020) 395:1096–9. doi: 10.1016/S0140-6736(20)30681-4
15. Rose S. Medical student education in the time of COVID-19. *JAMA*. *(*2020) doi: 10.1001/jama.2020.5227
16. Chatterjee, Surobhi. The COVID-19 pandemic through the lens of a medical student in India. *Int J Med Stud*. (2020) 8:82–3. doi: 10.5195/ijms.2020.537
17. Ruthberg JS, Quereshy HA, Ahmadmehrabi S, Trudeau S, Chaudry E, Hair B, et al. A multimodal multi-institutional solution to remote medical student education for otolaryngology during COVID-19. *Otolaryngol Head Neck Surg*. (2020) 163:707–9. doi: 10.1177/0194599820933599
18. Tang A. (2020). *Malaysia Announces Movement Control Order After Spike in Covid-19 Cases (Updated)*. The Star. Available online at: https://www.thestar.com.my/news/nation/2020/03/16/malaysia-announces-restricted-movement-measure-after-spike-in-covid-19-cases (accessed June 18, 2020).
19. Cardall S, Krupat E, Ulrich M. Live lecture versus video-recorded lecture: are students voting with their feet? *Acad Med*. (2008) 83:1174–8. doi: 10.1097/ACM.0b013e31818c6902
20. Debacker M, Delooz H, Corte F Della. The European master program in disaster medicine. *Int J Disaster Med*. (2003) 1:35–41. doi: 10.1080/15031430310004230
21. Zaini NA, Noor SFM, Zailani SZM. Design and development of flood disaster game-based learning based on learning domain. *Int J Eng Adv Technol*. (2020) 9:679–85. doi: 10.35940/ijeat.C6216.049420
22. Krejcie R V, Morgan DW. Determining sample size for research activities. *Educ Psychol Meas*. (1970) 30:607 doi: 10.1177/001316447003000308
23. Salmon G, Tombs M, Surman K. Teaching medical students about attention deficit hyperactivity disorder (ADHD): the design and development of an e-learning resource. *Adv Med Educ Pract*. (2019) 10:987–97. doi: 10.2147/AMEP.S220390
24. McGready J, Brookmeyer R. Evaluation of student outcomes in online vs. campus biostatistics education in a graduate school of public health. *Prev Med*. (2013) 56:142–4. doi: 10.1016/j.ypmed.2012.11.020
25. Worm BS. Learning from simple ebooks, online cases or classroom teaching when acquiring complex knowledge. A randomized controlled trial in respiratory physiology and pulmonology. *PLoS ONE*. (2013) 8:e73336. doi: 10.1371/journal.pone.0073336
26. Saiboon IM, Qamruddin RM, Jaafar JM, Bakar AA, Hamzah FA, Eng HS, et al. Effectiveness of teaching automated external defibrillators use using a traditional classroom instruction versus self-instruction video in non-critical care nurses. *Saudi Med J*. (2016) 37:429–35. doi: 10.15537/smj.2016.4.14833
27. Donkin R, Askew E, Stevenson H. Video feedback and e-Learning enhances laboratory skills and engagement in medical laboratory science students. *BMC Med Educ*. (2019) 19:310. doi: 10.1186/s12909-019-1745-1
28. Haniya S, Montebello M, Cope B, Tapping R. Promoting critical clinical thinking through e-learning. In: *Proceedings of the 10th International Conference on Education and New Learning Technologies*. Palma: EduLearn18 (2018). doi: 10.21125/edulearn.2018.1235
29. de Leng BA, Dolmans DHJM, Jöbsis R, Muijtjens AMM, van der Vleuten CPM. Exploration of an e-learning model to foster critical thinking on basic science concepts during work placements. *Comput Educ*. (2009) 53:1–13. doi: 10.1016/j.compedu.2008.12.012
30. Nganji JT. Towards learner-constructed e-learning environments for effective personal learning experiences. *Behav Inf Technol*. (2018) 37:647–57. doi: 10.1080/0144929X.2018.1470673
31. Moreno V, Cavazotte F, Alves I. Explaining university students' effective use of e-learning platforms. *Br J Educ Technol*. (2017) 48:995–1009. doi: 10.1111/bjet.12469
32. Mounsey A, Reid A. Auditory narrative does not improve learning when added to visual computer-based learning modules. *Med Sci Educ*. (2019) 29:1043–9. doi: 10.1007/s40670-019-00801-6
33. Myint YY, Tun Y. Gender ratio in undergraduate medical program, Medical Faculty, IIUM. In: IRIIE 2010. Kuala Lumpur: International Islamic University of Malaysia (2010). Available online at: http://irep.iium.edu.my/10878/ (accessed April 12, 2021).
34. Sah S, Kulhare S, Gray A, Venugopalan S, Prud'Hommeaux E, Ptucha R. Semantic text summarization of long videos. In: *2017 IEEE Winter Conference on Applications of Computer Vision (WACV)*. Santa Rosa, CA (2017). p. 989–97. doi: 10.1109/WACV.2017.115

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Medicine

ORIGINAL RESEARCH
published: 07 May 2021
doi: 10.3389/fmed.2021.677626

The Performance of Flexible Tip Bougie™ in Intubating Simulated Difficult Airway Model

Nurfadilah Mahli, Jaafar Md Zain, Siti Nidzwani Mohamad Mahdi, Yeoh Chih Nie, Liu Chian Yong, Ahmad Fairuz Abdul Shokri and Muhammad Maaya*

Department of Anaesthesiology & Intensive Care, Faculty of Medicine, Universiti Kebangsaan Malaysia Medical Centre, Kuala Lumpur, Malaysia

This prospective, randomized, cross-over study compared the performance of the novel Flexible Tip Bougie^{TM} (FTB) with a conventional bougie as an intubation aid in a simulated difficult airway manikin model among anaesthesiology trainees with regards of first pass success rate, time to intubation, number of attempts and ease of use. Sixty-two anesthesiology trainees, novice to the usage of FTB, participated in this study. Following a video demonstration, each participant performed endotracheal intubation on a manikin standardized to a difficult airway view. Each participant performed direct laryngoscopy and intubated the manikin using a conventional bougie and FTB, at least 1 day in between devices, in a randomized order. The first pass success rate was significantly higher with FTB (98.4%) compared to conventional bougie (85.5%), $p = 0.008$. The median time to intubation was significantly faster when using FTB, median = 32.0 s [Interquartile range (IQR): 23.8–41.3 s] compared to when using conventional bougie, median = 41.5 s (IQR: 31.8–69.5 s), $p < 0.001$. The FTB required significantly less intubation attempts compared to conventional bougie, $p = 0.024$. The overall ease of use, scored on a Likert scale from 1 to 5, was significantly higher in the FTB (4.26 ± 0.53) compared to the conventional bougie (3.19 ± 0.83), $p < 0.001$. This simulated difficult airway manikin study finding suggested that FTB is a useful adjunct for difficult airway intubation. The FTB offered a higher first pass success rate with a faster time to intubation and less required attempts.

Keywords: anesthesiology trainee, bougie, difficult intubation, direct laryngoscopy, flexible tip bougie, simulation

OPEN ACCESS

Edited by:
Dinker R. Pai,
Sri Balaji Vidyapeeth University, India

Reviewed by:
Jacek Smereka,
Wroclaw Medical University, Poland
Nadia Hanom Ishak,
Universiti Teknologi MARA, Malaysia

****Correspondence:***
Muhammad Maaya
muhammad@ppukm.ukm.edu.my

Specialty section:
This article was submitted to Intensive Care Medicine and Anesthesiology, a section of the journal Frontiers in Medicine

Received: *08 March 2021*
Accepted: *09 April 2021*
Published: *07 May 2021*

Citation:
Mahli N, Md Zain J, Mahdi SNM, Chih Nie Y, Chian Yong L, Shokri AFA and Maaya M (2021) The Performance of Flexible Tip Bougie^{TM} in Intubating Simulated Difficult Airway Model. Front. Med. 8:677626. doi: 10.3389/fmed.2021.677626

INTRODUCTION

Tracheal intubation is an essential skill that must be acquired by an anesthesiologist. While the incidence of difficult intubations was stated to be 6–11%, a failed intubation which is a more serious problem, varies in different settings (1). It can be ≈1 in 2,000 for elective cases, ≈1 in 300 during rapid sequence induction for the obstetric cases, and about ≈1 in 50–100 in the emergency department, intensive care unit and pre-hospital setting (2). Various strategies currently employed to manage difficult intubation ranges from simple adjuncts, such as the bougie, to the more sophisticated devices, like the videolaryngoscope. According to the Malaysia National Audit on Anesthetic Airway Management (2015), bougie was the second most preferred (24.8%) airway adjunct of choice in a difficult airway event, following the videolaryngoscope (44.6%) (3).

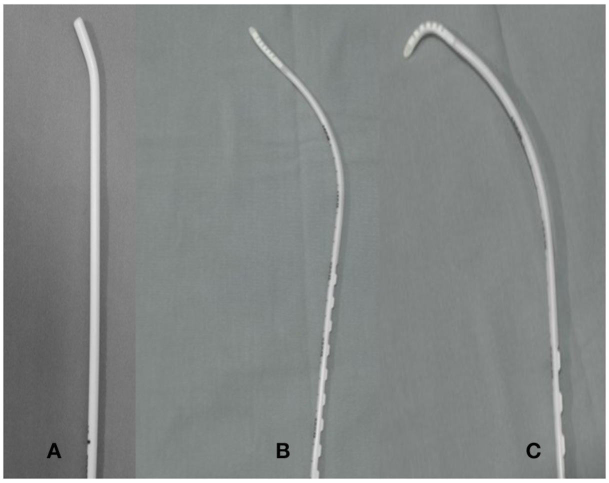


FIGURE 1 | The conventional bougie (Portex®, coude tip, 15 F) **(A)** shown in comparison to The Flexible tip bougie™ in neutral **(B)** and in anterior flexion **(C)**.

The use of a bougie, a simpler and cheaper device compared to the videolaryngoscope, first described by Macintosh in 1949, may increase the first pass success (FPS) of an endotracheal tube (ETT) placement by 78–100%, especially in poor laryngeal view (4, 5). The bougie (**Figure 1A**) is commonly about 15 F in diameter and 70 cm in length with the tip angled at 30° to facilitate its navigation toward an anteriorly located larynx (6). Successful endotracheal intubation with the bougie involves its insertion into the trachea, followed by sliding the ETT via the Seldinger technique (7). Common difficulties in bougie-assisted intubation are the inability to insert the bougie past the hypopharynx (14.8%), the inability to pass the ETT over the bougie (6.8%) and esophageal intubation (4.5%) (8). The bougie can also bend in the hypopharynx during the attempt to direct it anteriorly.

The Flexible Tip Bougie™ (FTB) by Construct Medical (Australia) (**Figure 1B**) has a mid-shaft slider which can be used to angle the tip anteriorly (**Figure 1C**) and posteriorly, thereby facilitating placement through the vocal cords. This flexibility may facilitate maneuvering the bougie past the hypopharynx as compared to the conventional bougie that has the tip fixed at 30°. The smooth silicon tip of the bougie also minimizes the risk of tracheal trauma during intubation, which is an advantage when dealing with a larynx with a very anterior view.

In this study, we evaluated the performance of the FTB in a simulated difficult airway model in comparison to a conventional bougie when used by anesthesiology trainees in terms of FPS, time needed for intubation and number of attempts for both types of bougie.

MATERIALS AND METHODS

This prospective, randomized, cross-over simulation study was approved by the Research Committee of Department of Anaesthesiology & Intensive Care, Universiti Kebangsaan Malaysia Medical Center (UKMMC) and the Medical Research & Ethics Committee, UKMMC (code no: FF-2019-356). Following approval and written consent, 62 anesthesiology trainees in UKMMC participated in this study. All participants had ample experience using the conventional bougie. Any participant who had prior experience with FTB were excluded from this study. Data on the participants' gender, years of clinical experience and the year of postgraduate anesthesia training were collected.

A video demonstration on intubation with FTB, slightly <2 min duration, produced by the manufacturer was shown to the participants who were then allowed to familiarize themselves in maneuvering the tip of bougie before proceeding to performance testing. There was no practice intubation with the bougie prior to the performance testing. The airway simulation model used was the Laerdal® Airway Management Trainer, which was simulated to a "Difficult view" (9). The "Difficult view" was achieved by application of a hard cervical collar on the manikin and verified by the same investigator to be a partial glottis opening of ∼20%. This mimics a Grade 2b Cormack-Lehane glottis view which is similar to an anterior larynx seen during laryngoscopy.

All participants were provided with standardized equipment, which were a 7.5 mm ETT, a Macintosh laryngoscope blade size 4, a bag valve mask device and a 10 ml syringe. Each participant performed direct laryngoscopy and intubated the manikin using a conventional bougie (Portex® Single Use Bougie coude tip, 15 F) and FTB in a randomized order determined by chance picking of binary numbers. Following intubation, the ETT was ventilated with the bag valve mask device and successful intubation was confirmed by lung inflation. At least a period of 1 day was observed before the participants attempted intubation using the other type of bougie. Any participant who did not return for the second placement test were considered as dropouts.

The primary outcome was the FPS rate, which was defined as successful placement of the ETT in the trachea on the participant's first attempt at laryngoscopy. The attempt was considered unsuccessful if there was no lung inflation or removal of the ETT with the bougie from the manikin. A failed intubation was defined as either failed three attempts of lung ventilation through the ETT or after 3 min of procedure, whichever occurred earlier. Any occurrence of esophageal intubation, which was insertion of the ETT into the esophagus resulting in stomach inflation were also recorded.

The secondary outcome was the time required for a successful tracheal intubation. The time to successfully intubate, measured to one decimal point using a stopwatch, was taken from the moment when the laryngoscope blade enters the mouth and ends with lung inflation with bag mask ventilation. After completion of intubation with both types of bougie, the participants were asked to complete a survey to assess the overall ease of intubation with both techniques in this simulated airway. The trainees were asked to score according to a five-point Likert scale of 1 (very difficult) to 5 (very easy) on the ease of passing both types of bougies through the hypopharynx, sliding the ETT over the bougie and maneuvering the flexible tip slider.

From a previous study, the FPS rate in utilizing conventional bougie in a simulated difficult airway was 75% (10). In this prospective crossover study, by setting the α = 0.05 with the β = 0.80 and using Statulator©, the sample size required was 62 participants to detect a 20% difference of FPS between bougies types (11).

All statistical analyses were performed with the statistical package for social science (SPPS) statistical software (ver26, NY: IBM Corp). The data was analyzed in three phases. Firstly, descriptive statistics were computed for all variables of interest. The normal distribution of data was tested using the Kolmogorov-Smirnov test. McNemar's test was used to determine whether the FPS rate was different between the two types of bougies. Due to distribution characteristics, non-parametric statistics were used, namely Wilcoxon Signed-rank test to determine the difference between times to intubation. Fisher exact test was used to analyze the association of attempts when using both bougies. The ease of use perceived by the participants was analyzed with paired *t*-test. Data were presented as median with interquartile range (IQR), number with percentage (%), or mean with standard deviation, as appropriate.

TABLE 1 | Demographic data, clinical experience, and year of postgraduate anesthesia training.

Parameters (n = 62)	
Gender	
Female	37 (59.7%)
Male	25 (40.3%)
Anesthesia clinical experiences (years)	6 (IQR: 5–7)
Year of postgraduate anesthesia training	
Year 1	9 (14.6%)
Year 2	15 (24.2%)
Year 3	20 (32.2%)
Year 4 and above	18 (29.0%)

Data presented as number (percentage), or median (interquartile range), as appropriate.

RESULTS

A total of 62 anesthesiology trainees in UKMMC participated in this study with a median of 6 years (IQR: 5–7) clinical experience in anesthesia (**Table 1**). There was no dropout.

The FPS rate when using FTB and conventional bogie was 98.4 and 85.5%, respectively. A total of eight participants who did not achieve FPS when using conventional bougie were successful on the first intubation attempt when FTB was used. An exact McNemar test determined that the change in the proportion of FPS was statistically significant ($p = 0.008$) as seen in **Table 2**.

Table 3 showed the comparison of FPS, intubation attempts, time to intubation, failed intubation and esophageal intubation.

TABLE 2 | The change of first pass success (FPS) when using Flexible Tip Bougie™ Values expressed in number.

		Flexible tip bougie™		
		FPS*	**Not FPS**	**Total**
Conventional bougie	FPS	53	0	53
	Not FPS	8	1	9
	Total	61	1	(n = 62)

**McNemar, p = 0.008.*

TABLE 3 | Comparison of first pass success (FPS), intubation attempts, time to intubation, failed intubation, esophageal intubation, and ease of use for each type of bougie.

	Flexible tip bougie™	**Conventional bougie**	***p*-value**
No. of intubation attempts			0.024
1 (FPS)	61 (98.4%)	53 (85.5%)	0.008
2	1 (1.6%)	6 (9.7%)	
3	0 (0.0%)	3 (4.8%)	
Time to intubation, sec	32.0 (23.8–41.3)	41.5 (31.8–69.5)	<0.001
Failed intubation	0 (0.0%)	1 (1.6%)	NS
Esophageal intubation	0 (0.0%)	5 (8.1%)	NS
Ease of use	4.26 (± 0.53)	3.19 (± 0.83)	<0.001
Ease of bougie passing hypopharynx	4.47 (± 0.59)	3.48 (± 1.04)	<0.001
Ease of ETT passing over bougie	4.56 (± 0.74)	4.08 (± 0.91)	0.002

Data presented as median (interquartile range) or number (percentage) as appropriate.
$p < 0.05$ is significant, NS, Not statistically significant.

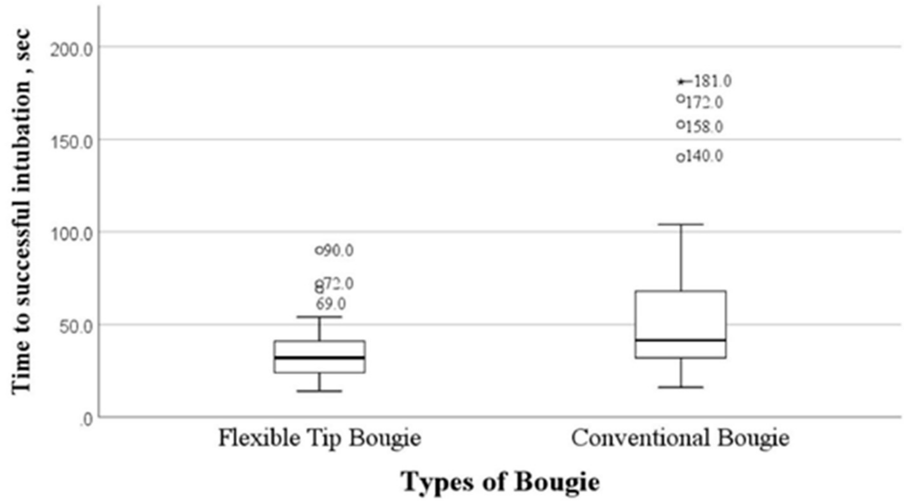


FIGURE 2 | Time to successful intubation (sec) of conventional bougie and Flexible Tip Bougie^{TM}. Values expressed in seconds (sec).

One participant (1.6%) was considered to have failed intubation as a duration of 181 s was taken with the conventional bougie. This participant took three attempts with the conventional bougie but was able to achieve FPS with FTB. Five participants (8.1%) intubated the esophagus when using the conventional bougie, whilst none occurred with the FTB. This finding was not statistically significant.

Figure 2 showed the time to successful intubation for both types of bougies. Four participants required more than 120 s to intubate when using conventional bougie due to the difficulty in laryngoscopy to achieve satisfactory glottic view prior to attempting intubation followed by further difficulty in manipulating the conventional bougie through the hypopharynx. These four participants had a range of 3 to 9 years of experience in anesthesia.

Reliability test was performed on the data of the ease of each type of bougie usage and a Cronbach's alpha of more than 0.7 was accepted as a reliable cut-off point. Overall, the participants perceived that FTB was easier to use with a mean score of 4.26 $\pm$ 0.53 compared to 3.19 $\pm$ 0.83 for the conventional bougie ($p < 0.001$) as seen in **Table 3**. The FTB was deemed easier to pass through the hypopharynx with a mean score of 4.47 $\pm$ 0.59 compared to the conventional bougie, which had a mean score of 3.48 $\pm$ 1.04. Passing of an ETT over the bougie was perceived as relatively easy in both the FTB and conventional bougie, with a mean score of 4.56 $\pm$ 0.74 and 4.08 $\pm$ 0.91, respectively. The participants perceived that it was easy to maneuver the slider of FTB, with a mean of 4.16 $\pm$ 0.81.

DISCUSSION

As the incidence of difficult and failed intubation varies, this study was conducted using a standardized simulated model (2). Despite the low technology level involved in our study, the manikin was prepared to provide the fidelity akin to difficult airway view of a real patient, thus avoiding the issue of patient safety (12). The FPS is often promoted as the goal of intubation because as the number of attempts increases, the incidence of adverse events such as aspiration, hypoxemia and esophageal intubation will likely increase considerably (13). Furthermore, the principles of securing the airway safely, accurately, and swiftly is of utmost importance for intubation, an aerosol-generating procedure, during the Covid-19 pandemic (14). Repeated intubation attempts would increase the exposure and infection risk to the anesthesiologists and other healthcare workers involved. Our study found a higher FPS rate when using the FTB as an intubation adjunct compared to the conventional bougie in a simulated difficult airway manikin. Similarly, Báczek found novice paramedics had a higher FPS rate with the FTB compared to the conventional bougie during cardiopulmonary resuscitation simulation (15). Additionally, in our cross-over study, the exact McNemar test found the change in the proportion of FPS was statistically significant in favor of the FTB.

We reported a statistically significant shorter time to a successful intubation by 9.1 s with lesser number of attempts required when the trainees used FTB compared to conventional bougie as an intubation aid. A recent simulation study with cervical immobilization compared the use of FTB and standard bougie also reported a faster duration of to a successful intubation with the FTB, 37 vs. 46 s ($p < 0.001$) (16). Another manikin study evaluated the usage of the two bougies for intubation during cardiopulmonary resuscitation and reported a statistically shorter intubation time (21.4 s) with the FTB compared to the gum elastic bougie (25.7 s), $p < 0.001$ (15). The shorter time to intubation suggested that the flexibility of the FTB produced better and faster steering than the conventional bougie to achieve a successful intubation.

The FTB was perceived as easier to be used compared to the conventional bougie amongst our trainees. Ruetzler et al.

also reported that the FTB was easier to use in difficult intubation situations especially in scenarios that involve limited cervical movement (16). The curve of the FTB resembles the anatomical airway curvature, thus facilitating its insertion into the hypopharynx region. This curvature can further be manipulated to swivel using the slider tab which provides further anterior and posterior movement of the tip and along with rotation, producing a 360° rotation aiding intubation, as reported in a case series (17). The FTB also has a bright phosphorous coating on its tip to enhance the bougie tip visibility to the intubator.

The findings of this study should be considered with a certain limitation. The high success rate could be attributed to the study being done among anesthesiology trainees that have plenty of clinical experience in intubation despite their novice experience to the FTB. Even though the result should not be generalized to physicians of different levels of experience, this study had provided a promising ground that the skill of the FTB usage can be learnt rapidly.

CONCLUSION

This simulated difficult airway manikin study finding suggested that FTB is a useful adjunct for difficult airway intubation. The FTB offered a higher FPS rate with a faster time to intubation and less required attempts.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR'S NOTE

Difficult and/or failed intubation, both anticipated and unanticipated, can be challenging and may result in patients' mortality or morbidity if not managed accordingly. Amongst the many airway management devices, the bougie is a simple, cheap, and accessible airway which can be used to manage the difficult airway. A simulation study is ideal for assessing the performance of a new device as it avoids the issue of patient safety and produces repeatable standardized situations. This cross-over study compared the performance an existing device with a novel device which has integrated a feature to enable the tip of the bougie to be flexed more anteriorly or posteriorly. As difficult intubation is relatively uncommon, the intubator can benefit by having an airway adjunct which can be utilized properly without extensive training. The primary and secondary objectives selected to assess the performance of both the novel and conventional bougies reflected the real-life challenges presented when dealing with a difficult airway. First pass success, faster time to successfully intubate and fewer attempts results in lesser morbidity related to a difficult or failed intubation.

AUTHOR CONTRIBUTIONS

NM and MM: investigators, proposal writing & editing, data analysis, and manuscript writing & editing. NM: data collection. JM, SM, YC, LC, AS, and MM: manuscript critic. All authors contributed to the article and approved the submitted version.

FUNDING

Research grant was awarded internally from our institution.

ACKNOWLEDGMENTS

We would like to thank Qurratu Aini Musthafa, Science Officer in The Department of Anaesthesiology & Intensive care, UKMMC for her advice, and assistance in the statistical analysis.

REFERENCES

1. Phelan MP. Use of the endotracheal bougie introducer for difficult intubations. *Am J Emerg Med.* (2004) 22:479–82. doi: 10.1016/j.ajem.2004.07.017
2. Cook TM, MacDougall-Davis SR. 2012. Complications and failure of airway management. *BJA*. (2012) 109:i68–85. doi: 10.1093/bja/aes393
3. Ministry of Health, Malaysia. *National Audit on Anaesthetic Airway Management*. (2015). Available online at: http://www.moh.gov.my/index.php/pages/view/1131 (accessed October 18, 2018).
4. Apfelbaum JL, Hagberg CA, Caplan RA, Blitt CD, Connis RT, Nickinovich DG, et al. Practice guidelines for management of the difficult airway: an updated report by the American society of anesthesiologists task force on management of the difficult airway. *Anesthesiology.* (2013) 118:251–70. doi: 10.1097/ALN.0b013e31827773b2
5. Driver B, Dodd K, Klein LR, Buckley R, Robinson A, McGill JW, et al. The bougie and first-pass success in the emergency department. *Ann Emerge Med.* (2017) 70:473–8. doi: 10.1016/j.annemergmed.2017.04.033
6. Baker JB, Maskell KF, Matlock AG, Walsh RM, Skinner, CG. Comparison of preloaded bougie versus standard bougie technique for endotracheal intubation in a cadaveric model. *West J of Emerg Med.* (2015) 16:588–93. doi: 10.5811/westjem.2015.4.22857
7. Shah KH, Kwong BM, Hazan A, Newman DH, Wiener D. Success of the gum elastic bougie as a rescue airway in the emergency department. *J Emerge Med.* (2011) 40:1–6. doi: 10.1016/j.jemermed.2008.04.045
8. Shah KH, Kwong B, Hazan A, Batista R, Newman DH, Wiener D. Difficulties with gum elastic bougie intubation in an academic emergency department. *J Emerge Med.* (2011) 41:429–34. doi: 10.1016/j.jemermed.2010.05.005
9. Messa MJ, Kuppas, DF, Dunham DL. Comparison of bougie-assisted intubation with traditional endotracheal intubation in a simulated difficult airway. *Prehosp Emerge Care.* (2011) 15:30–3. doi: 10.3109/10903127.2010.519821
10. Kingma K, Hofmeyr R, Zeng IS, Coomarasamy C, Brainard A. Comparison of four methods of endotracheal tube passage in simulated airways: there is room for improved techniques. *Emerge Med Austral.* (2017) 29:650–7. doi: 10.1111/1742-6723.12874
11. Dhand N, Khatkar M. Statulator: an online statistical calculator. *Sample Size Calculator for Comparing Paired Proportion*. (2014). Available online at: http://statulator.com/SampleSize/ss2PP.html (accessed November 27, 2018).

12. Zaleha AM, Muhammad M, Ixora KA, Azlan HAS, Mohd Hisham I, Ismail MS. Simulation in healthcare in the realm of education 4.0. *Sains Malays.* (2020) 49:1987–93. doi: 10.17576/jsm-2020-4908-21
13. Sackles JC, Chiu S, Mosier J, Walker C, Stolz U. The importance of first pass success when performing orotracheal intubation in the emergency department. *Acad Emerg Med*. (2013) 20:71–8. doi: 10.1111/acem.12055
14. Cook TM, El-Boghdadly K, McGuire B, McNarry AF, Patel A, Higgs A. Consensus guidelines for managing the airway in patients with COVID-19. *Anaesthesia.* (2020) 75:785–99. doi: 10.1111/anae.15054
15. Báczek M, Báczek MZ. Flexible tip bougie - the new introducer for intubation during cardiopulmonary resuscitation: a randomised crossover manikin study. *Medicine.* (2020) 99:e18452 doi: 10.1097/MD.0000000000018452
16. Ruetzler K, Smereka J, Abelairas-Gomez C, Frass M, Dabrowski M, Bialka S, et al. Comparison of the new flexible tip bougie catheter and standard bougie stylet for tracheal intubation by anesthesiologists in different difficult airway scenarios: a randomised crossover trial. *BMC Anesthesiol.* (2020) 20:90. doi: 10.1186/s12871-020-01009-7
17. Kumar P, Sharma J, Johar S, Singh V. Guiding flexible-tipped bougie under videolaryngoscopy: an alternative to fiberoptic nasotracheal intubation in maxillofacial surgeries. *J Maxillofac Oral Surg.* (2020) 19:324–6. doi: 10.1007/s12663-020-01327-w

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Pediatrics

ORIGINAL RESEARCH
published: 12 May 2021
doi: 10.3389/fped.2021.640236

Effects of Educational Video on Pre-operative Anxiety in Children - A Randomized Controlled Trial

Valentina Härter[1†], Claus Barkmann[2†], Christian Wiessner[3], Martin Rupprecht[4,5], Konrad Reinshagen[1] and Julian Trah[1]*

[1] *Department of Pediatric Surgery, University Medical Center Hamburg-Eppendorf, Hamburg, Germany,* [2] *Department of Child and Adolescent Psychiatry, University Medical Center Hamburg-Eppendorf, Hamburg, Germany,* [3] *Department of Medical Biometry and Epidemiology, University Medical Center Hamburg-Eppendorf, Hamburg, Germany,* [4] *Department of Pediatric Orthopedics, Altona Children's Hospital, Hamburg, Germany,* [5] *Department of Orthopedics, University Medical Center Hamburg-Eppendorf (UKE), Hamburg, Germany*

Objective: Audio-visual interventions have been used to provide relevant patient information to reduce pre-operative anxiety in children. The aim of the study was to investigate whether self-reported state anxiety in children could be reduced by presenting a child-friendly educational video on the day of surgery.

Methods: A prospective, single-blinded, two-armed, randomized controlled study was designed with three measurement time points including 90 children (6–17 years) and their parents. In the intervention group (IG), the children and their parents were shown a child-friendly video explaining the perioperative procedures that would be applied during the hospital stay, in addition to receiving standard information. In the control group (CG), children and parents received standard information provided by the nursing staff. The primary outcome was any change in the children's pre-operative state anxiety levels, as measured by the State-Trait Operation Anxiety Inventory (STOA). A secondary outcome was patient satisfaction regarding the received information.

Results: Anxiety was significantly reduced in both groups after receiving either the intervention plus standard information or the standard information only. No significant difference in anxiety reduction was observed between the IG and the CG. However, the children and parents in the IG reported fewer worries than those in the CG.

Conclusion: A child-friendly, educational video can be an additional tool for providing patient information and reducing pre-operative anxiety in children and their parents. Further studies should focus on the timing of the intervention and on age- and developmentally appropriate information formats and contents to address children's pre-operative anxiety.

Clinical Trial Registration: Patient Anxiety Reduction in Children by Using Simple Explanation Videos, ID: NCT0441377; www.clinicaltrials.gov, Data Sharing Statement: Deidentified individual participant data will not be made available.

Keywords: anxiety, children, surgery, patient information, audio-visual intervention, RCT

OPEN ACCESS

Edited by:
Dinker R. Pai,
Sri Balaji Vidyapeeth University, India

Reviewed by:
Erik David Skarsgard,
British Columbia Children's Hospital, Canada
Arun Bansal,
Post Graduate Institute of Medical Education and Research (PGIMER), India

Correspondence:
Julian Trah
jtrah@uke.de

† These authors share first authorship

Specialty section:
This article was submitted to Pediatric Surgery, a section of the journal Frontiers in Pediatrics

Received: *10 December 2020*
Accepted: *31 March 2021*
Published: *12 May 2021*

Citation:
Härter V, Barkmann C, Wiessner C, Rupprecht M, Reinshagen K and Trah J (2021) Effects of Educational Video on Pre-operative Anxiety in Children - A Randomized Controlled Trial. Front. Pediatr. 9:640236. doi: 10.3389/fped.2021.640236

INTRODUCTION

The presence of pre-operative anxiety in children and their parents before surgical interventions is clinically relevant to perioperative care. Surgery and hospitalization are stressful situations (1), and anxiety can negatively impact perioperative care and the patient's behaviors and ability to adjust to the hospital setting (2).

Previous studies have shown that high pre-operative anxiety states have a negative impact on post-operative pain experience (3) and increase post-operative anxiety levels in children (4, 5).

Self-reported state and trait anxiety evaluations are often used to assess patients' anxiety before surgery (6). State anxiety can be defined as an emotional reaction in response to a perceived threat that occurs at a specific point in time and with varying intensity, comprised of both affective and cognitive components of the current emotional state. Trait anxiety describes general feelings of worries and discomfort (7).

The experience of parental pre-operative anxiety regarding their child's operation is also an important issue that can affect the perioperative care setting (8, 9). Parental anxiety has been associated with distress and problematic behaviors in the child during and after hospitalization. Furthermore, unanswered questions and missing information regarding the operation can increase parental anxiety (8).

Children and their parents wish to be informed regarding the surgical intervention, anesthesia, potential pain problems, and other procedures they may undergo during the hospitalization period (10–13). The adaptation of information to meet the needs of children should focus on optimizing the timing, format, and content of the information being presented (14).

Various non-pharmacological interventions have shown that the provision of specific patient information can reduce pre-operative anxiety in children before an elective surgical procedure (15, 16). Research has increasingly focused on exploring the effects of audio-visual (17) and technology-based (18) interventions, particularly digital intervention programs.

A previous study concluded that the information presented in videos should be short and precise (17). Kain et al. showed that providing procedural information is sufficient to allow children to cope with the expected stress associated with the surgical intervention (19). Although evidence-based studies are important for pediatric pre-operative preparation, to our knowledge, no trials have focused on the effects of using an educational video with a laying technique (20). In this educational video new scenes are wiped in or out with two hands explaining complex information in a short and simple manner about hospital and care standards.

The questions under research were as follows:

1. Can a child-friendly, educational video reduce children's pre-operative state anxiety before elective surgery compared with the standard information procedure?
2. Does the use of such a video increase the reported patient satisfaction of the children and parents compared with the standard information procedure?

We expected that self-reported, pre-operative, state anxiety of children would decrease after the video intervention in addition to receiving standard information compared with children who received only the standard information procedure. Furthermore, we expected an increase in patient satisfaction among children and their parents who were shown the video compared with those who received standard information.

METHODS

Trial Design

The present study was conducted as a prospective intervention study with three measurement time points using a randomized-controlled design that included 90 participants. Data were collected from November 2019 until April 2020 at three primary care centers. The sources of information were children and their parents. Enrollment was conducted, as shown in **Figure 1**.

Families were randomized either to the intervention (IG, $n = 45$) or control arms (CG, $n = 45$). The children and parents included in the IG were shown a child-friendly, animated, educational video (see below), in addition to receiving standard information regarding the hospital stay. Standard information regarding the hospital stay was provided to all groups by the nursing staff.

Questionnaires were answered by both the child and one parent (mother or father) on the day of surgery, both before administering the intervention (t1) and directly after the intervention but before surgery (t2), and 1 day after surgery (t3).

Participants

Children aged 6–17 years who were undergoing elective surgery were eligible for inclusion. All patients agreed to participate and were randomly allocated to one of the study groups (**Figure 1**). All participants received treatment as allocated. The surgical interventions were divided into body regions: chest, abdomen, extremities (including head and neck), anal region, or spine. Sufficient German language skills to understand the video were required for both the child and parents for inclusion.

Exclusion criteria included children with chronic illnesses, mental disorders, and the use of regular medication to avoid conflicting effects with regard to anxiety levels.

Randomization

The randomization procedure was conducted as a written document (randomization table). Randomization was carried out on the day of the operation after assessing study eligibility by a member of the study team. Child and parent were informed that there were two groups, one of which they were randomly assigned. After being informed about the study, both received standard information procedure (TAU). The control group then completed the second questionnaire. The video group filled out the second questionnaire only after they had seen the educational video.

Abbreviations: STOA, State-Trait Operation Anxiety Inventory; TAU, Treatment-as-usual; IG, Intervention group; CG, Control group; t1, timepoint 1, before intervention; t2, timepoint 2, after intervention; t3, timepoint 3, after surgery.

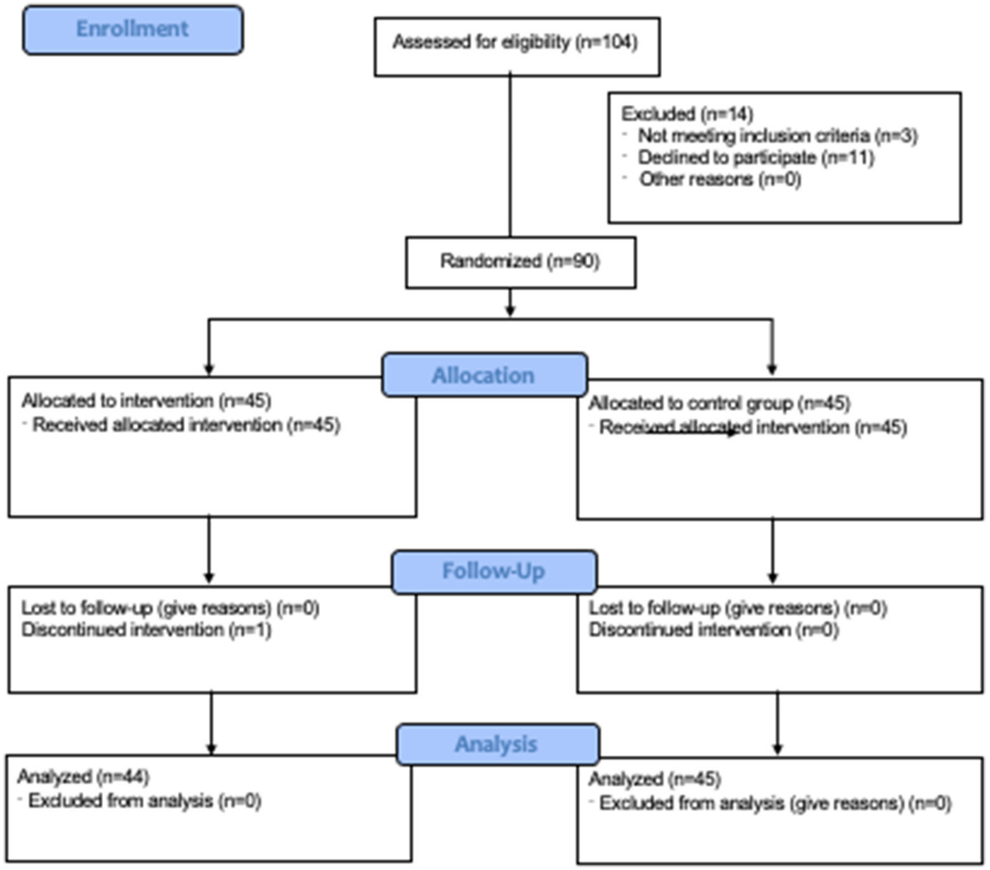


FIGURE 1 | Consort 2010 flow diagram of the study.

Intervention

Intervention Group: Educational Video

On the day of surgery, before undergoing the standard information procedure [treatment as usual (TAU), see below], the IG participants and their parents were shown a short, educational video with animated laying technique. The animated laying technique is used in the educational video of this study. The technique is characterized by illustrations that is placed in or out of the screen by two hands. The illustrations show information in a simple and short way in <4 min. This simplicity should lead to complex information being conveyed in a playful, animated way and in visual language. This should help children to get access to the procedures that will expect them in their hospital stay. The video was presented on a handheld tablet in the patient, holding, or examination room. The video contained information regarding the procedures the child was likely to encounter during the hospital stay, which was presented in a child-friendly way. This information included the medical procedures that would occur before and after surgery and the procedures that would be encountered during post-operative care (see **Appendix**). After viewing the video, questions about the information contained in the video could be asked of a member of the study team, who was present during the entire video viewing process.

Control Group: Treatment-As-Usual

On the day of surgery, participants in the CG received the standard information procedure (TAU), which was provided by the nursing staff and varied in form, length, and timing. The information provided at each center was identical. If sufficient time was available, the patients could visit the surgical ward. The nursing staff explained the procedures before the operation, including the application of pre-medication and post-operative care.

Outcomes and Instruments

Primary Outcome

The primary outcome of this study was the self-reported pre-operative state anxiety levels in children undergoing elective surgery as measured at t1 and t2 using the State-Trait Operation Anxiety Inventory (STOA) (2). The STOA is a psychometric questionnaire used to evaluate a patient's subjective fear of surgery. The questionnaire measures both state and trait anxiety. State anxiety can be further divided into cognitive and affective components using different subscales. Anxiety cognition is typically activated before the start of the operation, whereas the affective component increases strongly immediately before the stressful event, followed by a significant decrease (2). Parallel to the children's self-report, the parent self-report was assessed. For adults, the STOA has already been validated (2). For children and adolescents, psychometric analyses were conducted within this study (Cronbach's α, factor analysis), which confirm good reliability and factorial validity (e.g., $\alpha = 0.91$ for children's and parents state anxiety at t1, manuscript in preparation).

Secondary Outcome

The secondary outcome measured was patient satisfaction with the received information, as rated by both the children and their parents. A study-specific questionnaire comprising eight items was adapted (21). It was used in former studies to evaluate patient satisfaction regarding the information obtained before a medical procedure. The selection was made on aspects of face validity and item content. We used one item (**Table 4**, item 3) from the usefulness scale of patient information material (USE) and two items from the scale's preliminary item pool (**Table 4**, item 4 and 5). The other items were developed according to the objectives of the study. The questionnaire hasn't been used in a similar patient population. It was given to the children and their parents in both groups the day after surgery (t3).

Ethics

Approval was obtained from the Ethics Committee of the Hamburg Medical Association (Number PV6045). A written consent form was signed by study participants and their parents before study entry. The study was registered at https://clinicaltrials.gov/ under the ID: NCT04413773.

Statistical Methods

Student's *t*-test and Chi-square-test were used to analyze sociodemographic data. The prediction of surgery anxiety was analyzed using a longitudinal, mixed model (22). A priori power calculations were based on the assumption that the study would detect 3-point differences for state anxiety scores between the IG and the CG after the intervention, resulting in a sample size of 45 participants for each group (80% power; $\alpha < 0.05$, two-tailed). A *t*-test was used for independent samples to measure child and parent satisfaction. Missing data were treated using the Full Information Maximum Likelihood method (FIML). Statistical analysis was performed using SPSS Statistics 26.

RESULTS

Participants

The demographic and clinical information of the participants is shown in **Table 1**. No significant differences were observed between the IG and the CG in terms of age, gender, education, language, clinic setting, the number of previous operations, the number or type of surgeries performed on the extremities or time.

Course of Anxiety Over Time

The descriptive distribution of operation-associated anxiety from t1 to t2 and t3 for both groups is demonstrated in **Table 2**. Children in both groups reported reduced state anxiety from t1 to t2, with anxiety scores shifting from a mean (M) of 10.5 [standard deviation (SD) = 7.12] to 9.6 (SD = 6.86), respectively, in the IG and from 9.4 (SD = 6.23) to 8.0 (SD = 6.46) in the CG.

State anxiety decreased significantly compared with trait anxiety, especially at t3. Self- and parent-reported anxiety levels demonstrated similar but not identical patterns, with children rating state anxiety higher than trait anxiety.

Anxiety values tended to be in the lower range of the scale (slightly) and to decrease over time. Parents assessed their state and trait anxiety levels regarding their children's operations similarly but reported lower levels of state anxiety than trait anxiety after the operation.

In addition, no significant differences in the cognitive and affective components of state anxiety were observed between the IG and CG in children (not depicted).

Effect of the Video

Table 3 shows the test of the hypothesis using the longitudinal, mixed model. The control variables that were considered included age, gender, native speaker, previous surgery, region of surgery and time (t1-3). The numbers represent the mean anxiety values for each respective STOA scale, showing a starting constant value and the changes associated with the predictor-specific components. In the longitudinal multilevel analysis, a separate regression equation for the dependent variable over time is calculated first for each individual case (level 1) (22). Intercepts are the initial values at t1, slopes are the rates of change per year. The intercepts and slopes of all cases can now in turn be taken as variables and analyzed *via* (level 2) regression equations again. The mean values of the intercepts and slopes are referred to as fixed effects or regression coefficients, respectively. As shown in the table, state anxiety, as measured using the self-reported STOA scale, can be optimally predicted by starting with a constant value of 3.2 anxiety points, plus the age of each participant multiplied by 0.6. Each predictor-specific component is associated with an additional adjustment, such as the reduction of 2.9 anxiety points for boys or the addition of 3.1 anxiety points for non-native speakers. The interaction between the difference in anxiety scores between time t1 and t2 and the group, as shown on the lower part of **Table 3**, indicated no significant effect on the change in self-reported pre-operative state anxiety in children between before and after the intervention for the IG compared with the CG ($M = 0.3$, SE = 0.74, not significant). However, significant reductions in both state and trait anxiety were observed for both groups between t1 and t2 and between t1 and t3 in both the patient- and parent-reported surveys.

Patient Satisfaction

The results of the patient satisfaction evaluation regarding the received information are shown in **Table 4**. In total, children and parents rated their satisfaction equally high but showed no significant group differences. In one item (**Table 4**, Item 4), both children and parents rated their reduction in worry with the received information as being significantly higher (children $p = 0.01$; parents $p = 0.004$) in the IG than in the CG (b).

TABLE 1 | Sample description.

Variable	Control group ($n = 45$)	Intervention group ($n = 45$)	Total sample ($n = 90$)	Test statistic	p
Age in years *M* (SD)	12.63 (2.23)	12.37 (2.72)	12.50 (2.48)	$t = -0.489$	0.626
Gender *n* (%)				$\chi^2 = 0.400$	0.527
Female	21 (47)	24 (53)	45 (50)		
Male	24 (53)	21 (47)	45 (50)		
Education (*n*)				$\chi^2 = 12.129$	0.096
Elementary school	6	8	14		
Middle school	0	4	4		
High school	22	14	36		
Other	17	19	36		
Mother tongue German *n* (%)				$\chi^2 = 2.000$	0.157
No	5 (11)	10 (22)	15 (17)		
Yes	40 (89)	35 (78)	75 (83)		
Clinic *n* (%)				$\chi^2 = 4.320$	0.115
Primary care center 1	18 (40)	18 (40)	36 (40)		
Primary care center 2	23 (51)	27 (60)	50 (56)		
Primary care center 3	4 (9)	0 (0)	4 (4)		
Pre-operation *n* (%)				$\chi^2 = 0.179$	0.673
No	25 (56)	23 (51)	48 (53)		
Yes	20 (44)	22 (49)	42 (47)		
Surgery on extremities *n* (%)				$\chi^2 = 1.538$	0.215
No	5 (11)	10 (22)	15 (17)		
Yes	40 (89)	35 (78)	75 (83)		
Type of surgery (*n*)					
Minor	16	13	29		
Medium	25	24	49		
Major	3	8	11		
No data	1	0	1		

The variable "Pre-operation" indicates if the child was previously operated or not.

TABLE 2 | Distribution of surgery anxiety before (t1) and after (t2) intervention, and after surgery (t3).

			CG			IG		
			n	*M*	SD	*n*	*M*	SD
Self-report	STOA-State	t1	44	9.4	6.23	45	10.5	7.12
		t2	40	8.0	6.46	44	9.6	6.86
		t3	38	6.2	6.64	43	5.7	5.74
	STOA-Trait	t1	44	12.1	8.71	45	13.6	11.26
		t2	40	9.9	9.20	44	11.1	11.99
		t3	40	9.3	8.72	43	11.0	11.21
Parent report	STOA-State	t1	43	10.7	5.90	40	9.6	6.43
		t2	40	9.1	5.83	39	8.2	5.72
		t3	39	3.5	4.09	36	4.1	4.55
	STOA-Trait	t1	43	20.1	10.47	40	20.7	10.85
		t2	40	17.6	10.26	39	16.8	9.80
		t3	39	16.4	8.70	36	16.1	7.95

State anxiety is assessed with 10 items. The resulting score has a range from 0 to 30 with higher values indicating higher state anxiety. Children and parents respond to a 4-point rating scale (0 = not at all, 1 = somewhat, 2 = moderately so, 3 = very much so, Cronbach's alpha = 0.90), which describes the intensity of their momentary experienced anxiety. Trait anxiety consists of 20 items. The resulting score has a range from 0 to 60 with higher values indicating higher trait anxiety. Under the instruction "When I think about operations and anesthesia in general, I worry that..." patients should indicate the frequency of occurrence of such fears based on a 4-point Likert scale (e.g., "...one can still feel something of the operation despite the anesthesia"; "...pain occurs after the operation") on 0–3 (0 = almost never, 1 = sometimes, 2 = often, 3 = almost always, Cronbach's alpha = 0.92).

TABLE 3 | Prediction of surgery anxiety before (t1), after (t2) intervention, and after surgery (t3).

	Self-report State-anxiety		Self-report Trait-anxiety		Parent report State-anxiety		Parent report Trait-anxiety	
	Effect	SE	Effect	SE	Effect	SE	Effect	SE
Fixed effects								
Constant	3.23	3.65	−6.38	5.69	10.05	3.73	21.96	6.26
Age in years	0.57*	0.26	1.32**	0.41	−0.08	0.27	−0.25	0.45
Gender (boys)	−2.91*	1.30	−3.11	2.04	0.98	1.33	1.15	2.22
Native speaker (no)	3.09	1.76	6.28*	2.74	4.37*	1.75	4.65	2.94
Previous surgeries (yes)	−1.99	1.29	−0.85	2.02	−0.98	1.30	−2.31	2.15
Surgery region (extremities)	1.29	1.73	3.67	2.72	1.24	1.72	1.26	2.87
Time								
t1-t2	−1.30*	0.54	−2.14***	0.57	−1.24***	0.33	−2.15**	0.81
t1-t3	−3.06**	0.94	−2.24*	1.09	−6.74***	0.94	−3.38*	1.30
Group (video)	0.91	1.35	1.31	1.05	−1.18	0.33	0.55	2.34
Time × group (video)								
t1-t2 × group	0.29	0.74	−0.50	0.79	0.22	0.47	−1.66	1.15
t1-t3 × group	−1.95	1.30	−0.68	1.51	1.81	1.36	−0.93	1.88
Model fit (BIC)	1514.5	1639.2	1336.6	1587.6				

*Longitudinal Mixed Model, n = 90 children, Raw scores of the State-Trait Operation Anxiety Inventory, BIC, Bayesian Information Criterion, *p≤ 0.05, **p≤ 0.01, ***p≤ 0.001.*

TABLE 4 | Subjective evaluation of intervention.

Item	Self-report					Parent-report				
	CG (TAU)		IG (Video)			CG (TAU)		IG (Video)		
	M	SD	*M*	SD	*p*	*M*	SD	*M*	SD	*p*
Patient information										
1. All questions answered	3.3	0.82	3.3	0.87	0.984	3.4	0.74	3.3	0.88	0.798
2. Easy to understand	3.25	0.87	3.50	0.86	0.209	3.38	1.00	3.73	0.45	0.073
3. Worries reduced	2.33	1.10	3.02	1.20	0.010**	2.78	1.07	3.46	0.73	0.004**
4. Uncertain	1.08	1.08	1.38	1.46	0.306	0.59	0.91	0.97	1.44	0.191
5. Has caused anxiety	0.79	0.85	1.00	1.15	0.394	0.72	1.20	0.28	0.65	0.070
6. Were correct	2.97	1.19	3.06	1.26	0.773	3.25	0.88	3.17	1.14	0.768
7. Overall satisfied	3.29	0.94	3.19	1.14	0.691	3.38	0.91	3.14	1.03	0.345
8. Total evaluation	8.11	1.33	8.14	1.96	0.933	8.16	1.75	8.68	1.36	0.188
Video										
9. Easy to understand			3.74	0.95				3.96	0.20	
10. Visually appealing			3.57	0.78				3.73	0.53	
11. Total satisfaction			3.43	0.98				3.58	0.58	
12. Total evaluation Video 1–10			8.44	2.21				9.04	1.18	

Item 1 and 12 can be rated on a 1 to 10-point scale to evaluate the general satisfaction with the obtained patient information. Standardized items with a 5-point response scale derived from previous studies (21) (0 = strongly disagree, 1 = disagree, 2 = neither agree nor disagree, 3 = agree, 4 = strongly agree). The IG filled out four additional items for evaluating the quality and satisfaction of the video.
***p <= 0.01.*

DISCUSSION

The purpose of this study was to evaluate whether a child-friendly, educational video with a laying technique could reduce pre-operative anxiety in children undergoing elective surgery compared with the standard information procedure (CG). To our knowledge, this study also represents the first time that the STOA has been used to measure children's self-reported anxiety levels before elective surgery.

In contrast to previous research (1, 16, 23–26), no significant effects were found in the reduction of pre-operative anxiety among children following the addition of a video to TAU before surgery compared with TAU alone. Both the children and their parents reported their anxiety using a validated questionnaire

(STOA). The measurement of state and trait anxiety at three different time points allowed us to comprehensively investigate the development of anxiety over the perioperative time. Although we were unable to identify significant differences between the groups, significant reductions in pre-operative state anxiety were observed at t2 compared to t1 for the children in both groups (IG and CG). The depicted course of anxiety levels shows coherence with a stressful situation, with higher state anxiety before the surgical intervention (7). Trait anxiety remained the same over the course of the three measurement time points, confirming the results reported by previous studies indicating that trait anxiety follows a constant course, representing a stable, consistent personality characteristic (1, 7). We failed to identify any decrease in the pre-operative state (and trait) anxiety in parents regarding their children's operations from t1 to t2. Fernandes et al. reported similar non-significant group differences (16). Interestingly, high anxiety scores in parents have been shown to predict their children's anxiety scores (5, 26–29).

Recent studies have used the modified Yale Pre-operative Anxiety Scale (mYPAS) as the gold standard for the measurement of observer-rated child anxiety, although some limitations associated with observer bias have been noted (30–32). Compared with this and other questionnaires that have been applied to measure anxiety, the STOA appears to represent a good alternative. It can measure the self-reported anxiety of both children and their parents, can be used to distinguish state from trait anxiety, and includes both cognitive and emotional subscales. With remark the STOA is a validated questionnaire used in a previous study only with adults (2).

In this study, the time point for the intervention was chosen as the day of surgery, which was also the timing used to provide the standard information procedure. However, the day of the operation, particularly the period shortly before the induction of anesthesia, is particularly stressful for the child (33). The existing anxiety level might strongly influence the ability of the children to cognitively process procedural information in a short period of time. This may affect the ability of this information to reduce anxiety levels in highly stressful situations (18). Other studies have indicated that significant reductions in anxiety could be achieved when presenting the pre-operative program at least 1 day prior to surgery (28, 34).

Child's age has been identified as an important variable in the prediction of the child's pre-operative anxiety level (19). In the present study, older children reported higher anxiety levels than younger children. Younger children might have felt more responsive to the video because of the simple format, the child-friendly language, and illustrations. Older children may have reported more anxiety because the information regarding the expected medical procedures was not age-appropriate and sufficiently detailed (14). Recent research has successfully used interventions based on video distraction, such as cartoons (30) and streaming video clips (31), during anesthesia induction. Among the younger children the video might have functioned more as a distraction rather than as a source of information and thereby explains the better response in children.

Boys reported lower anxiety values than girls in the present study, which agrees with prior results among children suggesting that gender is an important predictor of anxiety before surgery (16, 35).

This study used an informational education method, in which procedural information was mediated using a peer-modeling concept. Batuman et al., using mYPAS scores, showed significantly reduced anxiety scores in the IG compared with the CG when using a role-playing model. Peer-modeling videos can assist children to cope with an upcoming event through the observation of a child peer in a similar situation (1, 16, 23, 25).

The video did not provide detailed information regarding any surgical procedures, and the children may not have felt directly addressed because the video did not reflect their personal medical situation. Previously, others have stated that information should include procedural information regarding the events that will occur and sensory information regarding what children might expect, including the sensation of pain (20, 25).

Children and parents in the IG watched the educational video in the patient, holding, or examination room. The use of settings in which the children and their parents feel familiar and comfortable might impact the effectiveness of video interventions presented prior to hospitalization and surgery (36). Wakimizu et al. reported significant differences when an intervention group was presented with a pre-operative video and complementary booklet prior to hospitalization and additional at home compared with a control group that received the same pre-operative video only before hospitalization (36).

The standard care procedure already resulted in anxiety reduction, as reported by both children and parents, which may also account for the non-significant difference observed between the IG and the CG. Children's hospitals typically provide family-centered and age-appropriate information (37). The hospital staff is trained to communicate child-friendly information regarding the operation and the hospital stay and to involve parents in the operative setting. Personal contact between hospital staff and patients appears to be very effective in reducing children's anxiety (38). However, time and well-trained personal are not always freely available in clinical practice, and additional technology-based programs might be helpful for the implementation of standardized patient information (39).

In addition to objective measures of anxiety, a subjective evaluation regarding various aspects of the video was performed. Both, the children and their parents in the IG reported significant reductions in their worries compared with those in the CG. A short educational video may be a useful tool for informing children and parents regarding operational procedures and preparing them adequately for the upcoming surgery, as both children and their parents desire comprehensive information regarding perioperative procedures (10).

Important limitations of the present study should be considered. The information mediated by the educational video might have been insufficient due to the short time period before surgery. The content and format of the patient information used in this trial were not adapted to each child's age- and developmentally related concerns and fears. Furthermore, the questionnaire measuring child and parent satisfaction has not been validated in the study's target group. Three items have been selected from the original scale with regard to the study purposes.

Considering that the children answered the STOA at t3, it is possible that the children were influenced by medication like painkillers when answering the questions regarding their surgical anxiety and thus reported less anxiety. In addition, procedures for which hospital admission was required after the operation of the child could have influenced the post-operative anxiety and pain level of the child. As this was not the main focus of this study, we did not collect this data. Unfortunatly we didn't register the time of the medical counseling in both groups, which could have been an important factor in a busy unit.

The educational video could have been implemented as a supplementary and patient-orientated source of information in the pre-operative medical educations about anesthesia and surgery. A possible opportunity in our study and a possible outlook for further studies could be to provide a link so that children and parents could view the video at home or at a time of their choosing before surgery. In addition they would have the possibility to ask questions about the educational video and its content in the pre-operative medical information visit.

No pre-test has been performed to investigate the effects of an educational video on children with regard to pre-operative anxiety levels.

CONCLUSION

Pre-operative anxiety is an important component of pediatric surgery. In this study we couldn't find an effect for the self-reported pre-operative anxiety with a video as an additional measure to the standard procedure. The optimization of well-chosen, pre-operative, educational programs remains necessary in terms of the timing before surgery, format, and content of the program. The STOA has been demonstrated to be a reliable and factorially valid measurement instrument for the parallel assessment of both state and trait anxiety among children and their parents. Further studies should include smaller age groups to test which types of media and intervention methods might be used to address the levels of anxiety experienced among children prior to surgery. Aside from influencing anxiety, audio-visual programs, available in a variety of languages could improve pediatric surgical care regardless of patient's origin and language barriers.

SUMMARY

This randomized controlled trial shows the effects of an educational video on the pre-operative anxiety of children and parents.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethics Committee of the Hamburg Medical Association (Number PV6045). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

VH conceptualized the study, conducted the data collection, analyzed the data, and drafted the initial manuscript. CB conceptualized and designed the study, analyzed the data, and reviewed and revised the manuscript. CW consulted on the statistical methods, analyzed the data, and approved the final manuscript. KR and MR reviewed and revised the manuscript. JT conceptualized and designed the study and the video and reviewed and revised the manuscript. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

FUNDING

This study was funded by Hamburg macht Kinder gesund e. V. The funder paid for the video production.

ACKNOWLEDGMENTS

The authors wish to thank all children and parents participating to the study. A special thank goes to the nurse staff in the departments of the Altonaer Kinderkrankenhaus and the University Medical Centre Hamburg-Eppendorf, Germany. We thank Marcial Velasco-Garrido for reviewing the manuscript.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fped.2021.640236/full#supplementary-material

REFERENCES

1. Melamed BG, Siegel LJ. Reduction of anxiety in children facing hospitalization and surgery by use of filmed modeling. *J Consult Clin Psychol.* (1975) 43:511–21. doi: 10.1037/h0076896
2. Krohne HW, Schmukle SC, de Bruin J. The inventory "State-Trait Operation Anxiety" (STOA): construction and empirical findings. *Psychother Psychosom Med Psychol.* (2005) 55:209–20. doi: 10.1055/s-2004-834604
3. Kain ZN, Mayes LC, Caldwell-Andrews AA, Karas DE, McClain BC. Preoperative anxiety, postoperative pain, and behavioral recovery in young children undergoing surgery. *Pediatrics.* (2006) 118:651–8. doi: 10.1542/peds.2005-2920
4. Caumo W, Broenstrub JC, Fialho L, Petry SM, Brathwait O, Bandeira D, et al. Risk factors for postoperative anxiety in children. *Acta Anaesthesiol Scand.* (2000) 44:782–9. doi: 10.1034/j.1399-6576.2000.440703.x

5. Fortier MA, Del Rosario AM, Martin SR, Kain ZN. Perioperative anxiety in children. *Paediatr Anaesth.* (2010) 20:318–22. doi: 10.1111/j.1460-9592.2010.03263.x
6. Alvarez-Garcia C, Yaban ZS. The effects of preoperative guided imagery interventions on preoperative anxiety and postoperative pain: a meta-analysis. *Complement Ther Clin Pract.* (2020) 38:101077. doi: 10.1016/j.ctcp.2019.101077
7. Spielberger CD, Auerbach SM, Wadsworth AP, Dunn TM, Taulbee ES. Emotional reactions to surgery. *J Consult Clin Psychol.* (1973) 40:33–8. doi: 10.1037/h0033982
8. Thompson N, Irwin MG, Gunawardene WM, Chan L. Pre-operative parental anxiety. *Anaesthesia.* (1996) 51:1008–12. doi: 10.1111/j.1365-2044.1996.tb14992.x
9. Kampouroglou G, Velonaki VS, Pavlopoulou I, Drakou E, Kosmopoulos M, Kouvas N, et al. Parental anxiety in pediatric surgery consultations: the role of health literacy and need for information. *J Pediatr Surg.* (2020) 55:590–6. doi: 10.1016/j.jpedsurg.2019.07.016
10. Fortier MA, Chorney JM, Rony RY, Perret-Karimi D, Rinehart JB, Camilon FS, et al. Children's desire for perioperative information. *Anesth Analg.* (2009) 109:1085–90. doi: 10.1213/ane.0b013e3181b1dd48
11. Smith L, Callery P. Children's accounts of their preoperative information needs. *J Clin Nurs.* (2005) 14:230–8. doi: 10.1111/j.1365-2702.2004.01029.x
12. Kain ZN, Wang SM, Caramico LA, Hofstadter M, Mayes LC. Parental desire for perioperative information and informed consent: a two-phase study. *Anesth Analg.* (1997) 84:299–306. doi: 10.1213/00000539-199702000-00011
13. Book F, Goedeke J, Poplawski A, Muensterer OJ. Access to an online video enhances the consent process, increases knowledge, and decreases anxiety of caregivers with children scheduled for inguinal hernia repair: a randomized controlled study. *J Pediatr Surg.* (2020) 55:18–28. doi: 10.1016/j.jpedsurg.2019.09.047
14. Jaaniste T, Hayes B, Von Baeyer CL. Providing children with information about forthcoming medical procedures: a review and synthesis. *Clin Psychol Sci Pract.* (2007) 14:124–43. doi: 10.1111/j.1468-2850.2007.00072.x
15. Dai Y, Livesley J. A mixed-method systematic review of the effectiveness and acceptability of preoperative psychological preparation programmes to reduce paediatric preoperative anxiety in elective surgery. *J Adv Nurs.* (2018). doi: 10.1111/jan.13713. [Epub ahead of print].
16. Fernandes SC, Arriaga P, Esteves F. Providing preoperative information for children undergoing surgery: a randomized study testing different types of educational material to reduce children's preoperative worries. *Health Educ Res.* (2014) 29:1058–76. doi: 10.1093/her/cyu066
17. Chow CH, Van Lieshout RJ, Schmidt LA, Dobson KG, Buckley N. Systematic review: audiovisual interventions for reducing preoperative anxiety in children undergoing elective surgery. *J Pediatr Psychol.* (2016) 41:182–203. doi: 10.1093/jpepsy/jsv094
18. Kim J, Chiesa N, Raazi M, Wright KD. A systematic review of technology-based preoperative preparation interventions for child and parent anxiety. *Can J Anaesth.* (2019) 66:966–86. doi: 10.1007/s12630-019-01387-8
19. Kain ZN, Mayes LC, O'Connor TZ, Cicchetti DV. Preoperative anxiety in children. Predictors and outcomes. *Arch Pediatr Adolesc Med.* (1996) 150:1238–45. doi: 10.1001/archpedi.1996.02170370016002
20. MacLaren J, Kain ZN. Pediatric preoperative preparation: a call for evidence-based practice. *Paediatr Anaesth.* (2007) 17:1019–20. doi: 10.1111/j.1460-9592.2007.02319.x
21. Holzel LP, Ries Z, Dirmaier J, Zill JM, Kriston L, Klesse C, et al. Usefulness scale for patient information material (USE) - development and psychometric properties. *BMC Med Inform Decis Mak.* 2015;15:34. doi: 10.1186/s12911-015-0153-7
22. Raudenbush SW, Bryk AS. *Hierarchical Linear Models: Applications and Data Analysis Methods.* Thousand Oaks: Sage Publications (2002).
23. Batuman A, Gulec E, Turktan M, Gunes Y, Ozcengiz D. Preoperative informational video reduces preoperative anxiety and postoperative negative behavioral changes in children. *Minerva Anestesiol.* (2016) 82:534–42.
24. Hatipoglu Z, Gulec E, Lafli D, Ozcengiz D. Effects of auditory and audiovisual presentations on anxiety and behavioral changes in children undergoing elective surgery. *Niger J Clin Pract.* (2018) 21:788–94. doi: 10.4103/njcp.njcp_227_17
25. Ferguson BF. Preparing young children for hospitalization: a comparison of two methods. *Pediatrics.* (1979) 64:656–64.
26. Pinto RP, Hollandsworth JG, Jr. Using videotape modeling to prepare children psychologically for surgery: influence of parents and costs versus benefits of providing preparation services. *Health Psychol.* (1989) 8:79–95. doi: 10.1037/0278-6133.8.1.79
27. Bevan JC, Johnston C, Haig MJ, Tousignant G, Lucy S, Kirnon V, et al. Preoperative parental anxiety predicts behavioural and emotional responses to induction of anaesthesia in children. *Can J Anaesth.* (1990) 37:177–82. doi: 10.1007/BF03005466
28. Fincher W, Shaw J, Ramelet AS. The effectiveness of a standardised preoperative preparation in reducing child and parent anxiety: a single-blind randomised controlled trial. *J Clin Nurs.* (2012) 21:946–55. doi: 10.1111/j.1365-2702.2011.03973.x
29. Li HC, Lopez V, Lee TL. Psychoeducational preparation of children for surgery: the importance of parental involvement. *Patient Educ Couns.* (2007) 65:34–41. doi: 10.1016/j.pec.2006.04.009
30. Lee J, Lee J, Lim H, Son JS, Lee JR, Kim DC, et al. Cartoon distraction alleviates anxiety in children during induction of anesthesia. *Anesth Analg.* (2012) 115:1168–73. doi: 10.1213/ANE.0b013e31824fb469
31. Mifflin KA, Hackmann T, Chorney JM. Streamed video clips to reduce anxiety in children during inhaled induction of anesthesia. *Anesth Analg.* (2012) 115:1162–7. doi: 10.1213/ANE.0b013e31824d5224
32. Kain ZN, Mayes LC, Cicchetti DV, Bagnall AL, Finley JD, Hofstadter MB. The yale preoperative anxiety scale: how does it compare with a "gold standard"? *Anesth Analg.* (1997) 85:783–8. doi: 10.1213/00000539-199710000-00012
33. Kain ZN, Caramico LA, Mayes LC, Genevro JL, Bornstein MH, Hofstadter MB. Preoperative preparation programs in children: a comparative examination. *Anesth Analg.* (1998) 87:1249–55. doi: 10.1213/00000539-199812000-00007
34. Fortier MA, Bunzli E, Walthall J, Olshansky E, Saadat H, Santistevan R, et al. Web-based tailored intervention for preparation of parents and children for outpatient surgery (WebTIPS): formative evaluation and randomized controlled trial. *Anesth Analg.* (2015) 120:915–22. doi: 10.1213/ANE.0000000000000632
35. Bender PK, Reinholdt-Dunne ML, Esbjørn BH, Pons F. Emotion dysregulation and anxiety in children and adolescents: gender differences. *Pers Ind Diff.* (2012) 53:284–8. doi: 10.1016/j.paid.2012.03.027
36. Wakimizu R, Kamagata S, Kuwabara T, Kamibeppu K. A randomized controlled trial of an at-home preparation programme for Japanese preschool children: effects on children's and caregivers' anxiety associated with surgery. *J Eval Clin Pract.* (2009) 15:393–401. doi: 10.1111/j.1365-2753.2008.01082.x
37. Chorney JM, Kain ZN. Family-centered pediatric perioperative care. *Anesthesiology.* (2010) 112:751–5. doi: 10.1097/ALN.0b013e3181cb5ade
38. Hines S, Munday J, Kynoch K. Effectiveness of nurse-led preoperative assessment services for elective surgery: a systematic review update protocol. *JBI Database Syst Rev Implement Rep.* (2013) 11:73–83. doi: 10.11124/jbisrir-2013-541
39. Wehkamp KH, Naegler H. The commercialization of patient-related decision making in hospitals. *Dtsch Arztebl Int.* (2017) 114:797–804. doi: 10.3238/arztebl.2017.0797
40. Krämer A, Böhrs S. The use of explainer videos as a learning tool: an internal and external view. *On Line.* (2018) 189–202. doi: 10.1007/978-3-319-62776-2_15

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

APPENDIX

The 3-min child-friendly educational video explains the procedures in a hospital, when an injury happens, from the perspective of a young boy (peer-modeling). It shows how patients are getting prepared by the nursing staff and how they enter the operating room accompanied by a nurse and a parent. Furthermore, the video explains to whom patients can refer to if they need analgesic drugs during their hospital stay. The illustration appears on a flat and white screen with soft background music. This video uses a format so-called hand lay-style, where new scenes are wiped in or out with two hands. Videos like this visualize and simplify abstract and complex information in a short and simple way (40).

Video can be found under:

https://www.uke.de/kliniken-institute/kliniken/kinderchirurgie/aufnahme/index.html

frontiers in Medicine

REVIEW
published: 09 July 2021
doi: 10.3389/fmed.2021.698855

Check for updates

An Overview of Ontologies in Virtual Reality-Based Training for Healthcare Domain

Ummul Hanan Mohamad[1], *Mohammad Nazir Ahmad*[1], *Youcef Benferdia*[1], *Azrulhizam Shapi'i*[2] *and Mohd Yazid Bajuri*[3]*

[1] Institute of IR4.0, Universiti Kebangsaan Malaysia, Bangi, Malaysia, [2] Faculty of Information Science & Technology, Universiti Kebangsaan Malaysia, Bangi, Malaysia, [3] Department of Orthopaedics and Traumatology, Faculty of Medicine, Universiti Kebangsaan Malaysia, Kuala Lumpur, Malaysia

Virtual reality (VR) is one of the state-of-the-art technological applications in the healthcare domain. One major aspect of VR applications in this domain includes virtual reality-based training (VRT), which simplifies the complicated visualization process of diagnosis, treatment, disease analysis, and prevention. However, not much is known on how well the domain knowledge is shared and considered in the development of VRT applications. A pertinent mechanism, known as ontology, has acted as an enabler toward making the domain knowledge more explicit. Hence, this paper presents an overview to reveal the basic concepts and explores the extent to which ontologies are used in VRT development for medical education and training in the healthcare domain. From this overview, a base of knowledge for VRT development is proposed to initiate a comprehensive strategy in creating an effective ontology design for VRT applications in the healthcare domain.

Keywords: knowledge representation, ontology engineering, domain knowledge, virtual reality, medical education and training

OPEN ACCESS

Edited by:
Michelle A. Kelly,
Curtin University, Australia

Reviewed by:
Ehab Seed Ahmed,
Inaya Medical Colleges, Saudi Arabia
Kamal Badr,
Sudan University of Science and Technology, South Sudan

***Correspondence:**
Mohd Yazid Bajuri
yb@ppukm.ukm.edu.my

Specialty section:
This article was submitted to Family Medicine and Primary Care, a section of the journal Frontiers in Medicine

Received: *22 April 2021*
Accepted: *14 June 2021*
Published: *09 July 2021*

Citation:
Mohamad UH, Ahmad MN, Benferdia Y, Shapi'i A and Bajuri MY (2021) An Overview of Ontologies in Virtual Reality-Based Training for Healthcare Domain. Front. Med. 8:698855. doi: 10.3389/fmed.2021.698855

INTRODUCTION

Virtual reality is a technology advancement that creates an immersive, virtual environment to allow users to interact and visualize the real world in a virtual form (1) through multiple sensory channels (2). As mentioned by Ajmera and Gonen (3), VR is commonly composed of three main components; art, audio and mechanics. The first component, art, describes the environment where users see, interact with objects and the animated surroundings in VR. Audio, on the other hand, provides some level of immersiveness and reality-like feeling during the real-time simulation of the VR. Meanwhile, mechanics is the main part of the VR that facilitates user interaction with the created virtual events.

In the healthcare domain, VR-based training often involves the use of VR headsets, instrumented clothing such as haptic gloves or tracking suits, along medical instruments. So far, a few VRTs in the healthcare domain have been developed to provide an alternative channel for medical education and training for healthcare personnel. Among them are virtual surgery for ophthalmology, laparoscopic, endoscopic procedures (4), anatomy dissection (5), emergency simulation (6), and many other procedural trainings (7). Hence, the need and scope for VRT in the healthcare domain are limitless. VRT in the healthcare domain is an interactive, immersive use of VR technology for medical education and training purposes, to provide a real-time simulation of an actual setting (8) related to the healthcare domain.

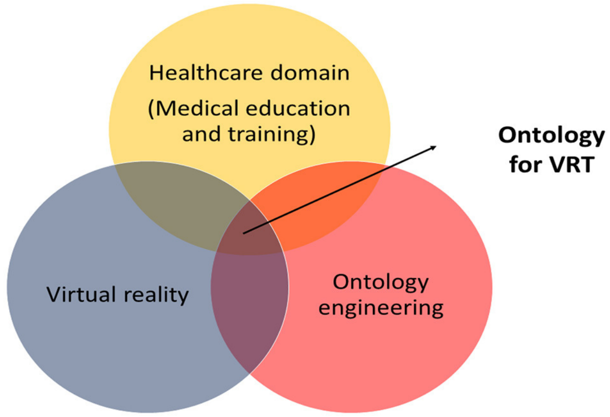


FIGURE 1 | The scope of ontology review in VRT.

One of the perks of having VRT in the healthcare domain is that it provides a progressive way to train healthcare personnel in a safe, controlled environment (9) while reducing the potential risks that exist when the training is performed on the actual patients (10). However, the development of VRT in its current state is time-consuming and complicated due to certain limitations such as accessibility, cost of virtual tools, perception of the VR technology and usability (11). Elaboration on these limitations under the ontological perspective will be further discussed in section Literature Review. Moreover, the knowledge from developing one VRT in the healthcare domain is rarely used to speed up the development of another VRT (12). Hence, there is a need to tackle this limitation to expand VRT development in the healthcare domain by understanding how the knowledge on this can be shared and reused across other VRT training activities.

One of the well-known mechanisms suitable for capturing knowledge and making it explicit for seamless sharing of information in a domain of interest is ontology (13, 14). Some studies have investigated the use of ontologies in the intersection of Ontology Engineering and virtual reality (15). However, the use of ontologies, specifically VRT, is not well-captured and is missing all the aspects and evidence that we are interested in. For example, how ontology has been used in VRT to manage the learning scenario, users' behavior, and interaction inside VR is not something that has been distinctly established. Therefore, this paper represents the field of ontology and gives an overview of the recent research in the field, in the context of medical education and training. The research questions of this paper are focused on finding the existing types of ontologies, the methodologies for building ontologies and defining the purpose of these ontologies for VRT in healthcare.

Figure 1 depicts the scope of this study. By demonstrating this, the focus is illuminated toward understanding the ontologies that currently exist to support VRT in medical education and training, what are the missing elements in the existing ontologies and what is yet to be explored in VRT in the healthcare domain from an ontological perspective.

The rest of the paper is structured as follows. Section Literature Review includes the general applications of VRT, issues in VRT development, ontology classification and the role of ontology in VRT development based on the context of healthcare. In section Methodology, we present the existing ontologies developed for VRT in the healthcare domain, providing an ontological perspective to be discussed in section Ontologies Application in VRT in Healthcare Domain. Then, section Discussion concludes the work with potential future directions.

LITERATURE REVIEW

In general, Zhou et al. (16) mentioned that the role of VR in medical education and training can be classified into two types; VR as a teaching tool or VR as a learning environment. VR as a teaching tool can be defined as "a visualization tool that uses VR technologies to engaging users to learn spatially complex topics" (17). Meanwhile, VR as a learning environment simulates complex objects in virtual form to facilitate better understanding and visualization.

General Applications of Virtual Reality in Healthcare

The virtual reality-based applications in the field of healthcare are growing tremendously with the advancement in technology, especially now, in the era of the fourth industrial revolution. In general, these applications fall into the following categories.

Virtual Surgery

VR simulations are now progressively being used for numerous surgical practices such as in ophthalmology, laparoscopic, endoscopic, and even cataract surgery procedures. The main purpose is to allow surgeons, regardless of their expertise level, to rehearse and practice complex surgical procedures using virtual reality before attempting the procedures on a patient. Previously, these types of training exercises were often performed during real surgery through observations and then, under the supervision of senior surgeons (18). Hence, when there are good training alternatives such as through VRT, this opens bigger opportunities for surgeons to enhance their surgery skills, with less need to practice on real patients. With realistic haptic feedback, surgeons can assess their performance. In agreement, a study by Thomsen et al. (19) revealed that the operating room performance improves when surgeons undergo VRT training.

Anatomy Dissection

Another essential virtual reality-based training in healthcare is anatomy dissection. Using VR, the anatomy of important organs such as the ear, bone, and others can be visualized and explored up to the level of intricate details that will help facilitate accurate dissection skills among surgeons. According to Jang et al. (5), VR-based training is more sustainable compared to human cadavers in long term. To accentuate the enormous potential of using VR in anatomy dissection, virtual training is now shaped to allow active manipulation of the 3D structures rather than just passive viewing. To add, VRT in anatomy dissection has reported a significant increase in the overall confidence among surgeons post-VRT training (20).

Disease Management

The use of virtual reality is also expanded to training in disease management. One important example is the VRT to train healthcare professionals that work with patients suffering from mental diseases. As mental diseases are not the type that impacts patients physically, it can be quite challenging to diagnose and provide accurate treatments and interventions. Through VR, physicians can experience what happens inside the mind of a patient with schizophrenia (21). The possibility of having VRT for this purpose eventually will carve a bigger path for the expansion of many VRT developments in the healthcare domain.

Emergency Simulation

A medical emergency is one of the most important training types for any healthcare professional. Hence, it only seems fitting that virtual reality technology is also adopted to develop VRT for emergency simulation. This type of training is important to ensure that healthcare personnel can respond immediately and effectively during any medical crisis. Using VR, simulations of any probable events can also be created. McGrath et al. (6) highlighted that having VR training for emergency simulations is beneficial in a way that it provides an environment that overcomes the issues of limited clinical training hours while allowing trainers to focus on improving their skills and training.

Procedural Trainings

Virtual reality is also applied in healthcare for procedural and communication training (21). To add, this becomes more important especially during the pandemic crisis of COVID-19 disease outbreak, when it is not possible to perform training in normal ways. Procedural training using VR may include the common medical standard operating procedures (SOPs), clinician-patient communication and more. A study by Sowndararajan et al. (22) mentioned that the immersiveness capability of VR training resulted in better compliance of the healthcare personnel toward the procedures. This is because they can efficiently remember complex procedures. In other words, VRT for procedural training can facilitate healthcare practitioner competencies and minimize unnecessary errors.

Limitations in Developing VRT in Healthcare

The healthcare domain is complex. Hence, implementing VR for medical education and training is quite a trivial task. Many adopters in the healthcare field have encountered problems at different phases within VRT development.

Firstly, as in many other domains, the development of VRT in healthcare is often limited by the difficulty to maintain a standardized vocabulary (23). This happens often due to the involvement of stakeholders of varying competencies and skills. For example, both subject matter experts (SMEs) and technological developers have their understanding of the central concepts. As a result, the same word may mean different things in different contexts or different words used in different domains could mean the same thing (24). This gap contributes toward complicating the development of VRTs for the healthcare domain (25). Until now, VRT remains expensive, complicated and time-consuming (26).

Secondly, there is a high rate of failure in VRT development in the healthcare domain (27). One of the reasons behind this is the lack of adequate information exchange and communication that supports the whole development process. So far, there are no clear and comprehensive guidelines on how to develop VRT for healthcare. Additionally, the VRT knowledge areas are also not explored in-depth. Although there is a basic workflow on VR development, many VRTs in healthcare are developed in-silo, for the certain specialization of skills and therefore, are non-reusable for the development of another VRT within the same domain (28).

Thirdly, the healthcare domain is a field rich in terminologies (29). Yet, the rapid accumulation of these various terminologies, taxonomies, tools, and applications has led to a more complicated situation of unsynchronised knowledge (30). This situation hinders the efficiency to capture, represent and structure the explicit knowledge in the healthcare domain, making it difficult to set up VRT with good system interoperability (31). Moreover, Burgun et al. (30) any missing knowledge or wrong understanding of the domain can negatively impact the VRT efficiency as alternative training channels. Therefore, it is best to provide explicit knowledge using a well-established mechanism such as ontology.

Fourthly, Zahabi and Razak (8) also mentioned that VRT should also consider user's capabilities, performance and needs to be effective. Often, the development of VRT is majorly focused on fulfilling the technical aspect. When this happens, many VRT users fail to achieve the learning benefits (32). Hence, the design of VRT needs to consider the users' requirements, which can be effectively captured using ontology.

Fifthly, the development of any VR-based training in healthcare must be driven by a well-defined methodology (12). Up till now, there is yet to be any consensus on the best methodology (33) that can be adopted into the healthcare context. The lifecycle of VR development activities needs to be supported with domain knowledge (34) due to the presence of the healthcare's knowledge-intensive tasks and the healthcare's domain complexity involving many stakeholders. So far, according to Gibaud et al. (35), most of the adopted methodologies for the development of VR-related healthcare modules have not been based on well-established methodologies, instead, they have occupied an *ad-hoc* approach. Therefore, it is crucial to find or to have the right methodology to ease the development of VRT in healthcare (36). This can be done by incorporating domain engineering into the lifecycle of the VR methodologies as a way forward.

Ontology Classification and Roles in Healthcare

Gruber (37) defined ontology as "a formal and explicit specification of a conceptualization." In general, there are four types of ontologies, as shown in **Figure 2**. A top-level

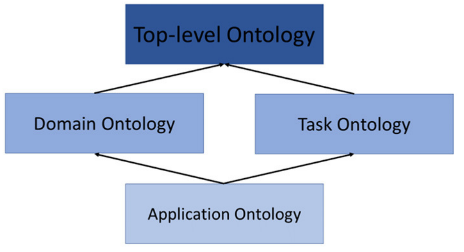


FIGURE 2 | The classification of ontology.

ontology is a general-purpose concept that is common across all domains. It is also known as an upper ontology. According to Hoehndorf (38), top-level ontology essentially provides rich definitions that can be applied across multiple domains. Hence, top-level ontology serves as a general foundation for a more elaborated ontology such as domain ontology. Usage of top-level ontology is important as it facilitates reusability, interoperability and much more. Meanwhile, domain ontology is a controlled vocabulary that represents concepts in a specific domain. Task ontology, on the other hand, is a detailed specification that describes the activity-related task. Application ontology describes specific applications.

Other than that, an ontology may also be categorized into a lightweight ontology or a heavyweight ontology. According to Corcho (39), a lightweight ontology is an ontology that describes the relationships between concepts in general associations. Whereas, a heavyweight ontology is an ontology enriched with axioms for semantic interpretation (40). A lightweight ontology is often informal and less expressive as compared to a heavyweight ontology (14).

Another way to classify ontology is based on the ontology motivation, either endurant or perdurant. Colomb and Ahmad (41) define an endurant as an entity that exists timelessly. All of its parts exist at the same time. Meanwhile, a perdurant is an entity that happens in time. If it has parts, it has temporal parts that happen at different times. A domain ontology can be designed to cover endurants and/or perdurants, depending on the domain characteristics and the purpose of ontology to be designed. For example, the domain of interlocking institutional worlds (IWs) such as the one explained by Colomb and Ahmad (41) is perdurant-centric and endurant is considered as a second-class object. Both perdurants and endurants are needed for modeling any kind of domain ontologies under domain IWs characteristics. In short, the endurant-based ontology describes the structural aspect of the domain while the perdurant-based ontology involves the dynamic (process) element of the domain.

Role of Ontology in the Development of VRT in Healthcare

The main benefit of using an ontology for VRT in healthcare is to show explicit knowledge in the domain to drive an effective VRT development. A simple example is depicted by (42) who used ontology in biomedicine. The ontology enabled access to domain knowledge, thereby providing a way to verify data consistency and to facilitate integrative analyses over biomedical data.

The healthcare domain is also filled with abundant knowledge that is heterogeneous in nature. Hence, ontology plays a role in providing a structured, common vocabulary that reflects the domain (43). This is important as VRT often involves VR designers and domain experts with different skill competencies and understanding. Hence, ontology can help to bridge the communication gap between the different players of VRT using common (shared) knowledge.

According to Tudorache (32), another main purpose that ontology carries is to enable seamless information sharing and reuse of knowledge between people and software agents, on a domain of interest. This allows the knowledge to be computationally useful and therefore, affects the interoperability of the systems.

To summarize, the role of ontology in the development of VRT in healthcare are:

- depict explicit knowledge in the domain to allow effective VRT development in medical education and training
- enable access to the domain knowledge for verification of data consistency
- provide a structured, common vocabulary that facilitates good systems interoperability
- allow knowledge sharing between different players of VRT

Table 1 demonstrates the characteristics of the existing training in the healthcare domain, the advantages of using virtual reality-based training, and highlights the benefits of applying ontology in VRT development in healthcare.

METHODOLOGY

This study reviewed papers focusing on the intersections between virtual reality-based training in the health domain that uses an ontology engineering approach. The initial selection criteria included papers that are journal articles, published from 2015 onwards, and which highlighted the use of ontology in virtual reality-based training in the healthcare domain. However, it was discovered that there are a very low number of papers that met these strict criteria. Hence, the criteria were revised to include:

- Peer-reviewed manuscripts (journal articles, proceedings, books);
- Published from 2010 onwards; AND
- Discussed the use of ontology in virtual reality-based training in the healthcare domain

From the review, we are to reveal in **Table 2**:

- the classification of the existing ontology in VRT in the healthcare domain;
- the VRT problems that have been addressed using the ontology-driven approach;
- the languages used in the ontology-driven VRT;
- whether the existing ontologies in VRT in the healthcare domain can be reused.

TABLE 1 | Characteristics of existing training in medical education and training, and the potential benefits gained from applying ontologies for VRT development.

Characteristics of existing training	Advantages of using VRT	Benefits of applying ontology in VRT
Restrained by time, sometimes hindered by situations and unavoidable circumstances such as pandemic, emergencies, lack of staff	Allows for training to be done at the time of convenience	Enables sharing and reuse of knowledge to develop other VRTs in medical and education training
Many sub-domains: hence, it is labor-intensive to conduct repeated training	Can be made to allow learning of procedures by other sub-domains	Capture common knowledge that exists across sub-domains
Training is limited to availability, especially when conducted on the real patients	Can simulate any probable situation to which practitioners can act upon	Provides facilitated integrative analyses and validation of data consistency to simulate a virtual training environment
Inadequate infrastructure such as tools to practice (cadavers, sutures, consumables, etc.)	Allows for repeated use of tools to practice (virtual patients, 3D simulated organs, virtual medical tools)	Structure the communication between different players of VRT to provide good system interoperability
Visualization in training is restricted to what the practitioners can see	Enables deeper and more detailed visualizations, up to the molecular level	Capture explicit knowledge in the healthcare domain for effective VRT development
Some training is depended on the patient's consent (in which many patients tend to refuse, such as episiotomy repair)	No consent needed from patients since procedural training is simulated in the virtual environment	Provides facilitated integrative analyses and validation of data consistency to simulate a virtual training environment
Training often comes with a risk to both practitioners and patients (exposure to disease or potential infection)	Minimizes unnecessary risk to both parties	Enable seamless information sharing and reuse

ONTOLOGIES APPLICATION IN VRT IN HEALTHCARE DOMAIN

Ontology for the Virtual Human Patients (MV-SYDIME)

The lack of experts and inadequate training conditions prevent the progressive learning and training of novice learners in medical diagnostics. This can potentially lead to a higher occurrence of false diagnoses (44). Practicing medical diagnostics is important for learners in healthcare to confidently decide, confirm and explain their diagnosis. Hence, this paper discussed developing a virtual patient. However, the human body is very complex to model entirely. Hence, in this study, they used MV-SYDIME ontology to capture the knowledge of the virtual human patients and represent the pathological concepts (see **Figure 3**) to ensure good interoperability among the systems involved.

Ontology for Virtual Doctor System (VDS)

Patients usually wait for hours to see the doctor. Hence, this study focused on designing an avatar that resembles a real human doctor to interact with the patients. This avatar, or the virtual doctor, will perform the initial diagnosis to classify patients based on how critical their cases are. The nature of the knowledge that exists in this kind of situation is not only abundant but also heterogeneous. To effectively deal with this, Fujita et al. (45) used ontology to build the probabilistic model of the VDS system. The model can perform medical diagnosis based on the doctor's knowledge and experience and then, sort the patient cases according to the generated weight (high, medium, low, not-simple etc.). Two types of ontologies, Physical Ontology (PhO) and Mental Ontology (MeO) are aligned and represented on Medical Ontology as shown in **Figure 4**. Both ontologies are independent of each other. The medical ontology represents the conceptual view of the medical diagnosis and the specialization is according to the doctor's experiences.

Ontology for Dentistry Structure

Dentistry anatomy is an area of important knowledge in which a dentist needs to be very well-versed. Hence, a study by Dias et al. (46) utilized virtual reality-based training to elevate the visualization of a dental structure as part of the learning process. The advanced VR system incorporates ontology as shown in **Figure 5**, to provide a semantic description of knowledge to the virtual 3D dental structures. Endurant ontology was used in the development process. However, the authors' paper did not mention the used tool and methodology for designing their ontology, other than indicating the use of an RDF file. This language enabled the semantic description and aggregation of multimedia contents as a 3D model. The VRT was evaluated by ten professionals in dentistry, to which all users believed that the system can be used as a training tool to support teaching dentistry structure and content.

TABLE 2 | Overview of the ontology applications for VRT development in the healthcare domain.

Category of healthcare services	Ontology	Purpose of ontology	Classification of ontology	Language	Tool	Methodology	Reuse ontology	References
Medical diagnosis	Ontology of virtual human patient (MV-SYDIME)	Ontology to capture the knowledge of the virtual human patients	Domain, Endurant, Heavyweight	-	Protégé 2000	-	/(SVDIME)	(44)
Medical diagnosis	Ontology for virtual doctor system (VDS)	Ontology to: 1. Explicitly derive knowledge related to all real patients including physical and mental view 2. Identify the right query/ decision based on the previous diagnosis gathered from a professional doctor	Domain, Endurant, Heavyweight	OWL	-	-	×	(45)
Dental treatment	Ontology for dentistry structure	Ontology to provide a semantic description of knowledge and content about the dentistry domain for VRT	Domain, Endurant, Heavyweight	RDF	-	-	×	(46)
Surgery procedures	ONTO-MAMA ontology	Ontology to: 1. To represent domain knowledge related to anatomy part 2. To extend guided surgical training for either students or health professionals in terms of mastering core needle biopsy procedures	Domain, Endurant, Heavyweight	OWL, RDF	Protégé (version 4.1)	Methontology	×	(47)
Dental treatment	Ontology for therapeutic interventions simulation in fixed prosthodontics (VirDent)	Ontology to drive the protocols for preparation of teeth for all-ceramic crowns	Domain, Heavyweight, Endurant	OWL DL, UML	Protégé	Noy and McGuiness	/(DOLCE)	(48)
Rehabilitation/Disease Management	VEULMoR ontology	Ontology to share a common understanding and facilitate the design of a virtual environment	Domain, Heavyweight, Perdurant	OWL, UML	Protégé	Methontology	×	(49)

(-) not mentioned; (/) yes; (×) no.

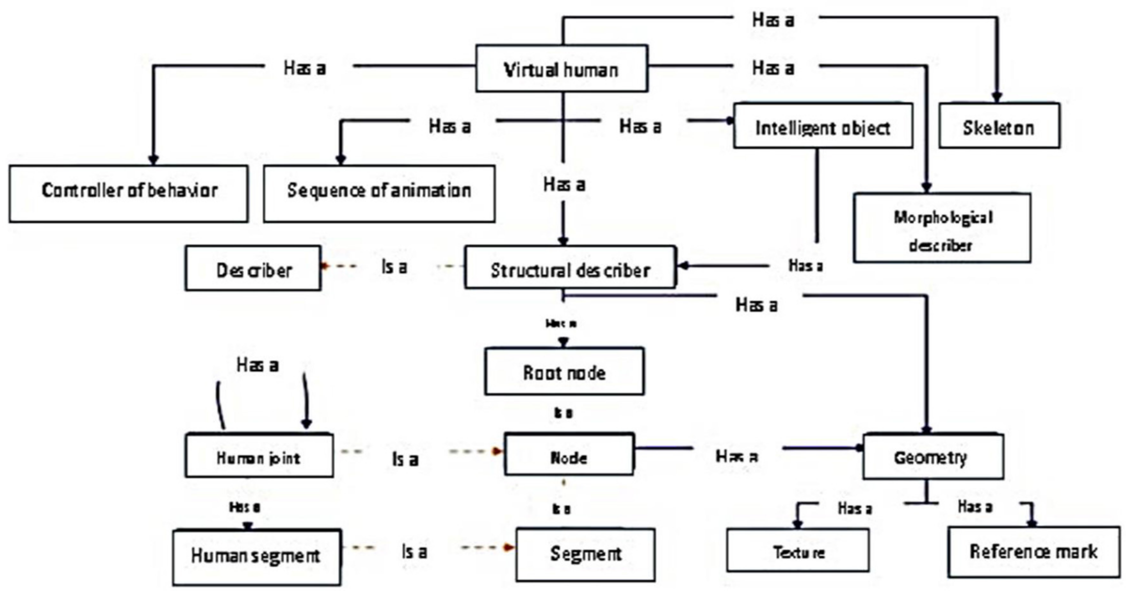


FIGURE 3 | The ontology fragment of virtual human [Source: Monthe et al. (44)].

Ontology and 3D Graphic Model of the Female Breast Anatomy (OntoMAMA)

Artificial intelligence and virtual reality have shown their potential to be used in medical training and simulations. Yet, organizing the knowledge of complex human anatomy and complicated medical procedures requires well-known mechanisms as the main guidance to develop good VRT modules. This study discussed the use of an ontology to express the vocabulary of the female breast anatomy in a virtual reality environment. As depicted in **Figure 6**, ONTO-MAMA ontology is a useful reference to provide guided surgical training for trainees to master core needle biopsy procedures. Klavdianos et al. (47) used the Methontology method and the Protégé tool in ONTO-MAMA ontology design. The OWL language was chosen to represent the domain knowledge related to the selected anatomy parts.

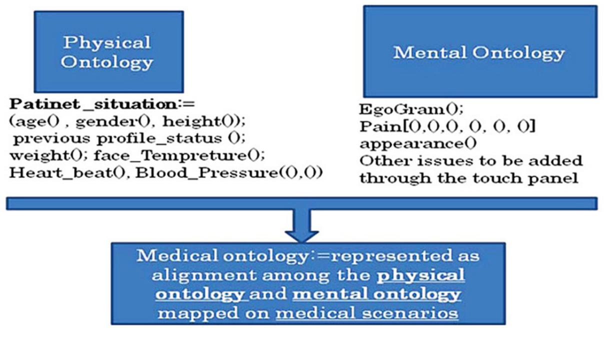


FIGURE 4 | The ontology fragment of virtual doctor system [Source: Fujita et al. (45)].

Ontology for Therapeutic Interventions Simulation in Fixed Prosthodontics (VirDent)

Prosthodontics is one branch of dentistry that deals with the restoration of missing teeth using prostheses. One of the procedures in prosthodontics includes teeth crowning. Teeth crowning comes with many restoration options; however, all-ceramic restoration is one of the most biocompatible restorations available. Nonetheless, it is not widely used because the procedure is delicate and requires high precision skills. Any misstep in all-ceramic restoration may lead to adverse effects such as pulp inflammation. In 2011, Bogdan described e-learning, a virtual reality-based system called VirDent. The sole purpose of the VirDent system is to help dentistry students learn how to prepare fixed teeth prosthodontics for ceramic crowns. To formally construct a knowledge base and synchronize the knowledge for the VirDent system architecture, a domain ontology is established using the OWL language and Protégé tools (see **Figure 7**).

VEULMoR Ontology

Even as VRT began to expand to many subdomains of healthcare, the design of VR-based training remains a trivial task. A study by Ramírez-Fernández et al. (49) focused on the issues faced in designing VR for upper limb motor rehabilitation. They argued that the available approaches to designing VR are insufficient, as no considerations are made to understand the knowledge in the domain, hence it is difficult to maintain a standardized vocabulary. A simpler mechanism to capture all this knowledge and represent it in a common language is required. Ramírez-Fernández et al. (49) designed the VEULMoR ontology (see **Figure 8**) to make it easier to design a virtual environment for upper limb motor rehabilitation using VR. The ontology can capture distinct aspects of the domain such as stroke-survivor, characteristic motor rehabilitation, interaction devices, and others.

DISCUSSION

As depicted in section Methodology, VRT development in healthcare that occupies the ontology engineering approach is not discussed extensively in the available scholarly literature. It indirectly suggests that the potential of using ontology in VRT development has not been fully explored nor given much attention.

From the overview, it can be learned that the ontology was mainly used to represent the common knowledge in the healthcare domain; however, each type of knowledge is very specific and suits specialized VRTs. However, the ontology is sufficient to bridge the communication problems between the SMEs (subject matter experts) and the technology experts (VR developer, 3D designer, etc).

Most of the ontology classification in healthcare VRTs can be narrowed down to domain ontology, as the main purpose is to explicitly capture the domain knowledge. Additionally, the existing ontology mostly falls under the heavyweight ontology category. This is consistent with the need for VRTs in healthcare, which requires formal standardization and expressiveness. However, heavyweight ontology uses lots of computational power and memory, hence utilizing considerable resources for understanding the specifications and maintaining the interoperability of the system (14). Sometimes, this becomes the limiting factor that deters further growth of VRT in healthcare.

Additionally, perdurant knowledge is not heavily considered in many ontology designs for VRT in healthcare. As shown in **Table 2**, many ontology developments in the healthcare domain tend to favor object-oriented ontologies (structural aspect), also known as endurant ontologies. Endurant knowledge represents the structural elements within the domain, while perdurant knowledge involves the dynamic elements of the domain. Since the healthcare domain is often flexible and dynamic, the perdurant design of ontology should not be neglected.

The language used for ontology design in many VRTs in healthcare is mostly OWL. Generally, OWL can be quite intimidating for non-expert users as it has a steep learning curve (50). To add to this, the current ontology editors, such as Protégé, offer an intimidating interface

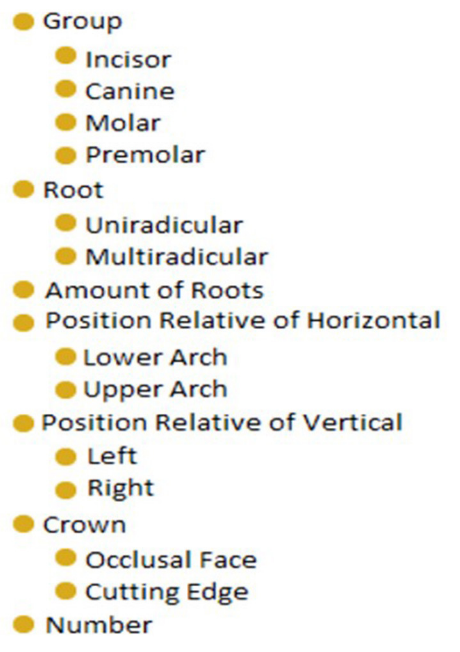


FIGURE 5 | The ontology fragment of dentistry structure [Source: Dias et al. (46)].

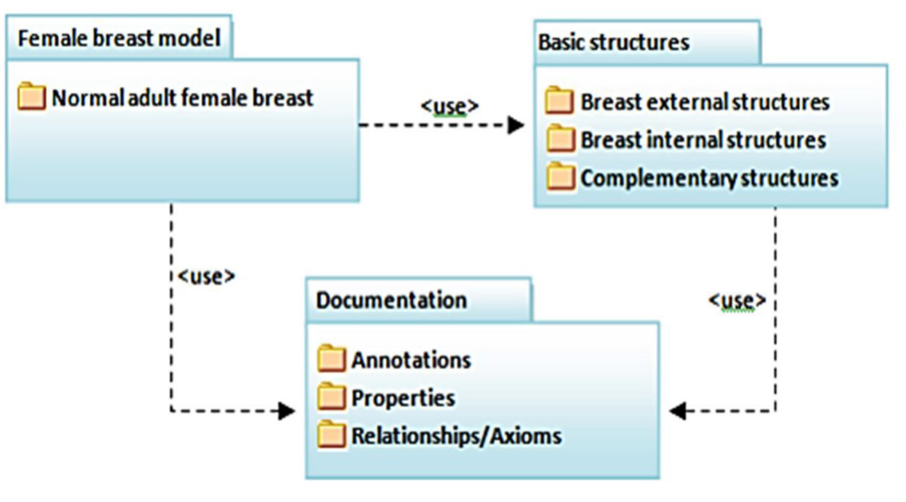


FIGURE 6 | The ontology fragment of ONTO-MAMA [Source: Klavdianos et al. (47)].

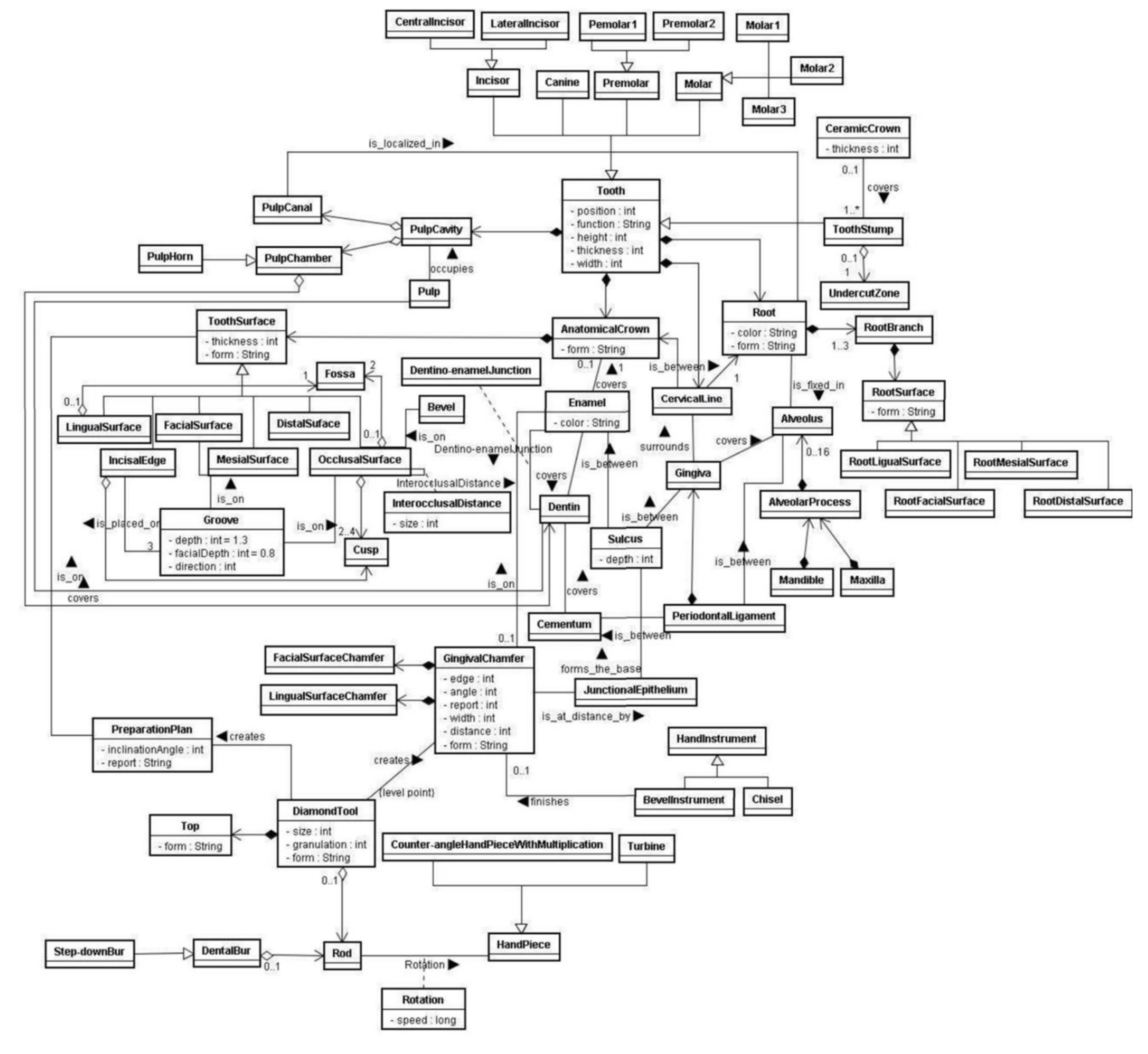


FIGURE 7 | The ontology fragment of VirDent [Source: Klavdianos et al. (47)].

for ontology development. Therefore, to encourage the adoption of ontologies in VRT development in the healthcare domain, the ontology design needs to be enhanced with developer-friendly tools and languages such as the UML-based ones.

The overview also denoted that a majority of the research did not disclose or explain the methodology used for the ontology design for VRTs in healthcare. Only two researchers mentioned the use of Methontology (47, 49), and another research by Bogdan (48) referred to the basic ontology development guideline (51). Additionally, the methodology in the literature also failed to discuss how the ontology engineering methodologies are blended or incorporated into VR methodology development. We argue that for healthcare purposes and context, establishing a generic ontology development methodology tailored to the domain-specific context is worthy since most ontology development methodologies are not designed for the general purpose of the domain (35). Moreover, there is also no consensus on the best ontology development methodologies so far (33).

Nonetheless, this carved the path toward having more research opportunities that would be able to establish on integrating or incorporating ontologies into VR development methodologies. For example, using ontology to design virtual environment for usability (52), interfaces (53) and applications (54).

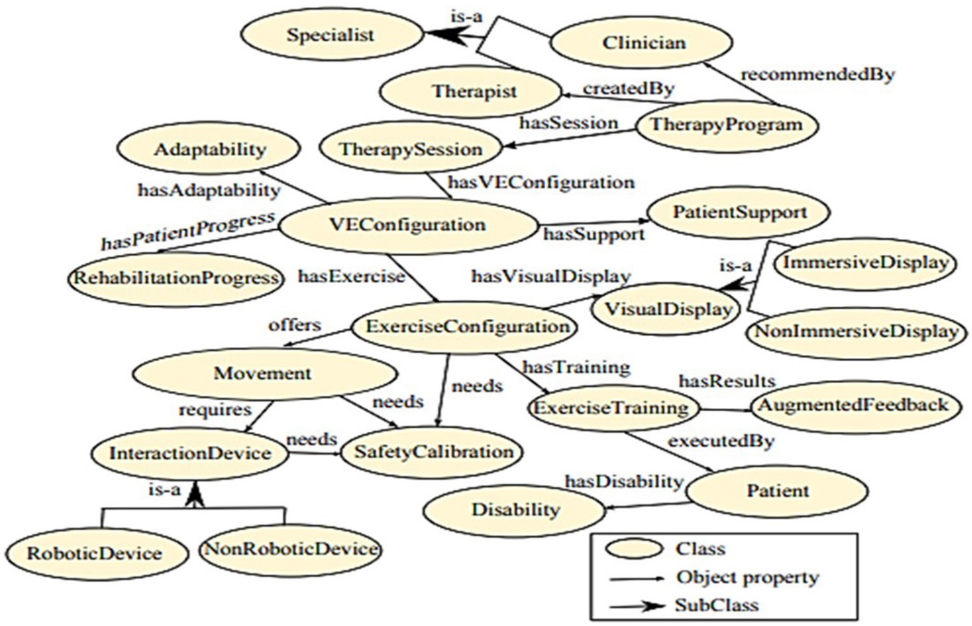


FIGURE 8 | The ontology fragment of VEULMoR [Source: Ramírez-Fernández et al. (49)].

The overview also depicted that ontology reuse across a given domain is not a consolidated practice. Enacting reuse of ontology in practice is difficult due to the heterogeneity in the conceptualization, the difficulty to select the suitable ontology to reuse, the struggle to extract the subset of ontology to reuse and maintaining the extracted subset as the source to which the ontology evolves. Yet, reusability is one of the important characteristics of a good ontology. Reusability of the ontology can drastically minimize the time and labor needed for building up new learning scenario models. As a result, the ontology promisingly speeds up the development of VRT processes while reducing the cost at the same time. Hence, the current situation needs to adopt advanced usage of the ontology engineering approach, such as the utilization of upper-level ontologies that can govern reusability.

The importance of a well-designed ontology for VRT can easily be explained using a "map" analogy. Ontology captures all the knowledge within a map. A world map contains all the knowledge of the "world." Yet, it is only meaningful if it is used for a certain interest or purpose. For example, the map in the Waze application, the map in navigation systems or the map in any GIS application uses the same map, but the interest and purpose are different. Hence, ontology in VRT is important to capture the whole knowledge within the domain to facilitate the different uses and to make it meaningful. So far, we have identified the limitations to the current ontology design for VRTs in healthcare through this overview. To have an ontology for VRT that can be utilized on the same page, we need a common framework that can govern its development and its utilization purpose. Therefore, an ontology engineering approach such as adopting the right upper ontology system can play an important role. Choosing the right ontology language that enables two-way transformation (e.g., OWL-UML vice versa) and is familiar to all stakeholders is also essential.

Nevertheless, for each existing VRT, ontology has shown huge potential in capturing, representing and sharing the knowledge within a complex domain such as healthcare. However, most of the existing ontologies are used in the implementation phases of VRT development life cycles. This causes the role of ontology to be insufficient. An ontology needs to be integrated earlier in the VRT development life cycle. Only then, the ontology can seamlessly share the common knowledge between the people and the system. Without an ontology, the resulting VRTs are often poor with a lack of relatedness, immersiveness, and being user-centered.

Healthcare is a knowledge-intensive domain. And many aspects of healthcare need explicit knowledge. Therefore, when we want to transfer this knowledge into the VR world, there is a need for a clear reference on these knowledge structures and controlled vocabularies. In this sense, an ontology can become the reference model. However, looking at the current progress of ontology for VRT development, it is not based on well-designed ontologies. Therefore, in **Figure 9**, we proposed a base of knowledge for VRT in healthcare to assist the VRT development in healthcare through an ontological approach.

The bases of knowledge for VRT in healthcare are divided into four, which are, VRT fundamentals, VRT devices, VRT development life cycle, and VRT management. In the scope of VRT for healthcare, the training models often involve interactions between virtual objects and virtual environments to achieve immersiveness and are often aided by the relevant VR devices. VRT development life cycles involve six phases, which

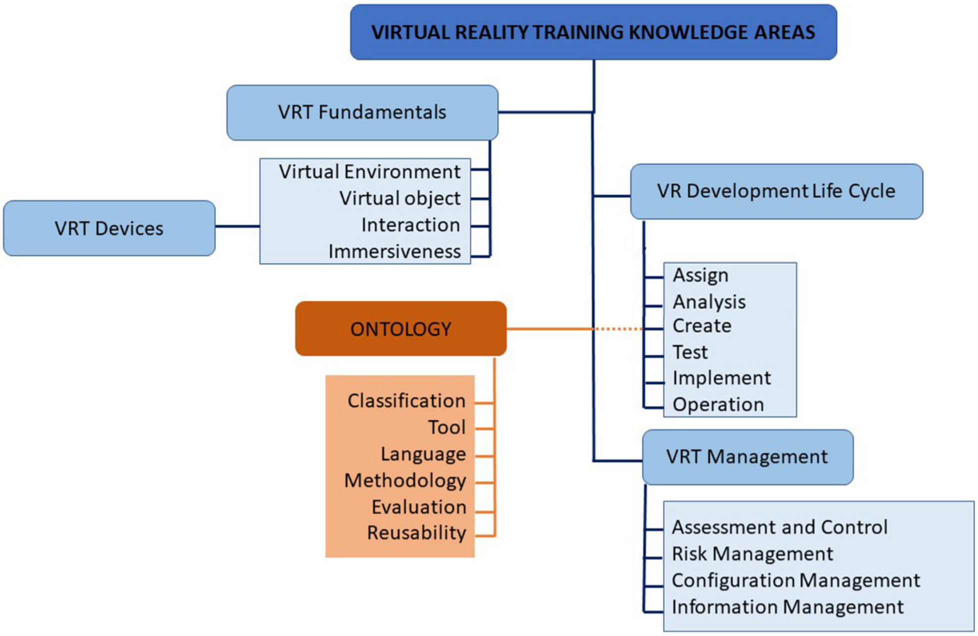


FIGURE 9 | Proposed linkage of ontology and base of knowledge for VRT development in healthcare.

are assignment, analysis, creation, testing, implementation, and operation. The existing ontologies are mostly integrated into the later phases of VRT development.

To increase the adoption of an ontology, consideration to involve the use of the ontology in the earlier phases is recommended. This can be done through the involvement of the domain experts in different stages of the VRT development process, for them to provide the necessary inputs and feedback (55).

Additionally, having ontology in VRT development will mitigate for better VRT management. This includes the management of assessment, control, risk, configuration, and information. An ontology represents the common knowledge that is applicable and understood by both technical developers and domain experts, as well as ease of systems interoperability.

The healthcare domain is complex due to the massive "knowledge-intensive" tasks. The training, in the traditional sense, involves many procedures, regulations, rules, and processes that need to be followed strictly. Therefore, translating these traditional training aspects into VR-based training can be quite a tedious task. Looking at the possibility whereby every single procedure needs to be converted into a VR-based procedure (regardless of being semi or fully immersive), we need to have explicit knowledge and its intended meaning to realize the possibilities. All the knowledge must be well-represented, accurate and applicable to the intended community. Without an ontology mechanism, it will not be easy to support VRT development in healthcare.

Another missing aspect in the current VRTs in the healthcare domain is the lack of discussion on how far the learning theories or educational models have been integrated to support the development of VRT. The overview depicted little evidence on any theories being applied for the development of the VRTs in healthcare. This is in agreement with a study by Zhou et al. (16). They suggested that the design of VR-based educational applications should also consider pedagogical models, apart from focusing on the technical perspectives of VR, to achieve the learning benefits.

Chimalakonda and Nori (56) also argued that most educational technologies today lack the support of strong instructional design knowledge. Yet, this limitation can easily be addressed through the use of ontology. Ontology can help decode the knowledge of the domain, represent it explicitly, and make the knowledge interpretable for machine processing. This will eventually open more doors of opportunity for further exploration and expansion of VRT in healthcare.

CONCLUSION

This review contributes to a holistic examination of the primary studies relevant to the topic of ontology-engineering in virtual reality-based training in healthcare, spanning the last decade. The findings provide a comprehensive understanding of and shed new lights on (1) the existing state of VRT development in healthcare supported by ontologies, (2) the contribution that ontologies make to the current VRTs in healthcare, (3) the state of ontology design for VRT development in healthcare, (4) and the limitations to the available ontologies in terms of reusability and future expansion of VRT in healthcare. From the overview, the adoption of ontology in the development of VRTs in healthcare is still at an infancy stage. This is based on the lack of scientific research and through analysis and literature on how ontology could be used in the development process of VRT in a variety of healthcare disciplines.

Despite the low number of scholarly papers discussing ontological perspectives of VRT in healthcare, the ontology engineering approach has begun to garner a great deal of attention, as it is one of the most pertinent mechanisms that can address the issues that deter the VRTs development in healthcare. Moreover, the reusability of the existing ontologies is low, to map concepts to concepts within the VRTs in healthcare. A comprehensive strategy to create an effective ontology for VRT in healthcare may include (1) tackling the base of knowledge for VRT in healthcare, (2) improving the ontology design through consideration of requirements from various stakeholders and adopting advanced ontology design principles such as the upper ontologies system, (3) identifying well-defined learning theories or models to strengthen the foundations, and (4) becoming part of the solution to VRT limitations.

There are two important bodies of knowledge (BOK) that this paper can spark further directions in, in terms of research opportunities. Firstly, how can we improve existing ontologies for supporting VRT from the lens of ontology engineering? By answering this question, the researcher would be able to make contributions to the BOK of ontology engineering, BOK-OE in short. For instance, new knowledge can be added to the BOK-OE such as a new approach on ontology design, new guidelines, new strategy, new knowledge from lessons learned in the healthcare domain context, new ontology development methodologies, and more. Secondly, how fundamental, or practical problems in BOK-VRT can be solved using ontology-based solutions? By answering this question, the researcher would be able to make contributions to the BOK-VRT. For example, fundamental issues concerning VRT management and evolution (see **Figure 9**) can be resolved by having an ontological approach as a solution.

AUTHOR CONTRIBUTIONS

MA contributed to the conception and design of the study. UM wrote the first draft of the manuscript. AS enhanced the VR-related sections of the manuscript while MB contributed to the sections with regard to healthcare virtual trainings. All authors contributed to manuscript revision, read, and approved the submitted version.

FUNDING

This research was supported by the Transdisciplinary Research Grant Scheme (TRGS), Ministry of Higher Education (MOHE), and Universiti Kebangsaan Malaysia (UKM), Vot. No: TRGS/1/2020/UKM/02/6/2. High appreciation goes to the above sponsors.

REFERENCES

1. Riva G, Wiederhold BK. Introduction to the special issue on virtual reality environments in behavioral sciences. *IEEE Trans Inform Technol Biomed.* (2002) 6:193–7. doi: 10.1109/TITB.2002.802369
2. Burdea GC, Coiffet P. *Virtual Reality Technology*. Hoboken, NJ: John Wiley and Sons (2003). doi: 10.1162/105474603322955950
3. Ajmera H, Gonen B. Virtual reality in health care. In: *2020 International Conference on Computing, Networking and Communications (ICNC)*. Bif Island, HI (2020). p. 51–5. doi: 10.1109/ICNC47757.2020.9049769
4. Slater M, Sanchez-Vives M. Enhancing our lives with immersive virtual reality. *Front Robot AI.* (2016) 3:74. doi: 10.3389/frobt.2016.00074
5. Jang S, Vitale JM, Jyung RW, Black JB. Direct manipulation is better than passive viewing for learning anatomy in a three-dimensional virtual reality environment. *Comput Educ.* (2017) 106:150–65. doi: 10.1016/j.compedu.2016.12.009
6. McGrath JL, Taekman JM, Dev P, Danforth DR, Mohan D, Kman N, et al. Using virtual reality simulation environments to assess competence for emergency medicine learners. *Acad Emerg Med.* (2018) 25:186–95. doi: 10.1111/acem.13308
7. McCarthy CJ, Uppot RN. Advances in virtual and augmented reality—exploring the role in health-care education. *J Radiol Nurs.* (2019) 38:104–5. doi: 10.1016/j.jradnu.2019.01.008
8. Zahabi M, Razak AMA. Adaptive virtual reality-based training: a systematic literature review and framework. *Virtual Reality.* (2020) 24:725–52. doi: 10.1007/s10055-020-00434-w
9. Fertleman C, Aubugeau-Williams P, Sher C, Lim, A.-N., Lumley S, et al. A discussion of virtual reality as a new tool for training healthcare professionals. *Front Public Health.* (2018) 6:44. doi: 10.3389/fpubh.2018.00044
10. Sahi PK, Mishra D, Singh T. Medical education amid the COVID-19 pandemic. *Indian Pediatr.* (2020) 57:652–657. doi: 10.1007/s13312-020-1894-7
11. Zanier ER, Zoerle T, Di Lernia D, Riva G. Virtual reality for traumatic brain injury. *Front Neurol.* (2018) 9:345. doi: 10.3389/fneur.2018.00345
12. Garrett B, Taverner T, Gromala D, Tao G, Cordingley E, Sun C. Virtual reality clinical research: promises and challenges. *JMIR Serious Games.* (2018) 6:e10839. doi: 10.2196/10839
13. Gilani S, Quinn C, McArthur JJ. A review of ontologies within the domain of smart and ongoing commissioning. *Build Environ.* (2020) 182:107099. doi: 10.1016/j.buildenv.2020.107099
14. Nagowah SD, Ben Sta H, Gobin-Rahimbux B. A systematic literature review on semantic models for IoT-enabled smart campus. *Appl Ontol.* (2020) 1:*27*—53. doi: 10.3233/AO-200240
15. Feng X. The ontology of virtual reality. *Soc Sci China.* (2003) 2.
16. Zhou Y, Ji S, Xu T, Wang Z. Promoting knowledge construction: a model for using virtual reality interaction to enhance learning. *Proc Comput Sci.* (2018) 130:239–46. doi: 10.1016/j.procs.2018.04.035
17. Hoffman H, Vu D. Virtual reality: teaching tool of the twenty-first century? *Acad Med.* (1997) 72:1076–81. doi: 10.1097/00001888-199712000-00018
18. Li L, Yu F, Shi D, Shi J, Tian Z, Yang J, et al. Application of virtual reality technology in clinical medicine. *Am J Transl Res.* (2017) 9:3867.
19. Thomsen ASS, Bach-Holm D, Kjærbo H, Højgaard-Olsen K, Subhi Y, Saleh GM, et al. Operating room performance improves after proficiency-based virtual reality cataract surgery training. *Ophthalmology.* (2017) 124:524–31. doi: 10.1016/j.ophtha.2016.11.015
20. Locketz GD, Lui JT, Chan S, Salisbury K, Dort JC, Youngblood P, et al. Anatomy-specific virtual reality simulation in temporal bone dissection: perceived utility and impact on surgeon confidence. *Otolaryngol HeadNeck Surg.* (2017) 156:1142–9. doi: 10.1177/0194599817691474
21. Mantovani F, Castelnuovo G, Gaggioli A, Riva G. Virtual reality training for health-care professionals. *CyberPsychol Behav.* (2003) 6:389–95. doi: 10.1089/109493103322278772
22. Sowndararajan A, Wang R, Bowman DA. Quantifying the benefits of immersion for procedural training. In: *Proceedings of the 2008 Workshop*

on Immersive Projection Technologies/Emerging Display Technologiges. Los Angeles, Ca (2008). p. 1–4. doi: 10.1145/1394669.1394672
23. Happel, H.-J., Seedorf S. Applications of ontologies in software engineering. *Proc Workshop Sematic Web Enabled Software Engineering (SWESE) on the ISWC.* Athens, GA (2006). p. 5–9
24. Noy NF, McGuinness DL. *Ontology Development 101: A Guide to Creating Your First Ontology*. Standford, CA: Stanford Knowledge Systems Laboratory (2001).
25. Hsieh MC, Lee JJ. Preliminary study of VR and AR applications in medical and healthcare education. *J Nurs Health Stud.* (2018) 3:1. doi: 10.21767/2574-2825.100030
26. Velev D, Zlateva P. Virtual reality challenges in education and training. *Int J Learn Teach.* (2017) 3:33–7. doi: 10.18178/ijlt.3.1.33-37
27. Benferdia Y, Ahmad M, Mustapha M, Baharin H, Bajuri MY. Critical success factors for virtual reality-based training in ophthalmology domain. *J Health Med Inform*. (2018) 9. doi: 10.4172/2157-7420.1000318
28. Silva E, Silva N, Morgado L. Model-driven generation of multi-user and multi-domain choreographies for staging in multiple virtual world platforms. In Ait Ameur Y, Bellatreche L, Papadopoulos GA, editors. *Model and Data Engineering. MEDI 2014Lecture Notes in Computer Science, Vol. 8748.* Cham: Springer (2014). p. 77–91. doi: 10.1007/978-3-319-11587-0_9
29. El Morr C, Subercaze J. Knowledge management in healthcare. In Cruz-Cunha MM, Tavares AJ, Simoes R, editors. *Handbook of Research on Developments in E-Health and Telemedicine: Technological and Social Perspectives.* Hershey, NY: IGI Global (2010). p. 490–510. doi: 10.4018/978-1-61520-670-4.ch023
30. Burgun A, Botti G, Le Beux. P. Issues in the design of medical ontologies used for knowledge sharing. *J Med Syst.* (2001) 25:95–108. doi: 10.1023/A:1005668530110
31. Delir Haghighi P, Burstein F, Zaslavsky A, Arbon P. Development and evaluation of ontology for intelligent decision support in medical emergency management for mass gatherings. *Decis Support Syst.* (2013) 54:1192–204. doi: 10.1016/j.dss.2012.11.013
32. Tudorache T. Ontology engineering: current state, challenges, future directions. *Semantic Web.* (2020) 11:125–38. doi: 10.3233/SW-190382
33. Ahmad MN, Abd Badr KB, Salwana E, Zakaria NH, Tahar Z, Sattar A. An ontology for the waste management domain. In: *22nd AIS Pacific Asia Conference on Information Systems (PACIS'18).* Yokohama (2018).
34. Westerinen A, Tauber R. Ontology development by domain experts (without using the "O" word). *Appl Ontol.* (2017) 12:299–311. doi: 10.3233/AO-170183
35. Gibaud B, Forestier G, Feldmann C, Ferrigno G, Gonçalves P, Haidegger T, et al. Toward a standard ontology of surgical process models. *Int J Comput Assist Radiol Surg.* (2018) 13:1397–408. doi: 10.1007/s11548-018-1824-5
36. Shinohara K. Preliminary study of ontological process analysis of surgical endoscopy. In: *International Conference on Applied Human Factors and Ergonomics.* Los Angeles, CA (2017). p. 455–61. doi: 10.1007/978-3-319-60483-1_47
37. Gruber TR. A translation approach to portable ontology specifications. *Knowl Acquis.* (1993) 5:199–221. doi: 10.1006/knac.1993.1008
38. Hoehndorf R. *What Is an Upper Level Ontology?* Ontogenesis (2010).
39. Corcho O. Ontology based document annotation: trends and open research problems. *Int J Metadata Semantics Ontol.* (2006) 1:47–57. doi: 10.1504/IJMSO.2006.008769
40. Fürst F, Trichet F. Heavyweight ontology engineering. In: *OTM Confederated International Conferences "On the Move to Meaningful Internet Systems.* Berlin; Heidelberg (2006). p. 38–9. doi: 10.1007/11915034_18
41. Colomb RM, Ahmad MN. Merging ontologies requires interlocking institutional worlds. *Appl Ontol.* (2007) 2:1–12. doi: 10.5555/1412396.1412398
42. Ivanović M, Budimac Z. An overview of ontologies and data resources in medical domains. *Expert Syst Appl.* (2014) 41:5158–66. doi: 10.1016/j.eswa.2014.02.045
43. Liandong Z, Qifeng W. Knowledge discovery and modeling approach for manufacturing enterprises. In: *2009 Third International Symposium on Intelligent Information Technology Application*. Vol. 1. IEEE (2009). p. 291–4.
44. Monthe VM, Batchakui B, Tangha C, Tietche F. MV-SYDIME: A virtual patient for medical diagnosis apprenticeship. In: *Proceedings of the 2012 IEEE Global Engineering Education Conference (EDUCON).* Marrakesh (2012). p. 1–10. doi: 10.1109/EDUCON.2012.6201054
45. Fujita H, Kurematsu M, Hakura J. Virtual doctor system (vds) and ontology based reasoning for medical diagnosis. In: Pap E, editor. *Intelligent Systems: Models and Applications*. Berlin, Heidelberg: Springer (2013). p. 197–214. doi: 10.1007/978-3-642-33959-2_11
46. Dias D, Brega J, Trevelin LC, Neto MP, Gnecco BB, Guimaraes M, et al. Design and evaluation of an advanced virtual reality system for visualization of dentistry structures. In: *18th International Conference on Virtual Systems and Multimedia*. Milan (2012). p. 429–35. doi: 10.1109/VSMM.2012.6365955
47. Klavdianos PBL, Parente M, Brasil LM, Lamas JM. ONTO-MAMA: an unified ontology and 3D graphic model of the female breast anatomy. In: *Proceedings Ofthe International Conference on Health Informatics (HEALTHINF-2012).* Algarve (2012). p. 106–16.
48. Bogdan CM. Domain ontology of the VirDenT system. *Int J Comput Commun Control.* (2011) 6:45–52. doi: 10.15837/ijccc.2011.1.2199
49. Ramírez-Fernández C, García-Canseco E, Morán AL, Gómez-Montalvo JR. Ontology-based design model of virtual environments for upper limb motor rehabilitation of stroke patients. In: *Proceedings of the 3rd 2015 Workshop on ICTs for Improving Patients Rehabilitation Research Techniques.* New York; NY (2015). p. 145–55. doi: 10.1145/2838944.2838970
50. Dzbor M, Motta E, Buil C, Gomez J, Görlitz O, Lewen H. *Developing Ontologies in OWL: An Observational Study* Athens, GA: OWL: Experiences and Directions (2006).
51. Noy N, McGuiness D. *A Guide to Create Your First Ontology*. Stanford University (2001). p. 10–24. Available online at: http://Www.Ksl.Stanford.Edu/People/Dlm/Papers/Ontology-Tutorial-Noymcguinness.Htm (accessed April 2, 2021).
52. Kaur K. Designing virtual environments for usability. *Human-Computer Interaction INTERACT'*97. Boston, MA (1997). p. 636–9. doi: 10.1007/978-0-387-35175-9_112
53. Tanriverdi V, Jacob RJK. VRID: a design model and methodology for developing virtual reality interfaces. In: *Proceedings of the ACM Symposium on Virtual Reality Software and Technology.* Banff, AB (2001). p. 175–82. doi: 10.1145/505008.505042
54. Romero D, Molina A. Forward - Green virtual enterprises and their breeding environments: Sustainable manufacturing, logistics and consumption. *IFIP Adv Inf Commun Technol.* (2014) 434:336–46. doi: 10.1007/978-3-662-44745-1_33
55. Bille W, Pellens B, Kleinermann F, De Troyer. O. Intelligent modelling of virtual worlds using domain ontologies. In: *IVEVA 97*. Brussel (2004).
56. Chimalakonda S, Nori KV. An ontology based modeling framework for design of educational technologies. *Smart Learn Environ.* (2020) 7:1–24. doi: 10.1186/s40561-020-00135-6

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Surgery

ORIGINAL RESEARCH
published: 10 August 2021
doi: 10.3389/fsurg.2021.713119

Interactive Video Simulation for Remote Healthcare Learning

*Dahlia Musa[1], Laura Gonzalez[2], Heidi Penney[2] and Salam Daher[1,2]**

[1] New Jersey Institute of Technology, Department of Informatics, Newark, NJ, United States, [2] College of Nursing, University of Central Florida, Orlando, FL, United States

Simulation is an essential component of healthcare education as it enables educators to replicate clinical scenarios in a controlled learning environment. Simulation has traditionally been conducted in-person through the use of manikins, however, the COVID-19 pandemic has challenged the practice of manikin simulation. Social distance constraints were enforced during the pandemic to reduce the potential spread of the virus and as a result, many educators and students were denied physical access to their universities' simulation facilities. Healthcare educators sought remote alternatives to manikin simulation and many resorted to instructional videos to educate their learners. While the use of videos increases safety, passively watching videos lacks interactivity which is an important component of simulation learning. In response to these challenges, we developed an interactive video simulation software that uses educators' existing video content to conduct a simulation remotely, thereby promoting safety during the pandemic while also meeting the interactivity standards of best practice for healthcare simulation. In this paper, we compare the interactive video simulation to the current practice of watching non-interactive video of a simulation using the same content. We found that interactivity promotes higher order learning, increases teamwork and enhances the perception of authenticity. Additionally, the majority of participants demonstrated positive reception of the interactive simulation. The simulation software provides the safety desired of a remote simulation during the pandemic while also engaging students in interactive learning experiences.

Keywords: healthcare simulation, interactivity, video, engagement (involvement), teamwork, authenticity, remote learning, nursing

Edited by:
Michelle A. Kelly,
Curtin University, Australia

Reviewed by:
Gaetano Gallo,
University of Catanzaro, Italy
Tamara Power,
The University of Sydney, Australia

****Correspondence:***
Salam Daher
daher@njit.edu

Specialty section:
This article was submitted to Visceral Surgery, a section of the journal Frontiers in Surgery

Received: *21 May 2021*
Accepted: *05 July 2021*
Published: *10 August 2021*

Citation:
Musa D, Gonzalez L, Penney H and Daher S (2021) Interactive Video Simulation for Remote Healthcare Learning. Front. Surg. 8:713119. doi: 10.3389/fsurg.2021.713119

1. INTRODUCTION

Nurse education technology and strategies are constantly changing, leading researchers in nursing education to identify the best ways to teach learners. Knowledge acquisition and learner engagement are requisite skills of nursing education (1, 2) and simulation has proven to be a very important strategy to achieve these skills (3). Simulation facilitates learning and promotes patient safety; it affords nursing students the opportunity to experience realistic replications of clinical cases and practice their skills without impacting the condition of a live patient (4). The use of simulation increases students' self-efficacy which is indicative of competence in the clinical setting (5). Additionally, repetition is an important component of learning nursing skills (6). Unlike actual clinical cases, simulation experiences can be infinitely repeated under the same or similar conditions.

Simulations are traditionally conducted using a manikin, a lifelike patient simulator that represents the whole or partial human body (7). Other simulation methods include standardized patients (SPs) and virtual simulations. SPs are human actors trained to play the role of a patient in a scenario, and virtual simulation allows students to apply knowledge and practice skills in a virtual recreation of reality (7). Traditional manikin simulation is a well-recognized nursing education strategy, however, it has limitations regarding visual fidelity (8), cost (1), and now safety. Manikin simulation requires students to interact directly with the manikin while an instructor oversees the simulation; therefore, students and instructors need to be present concurrently within the same space. Due to the cost of manikins and space restrictions, typically students enter the simulation in small groups. The restrictions enforced in response to the COVID-19 pandemic have made it difficult for nurse educators to safely conduct manikin simulations due to limited space, high manikin costs, and safety. Many schools of nursing have grappled with identifying quality clinical substitutions that could be experienced remotely. Nurse educators need the flexibility to be creative without space constraints (2).

In many healthcare educational institutions, educators adopted virtual technologies to continue providing simulation to students during the pandemic. Commercialized virtual simulation programs, such as Second Life (9), vSim (10), and Shadow Health (11), have been one virtual option. Second Life enables students and instructors to interact as avatars within a virtual world that depicts clinical environments. In Second Life, educators develop the virtual environment and simulation experience themselves, empowering them to design the most effective simulation experience for their learners. Second Life has been shown to promote positive learning outcomes in nursing education and to particularly impact students' collaboration and engagement (12). In a study by Beyer-Berjot et al. (13), Second Life was used by surgical educators to develop a comprehensive simulation when other virtual simulation options did not encompass all components of the curriculum. Second Life has demonstrated to be a beneficial tool for healthcare educators, however, it is complex. While development may be feasible for some educators, others need to hire developers to create their simulation or rent another user's virtual environment. In vSim and Shadow Health, students assess digital standardized patients in pre-developed simulations. Students have responded positively to the use of these virtual simulations and recommend their use (14), but the rigidity of the systems presents limitations to educators who are unable to modify or expand on the lessons. Telesimulation is another remote learning option that has recently been more widely adopted by nursing educators. Telesimulation refers to the use of telecommunication technologies to provide simulation experiences to learners in a distant location, typically where immediate access to the simulation facility is unavailable (15). In a telesimulation model developed by Naik et al. (16), students learn COVID-19 ventilator management by viewing a tutorial video and then joining a telesimulation session hosted by their instructor via a video conferencing application. Students in the telesimulation watch as the instructor performs ventilation on a manikin according to their instruction. This method of using video content to conduct remote simulation works as a low-cost replacement to in-person simulation and has been used by many educators during the pandemic. In our study, we used this method for control. Virtual platforms, such as Microsoft Teams, have also been used to support remote educational activities as well as facilitate collaboration and cultivate a sense of community during the pandemic (17).

Like many other schools of nursing, we had to pivot to ensure our learners met the expected curricular outcomes while learning in a remote environment. We recorded exemplar videos of a nurse instructor performing scenarios in a simulation laboratory and showed the videos to students remotely. The exemplar videos demonstrated the ideal conduct of the scenarios which students would have performed themselves if they had access to the simulation facility. The use of simulation videos, however, played a role as a mediocre replacement to in-person simulation activities. Interactivity is an essential component of healthcare simulation (18) and passively watching simulation videos without interactivity does not satisfy the standards of best practice for healthcare simulation (19). To resolve this issue, we developed an Interactive Video Simulation (IVS) software that converts a simulation video into an interactive experience using educators' existing video content. After we developed the IVS, we evaluated the validity of our software as a remote alternative to traditional simulation. We asked the following research questions:

Q1: Does **interaction** with the simulation system promote **higher order learning**?

Q2: Does **teamwork** promote **higher order learning** compared to individual work?

Q3: Does **interaction** with the simulation system increase the perception of **authenticity**?

Q4: Does the **order of participation** affect **perceptions** of the simulation?

2. MATERIALS AND METHODS

2.1. Study Design and Procedure

This section describes the design and procedure of the study as approved by the Institutional Review Board (IRB). In a mixed design study (between participants, and within participants) nursing students were split into teams of two participants at a time and were asked to participate in two different simulations: an interactive (INT) simulation, and a video (VID) simulation. The schedule was pre-allocated without prior knowledge about the students. All participants experienced both modalities with a unique scenario each time, but in a different order. The two scenarios (Stroke and Chest Pain) were included in both simulations. Participants were exposed to each of the simulations once and participated in both scenarios. For example, if a student viewed the Stroke scenario in the VID simulation, they

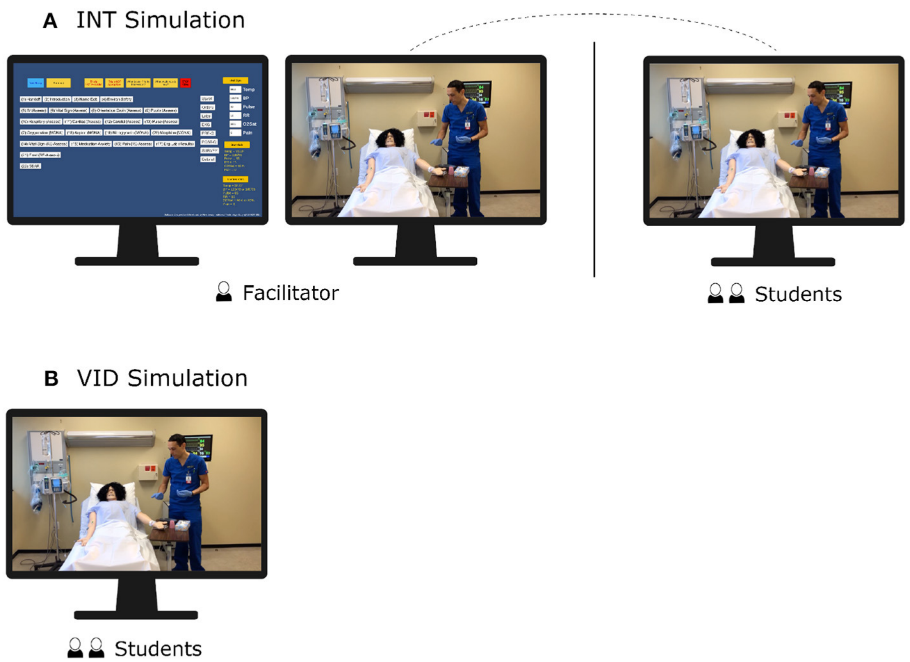


FIGURE 1 | This diagram shows the setup of the interactive simulation and video simulation used in this experiment. **(A)** For the INT simulation, the facilitator shared the content-controlled screen to the students via Zoom. **(B)** For the VID simulation, students watched the non-interactive video content.

would view the Chest Pain scenario in the INT simulation and vice versa.

2.1.1. INT Simulation Condition

Setup

The INT simulation was delivered through the use of the IVS simulation software that we developed. The facilitator ran the software on their computer using two screens: one that displayed a dashboard of buttons to control the simulation, and one that displayed the simulation content. From a remote location, the facilitator shared the screen displaying the simulation content with the students over Zoom. The screen displaying the dashboard of buttons was not visible to the students. The facilitator used these buttons to control the simulation content viewed by the students on the other screen. The students connected to Zoom from a computer in their classroom, where they watched the simulation content shared by the facilitator. The setup for the INT simulation is shown in **Figure 1A**.

Procedure

Students reviewed the Scenario, Background, Assessment, and Recommendation (SBAR) for 3 min and then had 4 min to complete the pre-questionnaire. After completing the pre-questionnaire, students participated in the INT simulation for 20 min. The facilitator asked the students to describe their nursing care interventions in the order they would perform them, and as a team, students described the steps of their patient care. For each step described by the students, the facilitator played the corresponding video clip on the shared screen showing a nurse performing the step. If the step described was not available as one of the video clips or was not appropriate, the facilitator displayed a message saying "This option is not available" or "This option is not appropriate," respectively. The facilitator also displayed lab images (EKG, CT, lab results), vital signs and the SBAR as needed by the students. By the end of the simulation, the students had made the decisions for the patient's care and watched videos of a nurse delivering care to the patient. The IVS software generated automated logs of the teams' answers during their simulation. Since the video clips displayed were the ones described by the students, it is possible that the students did not view all of the video clips. After the simulation, students had 4 min to complete an individual post-questionnaire and 5 min to complete a survey. Participants were then debriefed by the facilitator for 10 min.

2.1.2. VID Simulation Condition

Setup

Students watched a non-interactive exemplar video in a classroom. The video depicted a nurse performing interventions to care for a patient in the given scenario. The video was a concatenation of all the video clips that we recorded for the scenario. The facilitator played the video for the students and remained in the classroom with the students for the duration of the simulation, though the facilitator did not need to control any aspect of the simulation. The setup for the VID simulation is shown in **Figure 1B**.

Procedure

Students reviewed the SBAR for 3 min and then were given 4 min to complete the pre-questionnaire. Then, the students watched the exemplar video for either the chest pain or stroke scenario without interruption. Students watched as the nurse in the video provided the ideal sequence of care without their input. After watching the video, students were given 4 min to complete an individual post-questionnaire, and following the post-questionnaire, students discussed with each other and had 8 min to complete a team questionnaire. Students were then given 5 min to complete a survey. Lastly, students were debriefed by the facilitator for 10 min.

2.2. Software Design and Development

The IVS software is intended to be used by healthcare instructors to engage students in virtual simulations. We developed the IVS software in Unity (20) using the language C#. The software requires two screens: one screen displays a dashboard of the simulation controls for use by the instructor, and on the other screen the students view the simulation. The simulation content (videos, images, vital signs, and the SBAR) is imported into the software, and for each piece of content, the software creates a button which the instructor uses to control its display. To generate these buttons, the software retrieves information from databases that identify the button specifications. The instructor has the ability to enter the databases and make modifications to customize the software as needed by editing CSV files. To create the video and image buttons, the CSV files take data such as a button label, the associated file name and the order of the button on the screen as input.

The software is designed to separate the controls from the content to hide the options from the students while allowing the content to be shared over a video conferencing application, such as Zoom or WebEx. The frame rate of the videos is 30 fps but could be reduced depending on the connection of the video conferencing application. The instructor can share the content-controlled screen to the students over the video conferencing application while the other screen remains visible and accessible only to the instructor. During the simulation as students describe the steps of their nursing care, the instructor uses the button controls to display the content depicting those steps, simulating the students' delivery of the patient care. The software maintains a log of data identifying which buttons were pressed and what information was displayed throughout the simulation. The instructor can later review the log file to see the students' sequence of steps and the amount of time they required to decide each subsequent step. This technology can be used both in groups and with individual students.

2.3. Multimedia Content

For this study, we recorded a series of video clips that depicted a nurse at an American university performing two simulation scenarios. In one scenario, the nurse assesses a stroke patient and in the other scenario, the nurse determines the cause of a patient's chest pain and intervenes. Each video clip that we recorded shows the nurse performing an individual step in the scenario. There were 40 video clips in total, each in the MP4 format, with a frame rate of 30 fps and resolution of 1,920 × 1,080. Eighteen of the videos were for the stroke scenario and 22 were for the chest pain scenario.

The content for the INT condition included the video clips, images, and vital signs and an SBAR as text. For the VID condition, the video clips were concatenated back-to-back to form one exemplar video for each scenario. The clips were ordered so that the nursing steps would be shown in the ideal sequence. The length of the video for the stroke scenario was 15 min, 10 s, and the length of the video for the chest pain scenario was 16 min, 9 s.

2.4. Healthcare Scenarios

We chose two different patient care scenarios to conduct this study. The scenarios are part of the curriculum for the university's nursing program. Both patient scenarios required students to not only implement basic patient safety into their care, but also specific care or protocols that are necessary for positive patient outcomes for the different diagnoses. The scenarios involved the care of a stroke patient and a chest pain patient.

2.4.1. Stroke Scenario

The first scenario was nursing care of a patient named Vera Real with a cerebral vascular accident (CVA) or stroke. Along with completing patient safety interventions, the students were challenged to perform a comprehensive neurological assessment, identify hypertensive crisis, and administer appropriate prescribed medication. The scenario also included options to review laboratory data, review radiology data and also update the admitting provider as part of the simulation.

2.4.2. Chest Pain Patient

The second scenario was a patient named Anne Marie with complaints of chest pain and anxiety. This scenario challenged the students to determine if the chest pain was cardiac related or anxiety related and to intervene as appropriate. Safety interventions (hand hygiene, patient identification, and room safety) were also necessary for successful completion of the simulation. The students had options to administer oxygen, cardiac medications, and/or anxiety medication. This scenario had options for the students to review laboratory data, review an electrocardiogram (EKG), and contact the admitting provider.

2.5. Participants

The participants of this study consisted of 36 undergraduate nursing students at an American university. Of the 36 students, 32 identified as female, 3 as male, and 1 participant did not identify as either. In terms of ethnicity, 19 students identified as white, 12 as Hispanic or Latino, 3 as Asian, 1 as Black, and 1 as both Asian and Latino. All students had previous simulation experience. Thirty-four students had experience using mannequins and 32 students had experience with virtual simulations. All students were in at least their fourth semester of the nursing program. Two participants had incomplete data: one participant was missing a pre-questionnaire and team questionnaire and the other participant was missing a team questionnaire. These participants were excluded from tests that required the missing data.

TABLE 1 | Self-assessment teamwork tool for students (scale from 1 to 7).

SATTS1: Role	Each team member had a clear role.
SATTS2: Plan	A plan for treatment was communicated to the team.
SATTS3: Communication	When team members received instructions they closed the communication loop.
SATTS4: Instructions	Instructions and verbal communications were directed.
SATTS5: Overview	An overview of the situation was maintained.
SATTS6: Suggestions	Suggestions were invited from within the team when problem-solving.
SATTS7: Assistance	Team members offered assistance to one other.
SATTS8: Situational info	Situational information was verbalized.
SATTS9: Teamwork	Overall teamwork.

TABLE 2 | Virtual patient evaluation questions (scale from 1 to 5).

	While working on this case…
VPE1: Decisions	I felt I had to make the same decisions a nurse would make in real life.
VPE2: Nursing care	I felt as if I were the nurse caring for this patient.
VPE3: Gathering info	I was actively engaged in gathering the information (e.g., history questions, physical exams, lab tests) I needed to characterize the patient's problem.
VPE4: Revising image	I was actively engaged in revising my initial image of the patient's problem as new information became available.
VPE5: Summarizing problem	I was actively engaged in creating a short summary of the patient's problem using medical terms.
VPE6: Nursing priorities	I was actively engaged in thinking about which findings supported or refuted my nursing priorities.

2.6. Measures

During the study, participants completed pre-, post- and team questionnaires which all included the question: *After reviewing the SBAR, outline your nursing care in the order you would perform them and without omitting the basics (e.g., start with introducing yourself to the patient).* The pre-questionnaire was asked before the simulation and the post-questionnaire was asked after the simulation. The team questionnaire was asked following the post-questionnaire and was completed only by the VID condition. Team responses for the INT condition were collected from the data logs that were generated automatically by the IVS software during the simulation. The data logs for the INT condition and the team questionnaires for the VID condition were considered equivalent measures of team learning in our data analysis. The pre- and post-questionnaires were submitted as free text, as was the team questionnaire for the VID condition.

At the end of the study, participants completed a survey that measured two aspects: perception of teamwork and perception of the authenticity of the encounter. We used questions from the Self-Assessment Teamwork Tool for Students (SATTS) shown in **Table 1** (21). These questions were included in Factor 1: Teamwork Coordination and Communication, and Factor 2: Information Sharing and Support, of the SATTS questionnaire. Participants answered the SATTS questions on a Likert scale from "poor" (1) to "excellent" (7). We also measured the authenticity of the simulations using questions from the Virtual Patient Evaluation (VPE) shown in **Table 2** (22). These questions were included in Factor I: Authenticity of Patient Encounter and the Consultation, and Factor II: Cognitive Strategies in the Consultation, of the original VPE questionnaire. As the original questions in Factor I were intended for medical students, we modified the questions to be applicable to nursing students. Participants answered the VPE questions using a Likert scale from "strongly disagree" (1) to "strongly agree" (5).

In the last question of the survey, we asked participants which simulation technology they preferred, either video or interactive, and why. Participants also could optionally provide any comments about the technology they used.

3. RESULTS

The data was not normally distributed and therefore we needed to use non-parametric statistical tests (23, 24). The Mann-Whitney U-test was used for analyzing data between subjects and the Wilcoxon signed-rank test was used for analyzing data within subjects.

3.1. Learning

To gauge participants' learning, we analyzed the data of the pre-, post- and team questionnaires. We downloaded and prepared the questionnaire data for analysis, and then sorted participants' responses into categories using components of the Quality and Safety Education for Nurses (QSEN) competencies (25): assessment (A), intervention medication (IM), intervention communication (IC), evaluation (E), and safety (S). We assessed participants' learning at the level of these categories. The data was analyzed by comparing participants' responses to the correct sequence of videos. As many videos included more than one step, participants received credit if they identified the main significant step performed in the video. The post-questionnaire and team questionnaire were differentiated by the fact that participants completed the team questionnaire with their partners and the post-questionnaire individually. To reflect this differentiation, we will refer to the team questionnaire as the team response and the post-questionnaire as the individual response in this section and following sections. The data was analyzed for the scenarios separately as each scenario incorporated a different sequence of steps.

3.1.1. Scenario 1: Chest Pain

In the chest pain scenario, we found that interactivity overall had a positive effect on students' learning. We calculated students' team learning gains by subtracting their pre-questionnaire scores from their team response scores and compared the mean gains for the INT and VID conditions. The team learning gains were greater for the INT condition than the VID condition in the A ($p < 0.001$) and E ($p = 0.039$) categories, and in the IM category, a trend ($p = 0.059$) suggested the same results. In the IC category, the team learning gains were greater for the VID condition than the INT condition ($p = 0.001$): the mean for the VID condition was positive ($M = 0.83$) while the mean for the INT condition

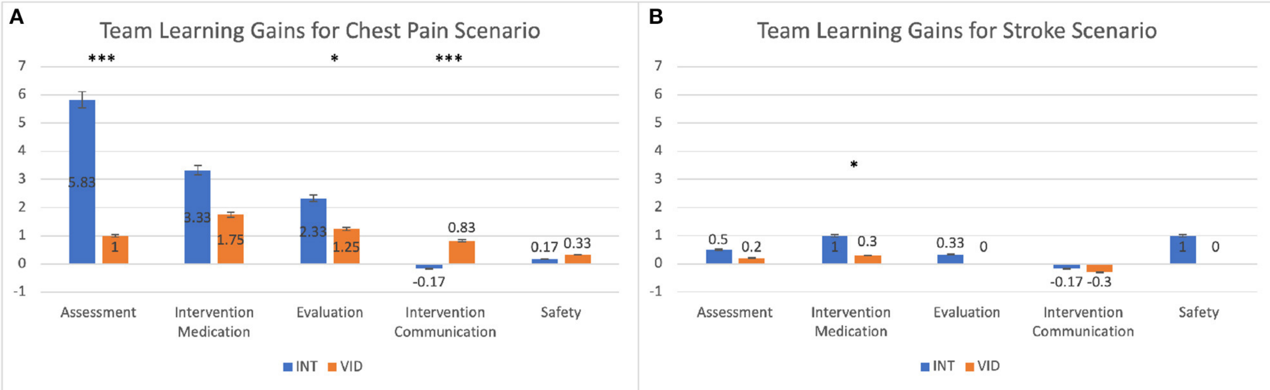


FIGURE 2 | This graph compares the mean gains in participants' scores between the pre-questionnaire and the team response (team minus pre) for the INT and VID conditions. The results are shown for **(A)** the chest pain scenario and **(B)** the stroke scenario. *$p \leq 0.05$; ***$p \leq 0.001$. See details in **Table 3**.

TABLE 3 | This table shows the data for the mean gains in participants' scores between the pre-questionnaire and team response (team questionnaire).

			Team learning gains for chest pain scenario			
Category	**W**	***p***	**Effect size**	**Condition**	**Mean**	**SD**
Assessment	0.5	<0.001	−0.99	INT	5.83	1.17
				VID	1.00	1.95
Intervention medication	16	0.059	−0.56	INT	3.33	0.52
				VID	1.75	1.82
Evaluation	15	0.039	−0.58	INT	2.33	0.52
				VID	1.25	1.14
Intervention communication	67	0.001	0.86	INT	−0.17	0.41
				VID	0.83	0.39
Safety	38	0.87	0.056	INT	0.17	0.41
				VID	0.33	0.99
			Team learning gains for stroke scenario			
Category	**W**	***p***	**Effect size**	**Condition**	**Mean**	**SD**
Assessment	24.5	0.58	−0.18	INT	0.50	0.84
				VID	0.20	2.20
Intervention medication	12.5	0.039	−0.58	INT	1.00	0.63
				VID	0.30	0.48
Evaluation	–	–	–	INT	0.33	0.52
				VID	0.00	0.00
Intervention communication	28.00	0.87	-0.067	INT	−0.17	1.17
				VID	-0.30	1.16
Safety	20.5	0.32	−0.32	INT	1.00	1.27
				VID	0.00	2.06

The statistical test for Evaluation in the stroke scenario could not be conducted because the variance of the means was equal to zero. This data is represented as graphs in ***Figure 2****.*

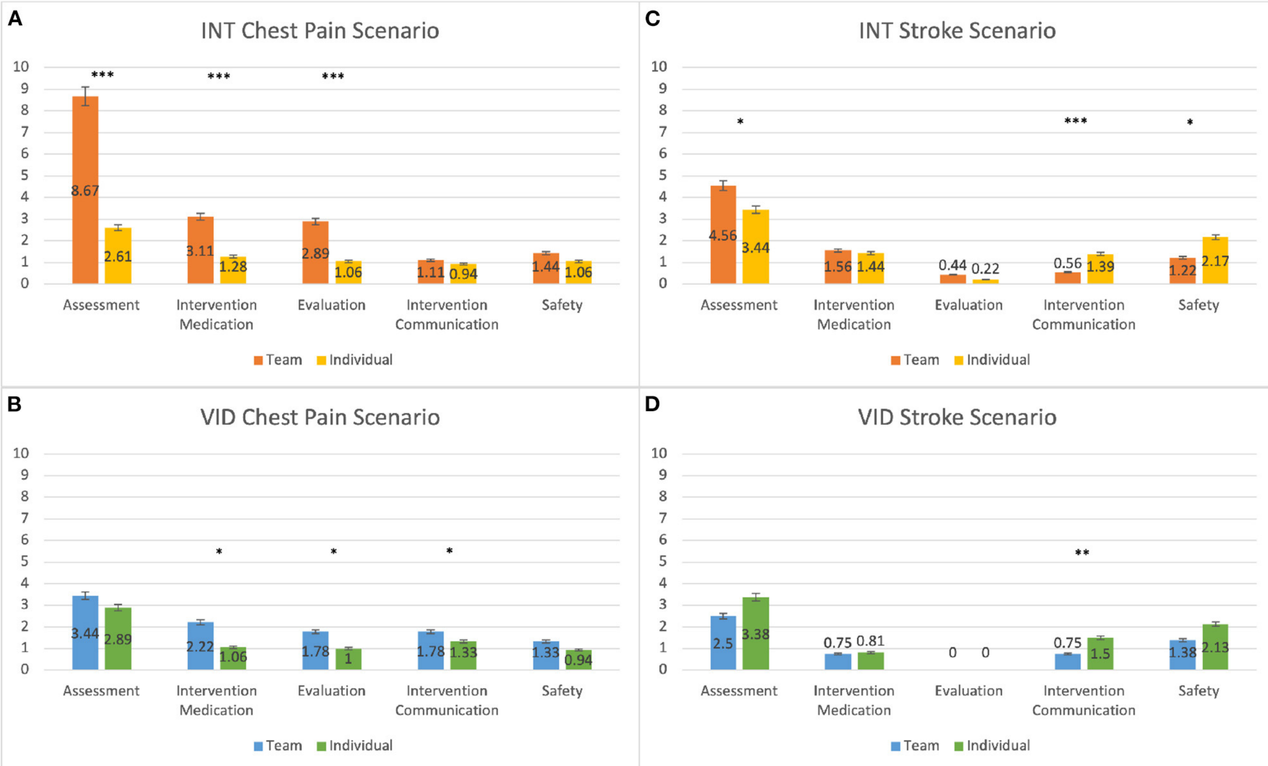


FIGURE 3 | This graph compares participants' mean scores for the individual response (post-questionnaire) and the team response (team questionnaire). The results are shown for the **(A)** INT condition in the chest pain scenario, **(B)** VID condition in the chest pain scenario, **(C)** INT condition in the stroke scenario, and **(D)** VID condition in the stroke scenario. $^{*}p \leq 0.05$; $^{**}p \leq 0.01$; $^{***}p \leq 0.001$. See details in **Tables 4**, **5**.

was negative ($M = -0.17$). The results for team learning gains in the chest pain scenario are shown in **Figure 2A** and **Table 3**.

We compared students' scores for the team response and individual response to determine the effect of teamwork on learning, and we found that teamwork had a positive impact on students' learning. For the INT condition, the team response scores were higher than the individual response scores in the A ($p < 0.001$), IM ($p < 0.001$), and E ($p < 0.001$) categories, and in the S category, a trend suggested the same results ($p = 0.059$). The results for the INT condition's team response and individual response scores in the chest pain scenario are shown in **Figure 3A** and **Table 4**. For the VID condition, the team response scores were higher than the individual response scores for the IM ($p = 0.013$), E ($p = 0.011$), and IC ($p = 0.024$) categories, and a trend in the S category suggested the same results ($p = 0.097$). The results for the VID condition's team response and individual response scores in the chest pain scenario are shown in **Figure 3B** and **Table 4**.

3.1.2. Scenario 2: Stroke

For the stroke scenario, we found that interactivity promoted students' learning in the IM category. We compared students' team learning gains (team minus pre) and found that in the IM category, the gains were greater for the INT condition than the VID condition ($p = 0.039$). The results for the team learning gains in the stroke scenario are shown in **Figure 2B** and **Table 3**.

We found that the effect of teamwork on students' learning for the stroke scenario was mixed. For the INT condition, the team response scores were higher than the individual response scores in the A category ($p = 0.027$), however, in the IC and S categories, the individual response scores were higher than the team response scores (IC: $p = 0.007$; S: $p = 0.015$). The results for the INT condition's team response and individual response scores in the stroke scenario are shown in **Figure 3C** and **Table 5**. For the VID condition, the individual response scores were higher than the team response scores in the IC category ($p = 0.007$). The results for the VID condition's team response and individual response scores are shown in **Figure 3D** and **Table 5**.

3.2. Survey

The following results describe participants' perceptions of teamwork and authenticity of the simulation. This data was collected through the SATTS and VPE questionnaires, respectively.

3.2.1. Self-Assessment Teamwork Tool for Students (SATTS)

Results indicated that participants were more engaged in teamwork in the INT condition than the VID condition. We

TABLE 4 | This table shows the data for participants' mean scores for the individual response (post-questionnaire) and team response (team questionnaire) for the INT and VID conditions in the chest pain scenario.

INT chest pain scenario						
Category	**W**	***p***	**Effect size**	**Answer type**	**Mean**	**SD**
Assessment	0	<0.001	−1.00	Team	8.67	0.97
				Individual	2.61	1.20
Intervention medication	0	<0.001	−1.00	Team	3.11	0.32
				Individual	1.28	1.18
Evaluation	0	<0.001	−1.00	Team	2.89	0.32
				Individual	1.06	0.80
Intervention communication	8	0.30	−0.43	Team	1.11	0.32
				Individual	0.94	0.54
Safety	10	0.059	−0.64	Team	1.44	0.51
				Individual	1.06	0.87
VID chest pain scenario						
Category	**W**	***p***	**Effect size**	**Answer type**	**Mean**	**SD**
Assessment	13.5	0.17	−0.51	Team	3.44	1.76
				Individual	2.89	1.97
Intervention medication	13.5	0.013	−0.74	Team	2.22	1.59
				Individual	1.06	1.39
Evaluation	10	0.011	−0.78	Team	1.78	0.94
				Individual	1.00	0.97
Intervention communication	13	0.024	−0.67	Team	1.78	0.43
				Individual	1.33	0.69
Safety	6	0.097	−0.67	Team	1.33	0.69
				Individual	0.94	0.87

*This data is represented as graphs in **Figures 3A,B**.*

found that students who participated in the INT condition after the VID condition scored the INT condition higher on the SATTS questionnaire than students who participated in the INT condition first; the difference was statistically significant for all questions on the SATTS questionnaire except SATTS2 (Plan), which suggested a trend ($p = 0.091$), and SATTS8 (Situational info), which was not statistically significant ($p = 0.11$). The results for SATTS scores for the order of participation in the INT condition are shown in **Figure 4A** and **Table 6**. Students who participated in the VID condition after the INT condition scored the VID condition lower in SATTS2 (Plan) than students who participated in the VID condition first ($p = 0.029$). For SATTS9 (Teamwork), a trend suggested the same results ($p = 0.08$). The results for SATTS scores for the order of participation in the VID condition are shown in **Figure 4B** and **Table 6**.

3.2.2. Virtual Patient Evaluation (VPE)

Participants perceived the INT condition to be more authentic than the VID condition. Students who participated in the VID condition after the INT condition scored the VID condition lower than students who participated in the VID condition first for all questions in the VPE questionnaire except for VPE3 (Gathering info) and VPE6 (Nursing priorities), which suggested trends (VPE3: $p = 0.081$; VPE6: $p = 0.053$). The results for VPE scores for the order of participation in the VID condition as shown in **Figure 5** and **Table 7**. We did not find statistically significant results in the VPE scores for order of participation in the INT condition. In another statistical test, we found that students scored the INT condition higher than the VID condition on VPE3 (Gathering info) and VPE5 (Summarizing problem), regardless of the order of their participation; the difference was statistically significant for all questions on the VPE questionnaire except VPE6 (Nursing priorities), which suggested a trend ($p = 0.084$), and VPE2 (Nursing care), which was not statistically significant ($p = 0.11$). The results for VPE scores without accounting for the order of participation are shown in **Figure 6** and **Table 8**. Lastly, we found that students' average VPE scores were higher for the INT condition ($M = 4.24$, SD $= 0.918$)

TABLE 5 | This table shows the data for participants' mean scores for the individual response (post-questionnaire) and team response (team questionnaire) for the INT and VID conditions in the chest pain scenario.

			INT stroke scenario			
Category	**W**	***p***	**Effect size**	**Answer type**	**Mean**	**SD**
Assessment	17	0.027	−0.68	Team	4.56	1.82
				Individual	3.44	1.79
Intervention medication	22.5	0.63	−0.18	Team	1.56	0.71
				Individual	1.44	0.78
Evaluation	9	0.18	−0.50	Team	0.44	0.51
				Individual	0.22	0.43
Intervention communication	78	0.001	1.00	Team	0.56	0.71
				Individual	1.39	0.61
Safety	91	0.015	0.73	Team	1.22	1.44
				Individual	2.17	0.79
			VID stroke scenario			
Category	**W**	***p***	**Effect size**	**Answer type**	**Mean**	**SD**
Assessment	58	0.14	0.49	Team	2.50	2.31
				Individual	3.38	2.06
Intervention medication	12	0.82	0.14	Team	0.75	0.86
				Individual	0.81	0.91
Evaluation	–	–	–	Team	0	–
				Individual	0	–
Intervention communication	45	0.007	1.00	Team	0.75	0.86
				Individual	1.50	0.63
Safety	36	0.12	0.60	Team	1.38	1.78
				Individual	2.13	1.26

For the VID condition in the stroke scenario, the statistical test for the evaluation category could not be conducted because the variance of the means was equal to zero. This data is represented as graphs in ***Figures 3C,D****.*

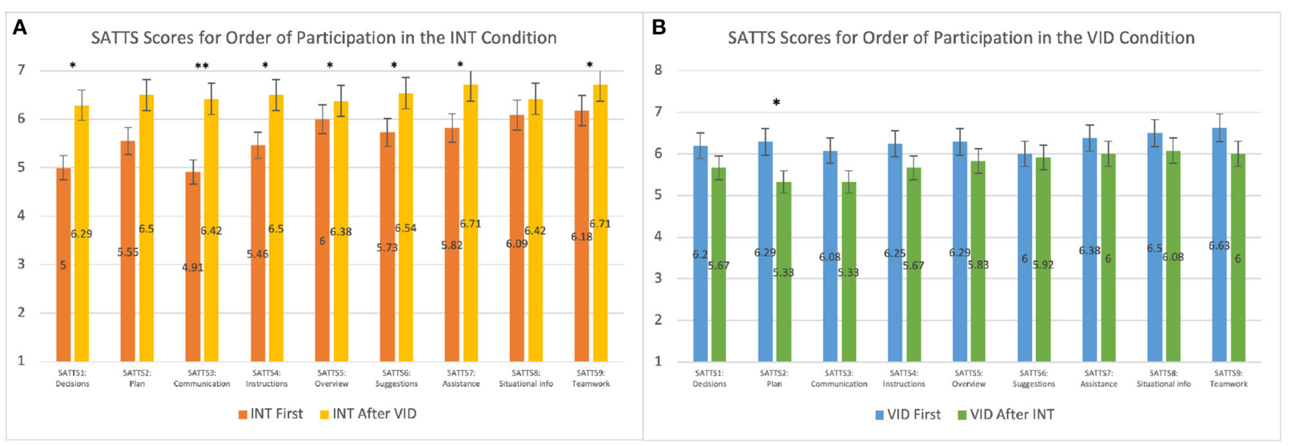


FIGURE 4 | This graph compares the mean SATTS scores for order of participation in the **(A)** INT condition and **(B)** VID condition. *$p \leq 0.05$; **$p \leq 0.01$. See details in **Table 6**.

TABLE 6 | This table compares the mean SATTS scores for order of participation in the INT and VID conditions.

SATTS scores for the order of participation in the INT condition						
Category	**W**	***p***	**Effect size**	**Condition**	**Mean**	**SD**
SATTS1: Role	76	0.032	−0.42	INT first INT after VID	5.00 6.29	2.10 1.20
SATTS2: Plan	90.5	0.091	−0.31	INT first INT after VID	5.55 6.50	1.97 1.10
SATTS3: Communication	55	0.003	−0.58	INT first INT after VID	4.91 6.42	1.92 1.18
SATTS4: Instructions	68.5	0.012	−0.48	INT first INT after VID	5.46 6.50	1.75 1.10
SATTS5: Overview	80.5	0.04	−0.39	INT first INT after VID	6.00 6.38	0.78 1.31
SATTS6: Suggestions	79.5	0.032	−0.40	INT first INT after VID	5.73 6.54	1.42 1.02
SATTS7: Assistance	79.5	0.02	−0.40	INT first INT after VID	5.82 6.71	1.78 0.86
SATTS8: Situational info	92	0.11	−0.30	INT first INT after VID	6.09 6.42	0.94 1.14
SATTS9: Teamwork	89	0.04	−0.33	INT first INT after VID	6.18 6.71	1.25 1.04
SATTS scores for the order of participation in the VID condition						
Category	**W**	***p***	**Effect size**	**Condition**	**Mean**	**SD**
SATTS1: Role	103	0.15	−0.29	VID first VID After INT	6.21 5.67	1.10 1.16
SATTS2: Plan	82.5	0.029	−0.43	VID first VID After INT	6.29 5.33	1.08 1.72
SATTS3: Communication	103.5	0.16	−0.28	VID first VID after INT	6.08 5.33	1.10 1.61
SATTS4: Instructions	101.5	0.13	−0.30	VID first VID after INT	6.25 5.67	1.07 1.37
SATTS5: Overview	113.5	0.28	−0.21	VID first VID after INT	6.29 5.83	0.96 1.40
SATTS6: Suggestions	139	0.87	−0.035	VID first VID after INT	6.00 5.92	1.14 1.24
SATTS7: Assistance	123.5	0.46	−0.14	VID first VID after INT	6.38 6.00	0.88 1.41
SATTS8: Situational info	101.5	0.12	−0.30	VID first VID after INT	6.50 6.08	0.89 0.90
SATTS9: Teamwork	98.5	0.08	−0.32	VID first VID after INT	6.63 6.00	0.71 1.41

*The data is represented as graphs in **Figure 4**.*

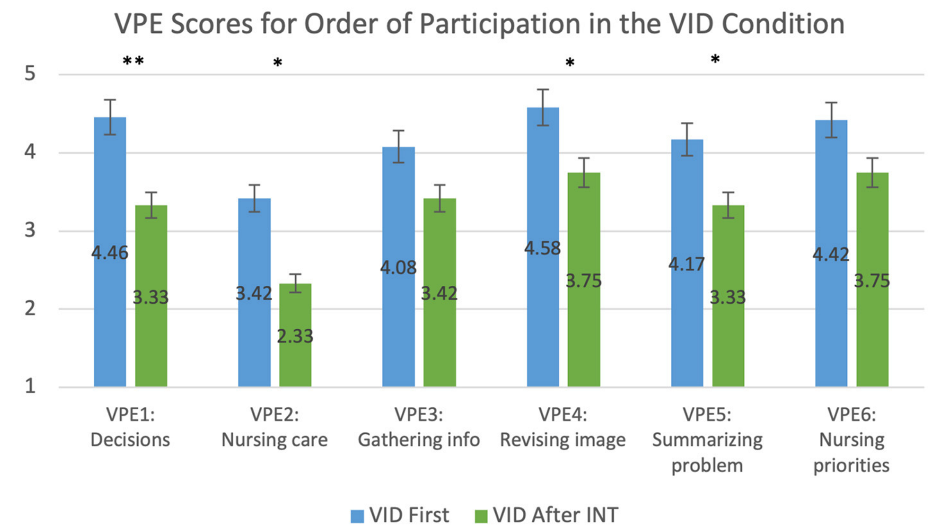


FIGURE 5 | This graph compares the mean VPE scores of participants who were exposed to the VID condition first and those were exposed after the INT condition. *$p \le 0.05$; **$p \le 0.01$. See details in **Table 7**.

TABLE 7 | This table compares the mean VPE scores of participants who were exposed to the VID condition first and those were exposed after the INT condition.

Category	W	*p*	Effect size	Condition	Mean	SD
VPE1: Decisions	64.5	0.005	−0.55	VID first	4.46	0.72
				VID after INT	3.33	1.23
VPE2: Nursing care	86.5	0.049	−0.40	VID first	3.42	1.50
				VID after INT	2.33	1.23
VPE3: Gathering info	94	0.081	−0.35	VID first	4.08	1.21
				VID after INT	3.42	1.24
VPE4: Revising image	83	0.022	−0.42	VID first	4.58	0.72
				VID after INT	3.75	1.22
VPE5: Summarizing problem	82	0.031	−0.43	VID first	4.17	0.96
				VID after INT	3.33	1.07
VPE6: Nursing priorities	90	0.053	−0.38	VID first	4.42	0.78
				VID after INT	3.75	1.06

*The data is represented as a graph in **Figure 5**.*

than the VID condition ($M = 3.90$, SD = 0.959). These results were statistically significant (W = 299.500, $p = 0.029$).

3.3. Qualitative Feedback

Out of the 36 participants, 23 participants preferred the INT condition, 11 participants preferred the VID condition, and 2 participants did not specify a preference. Seven participants preferred the INT condition because it was more engaging than the VID condition. Three participants mentioned that they preferred the INT condition because they had input in the sequence of steps. Three participants mentioned that it was helpful to receive feedback about their patient care decisions. Two participants preferred the INT condition because it required more critical thinking than the VID condition.

Out of the 11 participants that preferred the VID condition, three mentioned that it was unclear how to use the INT simulation technology. Two participants mentioned that the videos played in the INT condition were lagging. Two participants mentioned that they preferred to watch the nurse perform the full scenario in the correct sequence of steps.

4. DISCUSSION

The QSEN approach to categorizing the data allowed the researchers to identify deep learning through systems thinking and critical thinking (26). Critical thinking is identified using the QSEN categories and completing the nursing process (27).

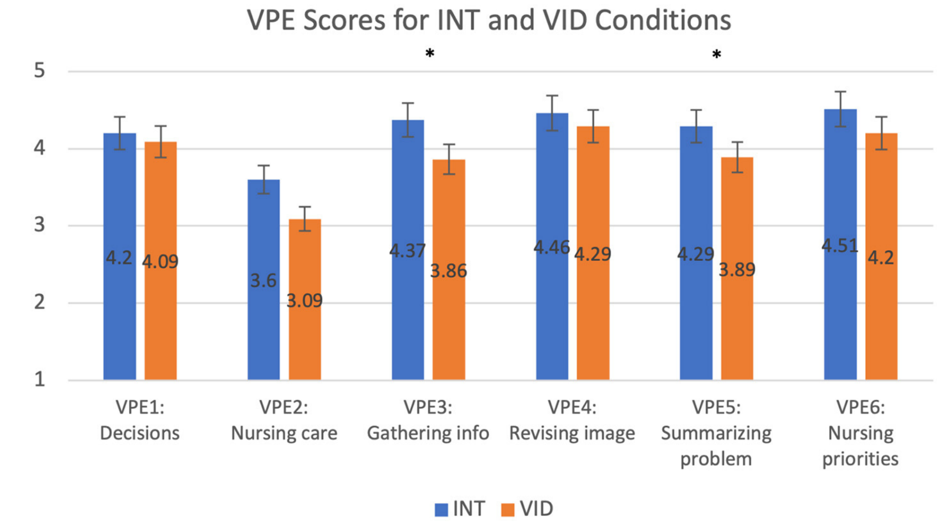


FIGURE 6 | This graph compares the mean VPE scores for the INT and VID conditions. *$p \leq 0.05$. See details in **Table 8**.

TABLE 8 | This table compares the mean VPE scores for the INT and VID conditions, regardless of order of participation.

Category	W	*p*	Effect size	Condition	Mean	SD
VPE1: Decisions	115	0.42	0.21	INT	4.20	1.16
				VID	4.09	1.07
VPE2: Nursing care	122.5	0.11	0.43	INT	3.60	1.48
				VID	3.09	1.50
VPE3: Gathering info	135.5	0.025	0.59	INT	4.37	0.91
				VID	3.86	1.26
VPE4: Revising image	76.5	0.35	0.28	INT	4.46	1.07
				VID	4.29	0.99
VPE5: Summarizing problem	143.5	0.046	0.51	INT	4.29	1.05
				VID	3.89	1.08
VPE6: Nursing priorities	90	0.084	0.50	INT	4.51	0.82
				VID	4.20	0.93

*The data is represented as a graph in **Figure 6**.*

Using consensus, we ranked the QSEN competencies based on the nature of the scenarios. The A, IM, and E competencies were ascribed greater weight since they required decision-making opportunities to interpret data, select correct medication and evaluate patient changes. We determined that the A, IM, and E categories constitute higher order learning and the IC and S categories constitute lower order learning. Additionally, the chest pain and stroke scenarios had differences in their levels of complexity, which is important to note when evaluating the results. The chest pain scenario required students to make more decisions and challenged them to determine the cause of the patient's pain and intervene appropriately, while the focus of the stroke scenario was the neurological assessment, which required fewer decisions and interventions. We evaluated whether the complexity of the scenario influenced the effects of interactivity.

Learning and Interactivity

We observed that higher order learning is promoted more through interactive simulation than non-interactive simulation. In our study, statistically significant results in the higher order learning categories showed that between the pre-questionnaire and team response, students had greater learning gains in the INT condition than the VID condition. IC was the only category for which students' scores were higher in the VID than the INT condition; in fact, the gains for the INT condition in this category were negative. We designed the interactivity to be focused on decisions as opposed to the manikin's responses for both the INT group and the VID group. By design of the intervention, communication was not supported during the care of the patient which might have created a situation where the students did not expect to get a response from the manikin and therefore did not engage in purposeful communication. We believe that this resulted in the decline of students' scores in the IC category. It is also interesting to note that the participants in the VID condition had watched the full solution to the scenario prior to responding to the questionnaires while students in the INT condition had no prior exposure to the solution. Despite this, participants in the INT condition overall demonstrated more significant higher order learning than those in the VID condition. This further demonstrates that interactivity promotes higher order learning more than non-interactivity. These results support our first research question (Q1).

Learning and Teamwork

Teamwork was shown to have a positive impact on students' higher order learning, but on lower order learning teamwork had a lesser impact. In our results, there were statistically significant differences for all three higher order learning categories between students' individual and team response scores, with the team response scores being higher. However, in the stroke scenario, we found that for the lower order learning categories (IC and S), individual work produced higher scores than teamwork. These results answer our second research question (Q2).

Perception of Authenticity

Interaction with the simulation system was shown to greatly increase perceptions of authenticity. Participants felt more actively engaged in gathering information (VPE3) and summarizing the problem (VPE5) in the INT condition than the VID condition. A trend also suggested that participants may have felt more actively engaged in thinking about nursing priorities (VPE6) in the INT condition than the VID condition. Additionally, participants' mean scores in the VPE questionnaire were overall higher for the INT condition than the VID condition. With the added interactive component, the simulation experience was perceived as largely more authentic than without interactivity. These results support our third research question (Q3).

Order of Participation

We found that the order of participation in the INT and VID conditions affected students' perceptions of the simulation. Students who experienced the VID simulation before the INT simulation perceived teamwork and authenticity in the INT simulation as greater than students who were exposed to the INT simulation first. Similarly, when students were exposed to the INT simulation before the VID simulation, they perceived teamwork and authenticity in the VID simulation to be lower than students who were exposed to the VID simulation first. Participants compared their initial simulation experience to their subsequent experience, which may suggest that the VID simulation comparatively generated a lesser sense of teamwork and perception of authenticity than the INT simulation. With these results, we found that the order of participation does affect perceptions of the simulation: students perceive both teamwork and authenticity to be highest when they are exposed to the VID simulation first and then the INT simulation. This supports our fourth research question (Q4).

Based on these results, we recommend that non-interactive video simulation is supplemented with interactive simulation. To promote higher order learning, we recommend that complex scenarios are used with teamwork activity. To promote lower order learning, we recommend that simple scenarios and are used with individual activity. The non-interactive simulation should be conducted before the interactive simulation to increase perceptions of teamwork and authenticity. This will enable comprehensive learning of both higher order and lower order knowledge and increase students' perceptions of the simulation experience.

The IVS software has demonstrated to be a valid remote simulation technology. The technology embraces three pedagogically sound strategies in simulation education: (1) The participant observer role, (2) teamwork, and (3) productive failure (PF). There is work to support the use of participant observers in simulation and evidence to suggest that learning outcomes such as clinical judgement, insight, and conceptual thinking can be achieved by viewing a simulation (28). Likewise, team-based learning has been used with much success in courses such as health assessment and with simulation (29). Team-based learning has been found to develop nursing students' teamwork and collaborative skills as they interact with one another (30). The IVS technology harnesses the power of remote availability and teamwork to enhance critical thinking skills. At various points in the simulation, the video is paused and students choose their next steps without being given options; in essence allowing the student to think critically before choosing the next action without showing them the answer. Showing the answer during the simulation can inadvertently make the activity easier or harder than necessary before giving the students the opportunity to think. Palominos et al. (31) established the concept of PF, an approach to simulation learning that emphasizes the educational value of making mistakes in a non-threatening environment. The premise of PF is to allow learners to make errors and then follow their error experiences with opportunities to identify the correct solution. By completing the pre-questionnaire prior to the simulations, students gained exposure to the SBAR and were able to plan their patient care interventions ahead of time. This allowed the students to attempt the solution despite the possibility of errors and prepared them to reconsidered their interventions at later points in the simulations, thus facilitating their learning. The INT condition implemented a reinforced PF strategy: in the simulation, students needed to rethink their decisions before communicating their steps to the facilitator. The INT condition promoted greater learning in the higher order categories and this may be attributed to the reinforced PF strategy. Additionally, in both conditions, the students had the opportunity to collaborate in pairs before finalizing their answers to the scenarios. The design of the study allowed students to make mistakes and then guided them to identify their errors before being debriefed by the facilitator.

During the pandemic, healthcare students' exposure to training has been maintained largely through video-based resources (32). The IVS software engages students in interactive simulation experiences remotely and while using educators' existing video content. By making simulation content more interactive, we are extending existing resources, allowing for the development of critical thinking and decision-making. The IVS technology allows for greater accessibility for students and faculty in remote environment.

4.1. Limitations

A notable feature of the software is that it allows instructors to upload their own content and customize the simulation to their preferences. For this study, the software development was focused on the functionality and display of the simulation, and as a result, the graphical user interface (GUI) for uploading content was not fully developed. This did not affect the execution of the study as the dashboard of control buttons and the students' video display were fully developed. Also, since the INT simulation was conducted over Zoom, the frame rate of the videos was reduced, causing lagging at times. Some participants noted this in their surveys, saying that it negatively affected their simulation experience. The INT simulation was also controlled by the facilitator, making students' interaction with the software indirect. Additionally, the study was designed to evaluate students' implementation of patient care and knowledge of protocols and did not evaluate communication skills. The simulation videos showed the nurse communicating with a manikin rather than an actual patient, with the patient's dialogue being displayed as captions in the videos, and in the INT condition, the interaction occurred between the student and simulation system and did not involve the patient. As a result, the study design was not optimal for students' learning of IC competencies. Lastly, in a typical simulation, the debrief would be longer than 10 min but due to limitations of scheduling and timing the debrief was shortened. Ideally, more time should be allocated for the debrief but the reduced debrief time did not affect the results of the study.

4.2. Future Work

We are planning to further develop the software's GUI to improve the usability and customizability of the software for educators. Additionally, streaming the videos over Zoom caused lagging and choppiness that negatively affected some students' experiences during the simulation. We intend to develop the software so that it is not dependent on Zoom; rather, the videos could be stored locally on students' computers instead of being streamed over a video conferencing application. This would eliminate the problem of lagging, providing a better simulation experience to students. We also intend to develop features that will eliminate the need for a facilitator to mediate the simulation for students, allowing the students to interact with the software directly and independently if desired.

4.2.1. Automated After-Action Review

Debrief is essential to the development of students' skills in healthcare simulation. In a debrief, the facilitator guides learners to reflect on their performance in a discussion that examines various aspects of the simulation exercise. After-action review (AAR) is a structured methodology for debriefing that was initially developed by the U.S. Army but has been adopted in healthcare simulation (33). As we further develop the IVS software, we intend to create an automated AAR in which the system would provide feedback at the end of the simulation to indicate where students' actions were correct or incorrect. The automated AAR can be used to guide the facilitator's debrief and provide students the option to practice simulation exercises independently with standardized feedback.

5. CONCLUSION

Through the COVID-19 pandemic, it became apparent that traditional manikin simulation has limitations, namely those of safety and flexibility. As a replacement for manikin simulation, many nursing educators resorted to videos to teach their learners remotely; however, without interactivity, the simulation does not meet the interactivity standards of best practice for healthcare simulation. By comparing the INT condition to the VID condition, we evaluated the effect of interactivity on students' learning and perceptions of the simulation. We found that interactive simulation promotes students' learning and is perceived as largely more authentic than non-interactive simulation. We also found that higher level learning is promoted more through teamwork while lower level learning is promoted more through individual work. Lastly, we found that students' order of participation in interactive and non-interactive simulation affects their perceptions of the experience; perceptions of teamwork and authenticity are increased when students participate in non-interactive simulation before interactive simulation, though this also indicates that students perceive teamwork and authenticity to be comparatively better in the interactive simulation than the non-interactive simulation. Given these findings, we recommend that non-interactive simulation is supplemented by interactive simulation to promote comprehensive learning and increase students' perceptions of the experience. We recommend that educators use teamwork for complex scenarios to promote higher level learning, and individual work for simple scenarios to promote lower level learning. Future research into remote simulation options should strive to limit dependence on facilitators and other platforms, allowing students to practice scenarios independently and with a standardized after action review.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by IRB at University of Central Florida.

The participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

The study was designed by all authors. LG and HP provided nursing education expertise and collected the data. SD and DM developed the IVS software and analyzed the data. The manuscript was written by DM, LG, HP, and SD. SD supervised the project and provided extensive comments and revisions to the manuscript. All authors contributed to the article considerably and deserve authorship, reviewed the article, and approved the submitted version.

ACKNOWLEDGMENTS

We thank Talaar Rastguelenian for assisting with the development of the IVS software, Dr. Ji Meng Lo for advising our statistical analysis methods, and Syretta Spears and Danna McKay for helping with the execution of the study.

REFERENCES

1. Liaw SY, Zhou WT, Lau TC, Siau C, Chan SWc. An interprofessional communication training using simulation to enhance safe care for a deteriorating patient. *Nurse Educ Today*. (2014) 34:259–64. doi: 10.1016/j.nedt.2013.02.019
2. Morse C, Fey M, Kardong-Edgren S, Mullen A, Barlow M, Barwick S. The changing landscape of simulation-based education. *Am J Nurs*. (2019) 119:42–8. doi: 10.1097/01.NAJ.0000577436.23986.81
3. Cant RP, Cooper SJ. Use of simulation-based learning in undergraduate nurse education: An umbrella systematic review. *Nurse Educ Today*. (2017) 49:63–71. doi: 10.1016/j.nedt.2016.11.015
4. Lavoie P, Clarke SP. Simulation in nursing education. *Nurs Manage*. (2017) 48:16–7. doi: 10.1097/01.NUMA.0000511924.21011.1b
5. Kiernan LC. Evaluating competence and confidence using simulation technology. *Nursing*. (2018) 48:45. doi: 10.1097/01.NURSE.0000545022.36908.f3
6. Scherer YK, Foltz-Ramos K, Fabry D, Chao YY. Evaluating simulation methodologies to determine best strategies to maximize student learning. *J Prof Nurs*. (2016) 32:349–57. doi: 10.1016/j.profnurs.2016.01.003
7. Lioce L, Lopreiato J, Downing D, Chang T, Robertson J, Anderson M, et al. *Healthcare Simulation Dictionary*. Rockville, MD: Agency for Healthcare Research and Quality. Available online at: https://wwwssihorg/dictionary (2020). doi: 10.23970/simulationv2
8. Gonzalez L, Daher S, Welch G. Neurological assessment using a physical-virtual patient (PVP). *Simul Gam*. (2020) 51:802–18. doi: 10.1177/1046878120947462
9. Linden Research, Inc. *Second Life | Education - Teach & Learn in the Virtual World*. Linden Research, Inc. (2020). Available online at: http://go.secondlife.com/landing/education/?lang=en (accessed March 12, 2021).
10. Wolters Kluwer NV. *vSim for Nursing | Lippincott Nursing Education*. Wolters Kluwer NV. (2021). Available online at: https://www.wolterskluwer.com/en/solutions/lippincott-nursing-faculty/vsim-for-nursing (accessed March 12, 2021).
11. Shadow Health®, Inc. *Home | Shadow Health*. Shadow Health®, Inc. (2021). Available online at: https://www.shadowhealth.com/ (accessed March 12, 2021).
12. Irwin P, Coutts R. A systematic review of the experience of using Second Life in the education of undergraduate nurses. *J Nurs Educ*. (2015) 54:572–7. doi: 10.3928/01484834-20150916-05
13. Beyer-Berjot L, Patel V, Acharya A, Taylor D, Bonrath E, Grantcharov T, et al. Surgical training: design of a virtual care pathway approach. *Surgery*. (2014) 156:689–97. doi: 10.1016/j.surg.2014.04.045
14. Foronda CL, Swoboda SM, Hudson KW, Jones E, Sullivan N, Ockimey J, et al. Evaluation of vSIM for Nursing: a trial of innovation. *Clin Simul Nurs*. (2016) 12:128–31. doi: 10.1016/j.ecns.2015.12.006
15. McCoy CE, Sayegh J, Alrabah R, Yarris LM. Telesimulation: an innovative tool for health professions education. *AEM Educ Train*. (2017) 1:132–6. doi: 10.1002/aet2.10015
16. Naik N, Finkelstein RA, Howell J, Rajwani K, Ching K. Telesimulation for COVID-19 ventilator management training with social-distancing restrictions during the coronavirus pandemic. *Simul Gam*. (2020) 51:571–7. doi: 10.1177/1046878120926561
17. Almarzooq ZI, Lopes M, Kochar A. *Virtual Learning During the COVID-19 Pandemic: A Disruptive Technology in Graduate Medical Education*. Washington, DC: American College of Cardiology Foundation (2020). doi: 10.1016/j.jacc.2020.04.015
18. D'Souza M, Venkatesaperumal R, Chavez F, Parahoo K, Jacob D. Effectiveness of simulation among undergraduate students in the critical care nursing. *Int Arch Nurs Health Care*. (2017) 3:1–8. doi: 10.23937/2469-5823/1510084
19. Lioce L, Meakim CH, Fey MK, Chmil JV, Mariani B, Alinier G. Standards of best practice: simulation standard IX: simulation design. *Clin Simul Nurs*. (2015) 11:309–15. doi: 10.1016/j.ecns.2015.03.005
20. Unity Technologies. *Unity Real-Time Development Platform | 3D, 2D VR & AR Engine*. (2021). Available online at: https://unity.com/ (accessed March 12, 2021).
21. Gordon CJ, Jorm C, Shulruf B, Weller J, Currie J, Lim R, et al. Development of a self-assessment teamwork tool for use by medical and nursing students. *BMC Med Educ*. (2016) 16:9. doi: 10.1186/s12909-016-0743-9
22. Huwendiek S, De Leng BA, Kononowicz AA, Kunzmann R, Muijtjens AM, Van Der Vleuten CP, et al. Exploring the validity and reliability of a questionnaire for evaluating virtual patient design with a special emphasis on fostering clinical reasoning. *Med Teach*. (2015) 37:775–82. doi: 10.3109/0142159X.2014.970622
23. Knapp TR. Treating ordinal scales as interval scales: an attempt to resolve the controversy. *Nurs Res*. (1990) 39:121–3. doi: 10.1097/00006199-199003000-00019
24. Kuzon W, Urbanchek M, McCabe S. The seven deadly sins of statistical analysis. *Ann Plast Surg*. (1996) 37:265–72. doi: 10.1097/00000637-199609000-00006
25. qsen org. *Quality and Safety Education for Nurses*. (2020). Available online at: https://qsen.org/ (accessed April 21, 2021).
26. Stalter AM, Phillips JM, Ruggiero JS, Scardaville DL, Merriam D, Dolansky MA, et al. A concept analysis of systems thinking. In: *Nursing Forum*. Vol. 52. Wiley Online Library (2017). p. 323–30. doi: 10.1111/nuf.12196
27. Altmiller G. Content validation of a quality and safety education for nurses-Based clinical evaluation instrument. *Nurse Educ*. (2017) 42:23–7. doi: 10.1097/NNE.0000000000000307
28. Rogers B, Baker KA, Franklin AE. Learning outcomes of the observer role in nursing simulation: a scoping review. *Clin Simul Nurs*. (2020) 49:81–9. doi: 10.1016/j.ecns.2020.06.003

29. Roh YS, Kim SS, Park S, Ahn JW. Effects of a simulation with team-based learning on knowledge, team performance, and teamwork for nursing students. *Comput Inform Nurs*. (2020) 38:367–72. doi: 10.1097/CIN.0000000000000628
30. Park HR, Kim CJ, Park JW, Park E. Effects of team-based learning on perceived teamwork and academic performance in a health assessment subject. *Collegian*. (2015) 22:299–305. doi: 10.1016/j.colegn.2014.05.001
31. Palominos E, Levett-Jones T, Power T, Alcorn N, Martinez-Maldonado R. Measuring the impact of productive failure on nursing students' learning in healthcare simulation: a quasi-experimental study. *Nurse Educ Today*. (2021) 101:104871. doi: 10.1016/j.nedt.2021.104871
32. Doulias T, Gallo G, Rubio-Perez I, Breukink SO, Hahnloser D. Doing more with less: surgical training in the COVID-19 era. *J Invest Surg*. (2020) 1–9. doi: 10.1080/08941939.2020.1824250. [Epub ahead of print].
33. Sawyer TL, Deering S. Adaptation of the US Army's after-action review for simulation debriefing in healthcare. *Simul Healthc*. (2013) 8:388–97. doi: 10.1097/SIH.0b013e31829ac85c

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

frontiers in Oncology

OPINION
published: 11 August 2021
doi: 10.3389/fonc.2021.713343

Check for updates

Haptic Fidelity: The Game Changer in Surgical Simulators for the Next Decade?

Valentin Favier[1,2,3], Gérard Subsol[3], Martha Duraes[2], Guillaume Captier[2,3] and Patrice Gallet[4,5,6]*

[1] Department of Otolaryngology-Head and Neck Surgery, Gui de Chauliac Hospital, University Hospital of Montpellier, Montpellier, France, [2] Laboratory of Anatomy of Montpellier, Faculty of Medicine, Univ. Montpellier, Montpellier, France, [3] Research-team ICAR, Laboratory of Computer Science, Robotics and Microelectronics of Montpellier (LIRMM), Univ. Montpellier, French National Centre for Scientific Research (CNRS), Montpellier, France, [4] Department of Otolaryngology-Head and Neck Surgery, Brabois Hospital, University Regional Hospital of Nancy, Lorraine University, Vandoeuvre-lès-Nancy, France, [5] Virtual Hospital of Lorraine, University of Lorraine, Vandoeuvre-lès-Nancy, France, [6] NGERE, INSERM U1256 lab, University of Lorraine, Vandoeuvre-lès-Nancy, France

Keywords: surgical simulation, haptics, fidelity, simulator assessment, surgical education

OPEN ACCESS

Edited by:
Ismail Mohd Saiboon, National University of Malaysia, Malaysia

Reviewed by:
Ravali Gourishetti, Max Planck Institute for Intelligent Systems, Germany

****Correspondence:***
Valentin Favier
Valentin_favier@hotmail.com
orcid.org/0000-0002-7999-951X

Specialty section:
This article was submitted to Surgical Oncology, a section of the journal Frontiers in Oncology

Received: *22 May 2021*
Accepted: *22 July 2021*
Published: *11 August 2021*

Citation:
Favier V, Subsol G, Duraes M, Captier G and Gallet P (2021) Haptic Fidelity: The Game Changer in Surgical Simulators for the Next Decade? Front. Oncol. 11:713343. doi: 10.3389/fonc.2021.713343

INTRODUCTION

Over the last 20 years, surgical simulation has evolved tremendously from bench models to "high-fidelity" virtual reality surgical simulators. The main objective of these simulators is to acquire the technical skills to be transferred to the operating room without any risk for patients. In this intent, both simulator and the progression of the simulation training process (1) must be validated and follow the standards (2). Nevertheless, a facet of surgical simulation lacks a deep consideration: the haptic feedback, which is essential in most surgical procedures, is rarely assessed and the place of haptic fidelity is unclear (3). Then, how can we determine the place of haptic fidelity in surgical simulation training?

FIDELITY AND SIMULATION IN SURGERY

The definition of "fidelity" in healthcare simulation remains a major matter of debate. Fidelity is, in essence, a multifactorial concept (4). It refers to sensory resemblance (auditory, visual, tactile) as well as functional resemblance and, therefore, depends on the context and learning objectives. In surgical simulation, fidelity has too often been reduced to "face validity" (i.e., the simulator "looks like" the reality) and even more reduced to visual resemblance. The underlying concepts of "face validity"—i.e., the perception of the user which contributes to simulator credibility, adhesion to it, and enhance information retention and transfer to practice—are relevant but a visual resemblance (closeness to the shape and color of the anatomical structures) is not sufficient to assess a surgical simulator. This is why "face validity" is not part of the Standards for Educational and Psychological Tests and Manuals (2) even if it continues to be wrongly used.

In fact, Paige and Morin (4) defined three dimensions of fidelity and proposed a "fidelity matrix" based on the following:

1. physical (or engineering) fidelity (of the equipment and environment);

2. psychological fidelity, which ensures that the trainee is engaged in the simulation. It characterizes the extent to which events and scenarios reflect real situations and the extent to which the simulator provides realistic responses to the actions of the learners; and
3. conceptual fidelity, which ensures that the scenario makes sense and corresponds to the human conceptual mode of thinking, such as problem solving or decision-making.

Each dimension is independent and has to be adapted to the context and task to be simulated. Following these concepts, Hamstra et al. (5) proposed to distinguish the "physical resemblance" from the "functional task alignment" (FTA) (i.e., how much a simulator functions like the reality in response to the actions of a user). They advocated that the conception and design of simulators should follow the FTA analysis to functionally represent a patient in response to the physical action of the task, rather than seeking to achieve a physical resemblance. Following this definition, the simulator fidelity is achieved when the simulator functional parts are in congruence with the learning objectives.

TOWARD A BETTER EVALUATION OF HAPTIC FIDELITY IN SURGICAL SIMULATION

One of the components of the physical resemblance is the haptic fidelity (i.e., the perception by touch and proprioception). Haptic skills are crucial to learning surgery: it is of utmost importance for a surgeon to learn how to handle tissues safely, how to "feel" the dissection plan, and how to palpate a tumor. These haptic skills are essential for a safe use of surgical instruments, spatial representation, understanding of tumor relationships and limits, and evaluation of surgical risks at each step of a procedure. In surgery, the risk of a regular training with a simulator lacking realistic haptic rendering is to provide a negative transfer in the operating theater, where the learner might apply dangerous forces which is possibly difficult to untrain later (6). Therefore, the haptic fidelity assessment of surgical simulators is essential and should be taken into consideration from the beginning of the design of the simulators, according to the simulated tasks (in agreement with FTA). For example, to simulate a realistic neurovascular dissection, the simulated tissues should be adequately adherent to each other and have a consistent physical behavior to experience which forces should be applied on anatomical structures. Haptic feedback is all the more important in endoscopic surgery (7), in which surgeons are proceeding without directly seeing their hands, only with the visual support of a two-dimensional display, and in which haptic feedback provides crucial information for decision-making and movement planning. Thus, the study of haptics is of growing interest especially for virtual reality surgical simulation which deals with the same issues (8). It was shown that haptic feedback may play an important role in motor skills acquisition (9), but haptic skills are difficult to teach in an objective and standardized manner. Therefore, research on procedural simulation should focus on biomechanical characterization of the tissues to be simulated, to select suitable synthetic materials for physical simulators and improve the haptic feedback of virtual reality simulators. Most virtual reality systems provide force feedback only for anatomical structures that have been segmented and assigned properties, but such biomechanical data are often missing (3).

A recent review of the literature (8) highlighted "the inconsistency and paucity of current evidence with regard to haptics and its validity and evidence of its value in [surgical] training". Few authors actually measured the applied forces or the precision of movements during surgical procedures which give quantitative parameters that could be used for haptics application (10–12). Moreover, these well-designed studies are often published in biomedical engineering journals and may be poorly disseminated within the medical community. Finally, the assessment of haptic fidelity on surgical simulators is often qualitative, provided by users or designers, and usually compared to "reality" using binary questionnaires or Likert-type scales. As an illustration, Chan et al. (13), who conducted a very substantial work on modeling and virtual rendering for temporal bone surgery simulation, evaluated the "high-fidelity" on visual appearance (comparison with videos) only rather than on objective parameters (such as the amount of bone removed or the applied forces). We believe that this approach is insufficient to create and validate "high-fidelity" haptic procedural simulators. It is indeed with a better knowledge of the biomechanical characteristics and through the objective evaluation of these parameters that the evaluation of haptic fidelity would be more relevant than questionnaires specific to each simulator designer/evaluator.

DEFINING HAPTIC FIDELITY LEVELS ADAPTED TO SURGICAL TASKS

The FTA theory (5) highlights the need to think about the objectives of the learners before designing a simulator. Thus, we advocate for a more robust method of classification of the level of fidelity, in accordance with the learning objectives (FTA-based approach).

The first step is to define which level of haptic fidelity is required according to the surgical skill to learn. Indeed, basic technical skills (e.g., navigation with an endoscope) do not always require high haptic fidelity levels, in contrast to some advanced skills (e.g., neurovascular dissection). We propose to define three levels of haptic fidelity (**Figure 1**). Simulators with a low haptic accuracy level (i) could be used to learn basic manipulations of surgical materials or instruments and to increase the eye-hand coordination. Simulators with a medium haptic accuracy level (ii) could be used to become familiar with the surgical procedures (e.g., learning procedure steps). Finally, high haptic accuracy simulators (iii) may help in the acquisition of fine technical skills like tumor dissection. This distinction might help in undertaking a preliminary reflection on the essential aspects of the task to be simulated to choose the appropriate level of fidelity, before designing any training device or create a surgical curriculum.

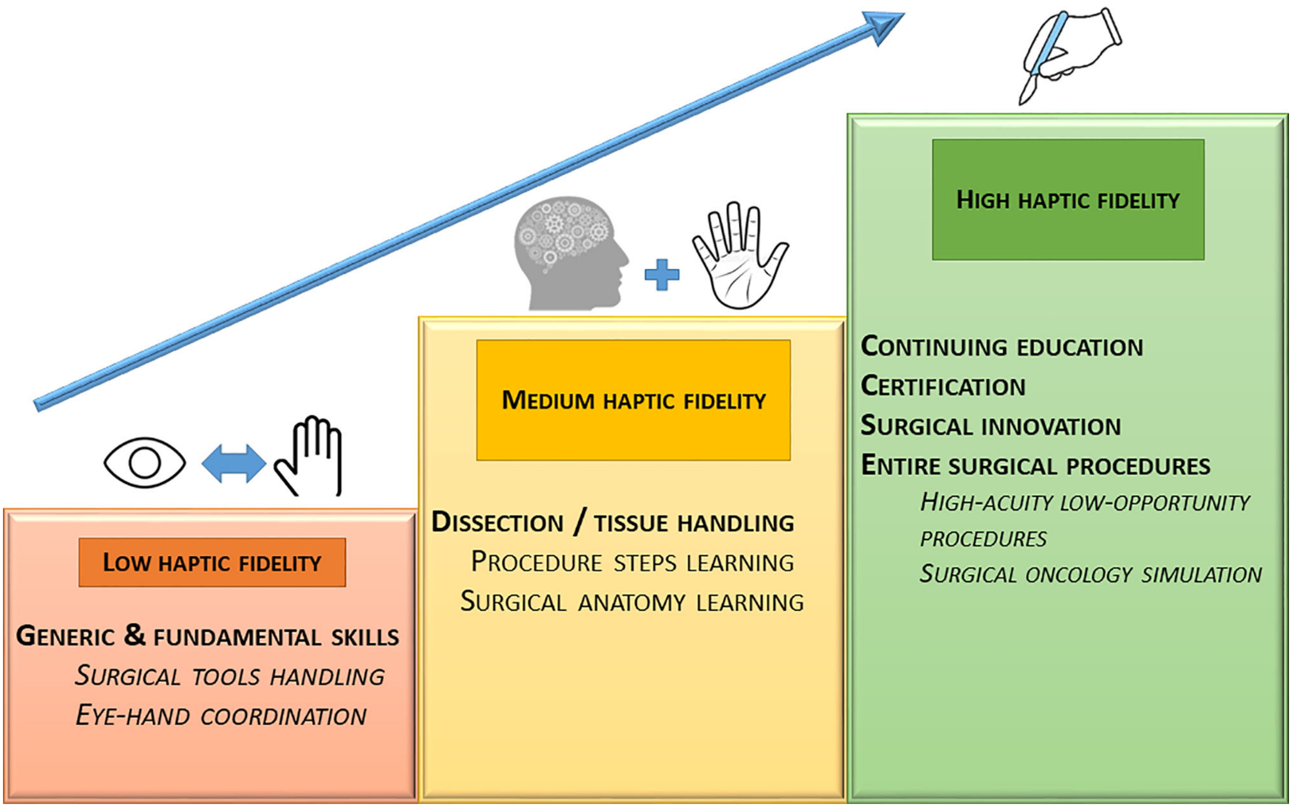


FIGURE 1 | Proposed levels of haptic fidelity and corresponding skills to learn.

The second step is to provide guidance on the haptic fidelity assessment. The experiment of Batteau et al. (14) showed that haptic recall consistency (i.e., how consistently a haptic experience can be recalled) can vary widely among individuals and may be independent of experience. This finding suggests that the method of using "expert" opinion to fine-tune haptic feedback in surgical simulators may be insufficiently reliable, as it depends on the ability of the experts to accurately recall and compare haptic events. In all other domains of training by simulation, efficacy and learning transfer can be assessed using Kirkpatrick's pyramid model (15). Haptic rendering fidelity could then be adequately assessed according to a similar scheme in order to determine the value and level of a simulator, using three grades of accuracy: a) not proven accuracy, absence of assessment of the simulator haptic feedback; b) subjective accuracy, favorable opinion on the haptic accuracy provided by a panel of experts; and c) objective accuracy, proof of the haptic rendering accuracy through biomechanical measurements. According to Mahvash et al. (16) and, more recently, Lelevé et al. (17), biomechanical measurements and objective tests may include at least:

1. tissue basic physical (texture, shape, volume, weight, temperature) and mechanical properties (compressive, tensile, bending, or shear properties) measurements. These properties can easily be assessed by calibrated testing for both soft (18) and hard tissues (19). For instance, erroneous elastic properties of soft tissues could lead to an inadequate manipulation of tumors next to neurovascular structures leading to injuries; and
2. characterization of the tissue response to different surgical actions (scissor cutting, drilling, peeling, biting, twisting, etc.). This can be done by measuring forces applied on tissues with surgical instruments commonly used in the operating room (20–22). For instance, a synthetic plastic device perfectly mimicking a bone tissue as for mechanical resistance to compression might behave unrealistically with other actions like drilling (the plastic might melt with the drilling overheating) or twisting (with unrealistic fracture line, due to the orientation of resistance spans).

Assessing haptic rendering accuracy is an absolute requirement for simulators to be used for surgical training certification—a process by which individuals are recognized (or certified) as having demonstrated some level of knowledge and skill in some domain (2). This certification is already the norm in aviation where pilots must have accumulated a specific number of hours of flight training with validated simulators. This is not routinely done in surgery, but the society attitude toward surgical training will certainly lead to the requirement of an objective proof of the skills of the surgeon before being allowed to work with patients. Haptic fidelity can be the game changer of the decade.

AUTHOR CONTRIBUTIONS

All authors contributed to the article and approved the submitted version.

FUNDING

The first author (VF) received the funding of the "Collège Français d'ORL et chirurgie cervico-faciale" for a scholarship from November 2019 to November 2020 to support his PhD thesis.

ACKNOWLEDGMENTS

Authors want to acknowledge Mrs. Marjorie Mazeau, Mr. Erwan De Penfentenyo, Mr. Jean-Pierre Henry (pilots and experts in the crew resource management at Stan Institute, Nancy, France), and Dr. Delphine Wannenmacher (expert in the team management at University of Lorraine - IUT Nancy -Charlemagne, France) for their thoughtful and thorough advice regarding aviation simulation.

REFERENCES

1. Mazzone E, Puliatti S, Amato M, Bunting B, Rocco B, Montorsi F, et al. A Systematic Review and Meta-Analysis on the Impact of Proficiency-Based Progression Simulation Training on Performance Outcomes. *Ann Surg* (2020) 274(2):281–9. doi: 10.1097/SLA.0000000000004650
2. American Educational Research Association. Standards for Educational and Psychological Testing. In: *American Psychological Association, National Council on Measurement in Education*. Washington, D.C: American Educational Research Association (2014).
3. Favier V, Gallet P, Subsol G, Captier G. Understanding the Biomechanical Properties of Skull Base Tissues Is Essential for the Future of Virtual Reality Endoscopic Sinus and Skull Base Surgery Simulators. *Clin Exp Otorhinolaryngol* (2019) 12(2):231–2. doi: 10.21053/ceo.2018.01627
4. Paige JB, Morin KH. Simulation Fidelity and Cueing: A Systematic Review of the Literature. *Clin Simulation In Nursing* (2013) 9(11):e481–9. doi: 10.1016/j.ecns.2013.01.001
5. Hamstra SJ, Brydges R, Hatala R, Zendejas B, Cook DA. Reconsidering Fidelity in Simulation-Based Training. *Acad Med* (2014) 89(3):387–92. doi: 10.1097/ACM.0000000000000130
6. Gallagher AG, O'Sullivan GC. *Fundamentals of Surgical Simulation: Principles and Practice*. London: Springer-Verlag (2012).
7. Tholey G, Desai JP, Castellanos AE. Force Feedback Plays a Significant Role in Minimally Invasive Surgery: Results and Analysis. *Ann Surg* (2005) 241 (1):102–9. doi: 10.1097/01.sla.0000149301.60553.1e
8. Basdogan C, De S, Kim J, Manivannan M, Kim H, Srinivasan MA. Haptics in Minimally Invasive Surgical Simulation and Training. *IEEE Comput Graphics Applications* (2004) 24(2):56–64. doi: 10.1109/MCG.2004.1274062
9. Rangarajan K, Davis H, Pucher PH. Systematic Review of Virtual Haptics in Surgical Simulation: A Valid Educational Tool? *J Surg Educ* (2020) 77(2):337–47. doi: 10.1016/j.jsurg.2019.09.006
10. Shen JJ, Kalantari M, Kovecses J, Angeles J, Dargahi J. Viscoelastic Modeling of the Contact Interaction Between a Tactile Sensor and an Atrial Tissue. *IEEE Trans Biomed Eng* (2012) 9(6):1727–38. doi: 10.1109/TBME.2012.2193127
11. Ehrampoosh S, Dave M, Kia MA, Rablau C, Zadeh MH. Providing Haptic Feedback in Robot-Assisted Minimally Invasive Surgery: A Direct Optical Force-Sensing Solution for Haptic Rendering of Deformable Bodies. *Comput Aided Surg* (2013) 18(5–6):129–41. doi: 10.3109/10929088.2013.839744
12. Faieghi M, Atashzar SF, Tutunea-Fatan OR, Eagleson R. Parallel Haptic Rendering for Orthopedic Surgery Simulators. *IEEE Robotics Automation Lett* (2020) 5(4):6388–95. doi: 10.1109/LRA.2020.3013891
13. Chan S, Li P, Locketz G, Salisbury K, Blevins NH. High-Fidelity Haptic and Visual Rendering for Patient-Specific Simulation of Temporal Bone Surgery. *Comput Assisted Surg* (2016) 21(1):85–101. doi: 10.1080/24699322.2016.1189966
14. Batteau LM, Liu A, Maintz JBA, Bhasin Y, Bowyer MW. A Study on the Perception of Haptics in Surgical Simulation. In: S Cotin, D Metaxas, editors. *Medical Simulation*. Berlin, Heidelberg: Springer (2004). p. 185–92. Lecture Notes in Computer Science.
15. Kirkpatrick JD. *Kirkpatrick's Four Levels of Training Evaluation*. Alexandria, VA: ATD Press (2016). p. 256.
16. Mahvash M, Hayward V. High Fidelity Haptic Synthesis of Contact With Deformable Bodies. *IEEE Comput Graphics Appl* (2004) 24:48–55. doi: 10.1109/MCG.2004.1274061
17. Lelevé A, McDaniel T, Rossa C. Haptic Training Simulation. *Front Virtual Real* (2020) 1:3. doi: 10.3389/frvir.2020.00003
18. Griffin M, Premakumar Y, Seifalian A, Butler PE, Szarko M. Biomechanical Characterization of Human Soft Tissues Using Indentation and Tensile Testing. *J Vis Exp* (2016) 118):e54872. doi: 10.3791/54872
19. Favier V, Gallet P, Ferry O, Jehl J-P. Spherical Depth-Sensing Nanoindentation of Human Anterior Skull Base Bones: Establishment of a Test Protocol. *J Mech Behav Biomed Mater* (2020) 110:103954. doi: 10.1016/j.jmbbm.2020.103954
20. Joice P, Ross PD, Wang D, Abel EW, White PS. Measurement of Osteotomy Force During Endoscopic Sinus Surgery. *Allergy Rhinol (Providence)* (2012) 3 (2):ar.2012.3.0032. doi: 10.2500/ar.2012.3.0032
21. Favier V, Zemiti N, Caravaca Mora O, Subsol G, Captier G, Lebrun R, et al. Geometric and Mechanical Evaluation of 3D-Printing Materials for Skull Base Anatomical Education and Endoscopic Surgery Simulation - A First Step to Create Reliable Customized Simulators. *PloS One* (2017) 12(12):e0189486. doi: 10.1371/journal.pone.0189486
22. Barrie J, Russell L, Hood AJ, Jayne DG, Neville A, Culmer PR. An *In Vivo* Analysis of Safe Laparoscopic Grasping Thresholds for Colorectal Surgery. *Surg Endosc* (2018) 32(10):4244–50. doi: 10.1007/s00464-018-6172-6

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Surgery

ORIGINAL RESEARCH
published: 17 August 2021
doi: 10.3389/fsurg.2021.698774

The Effectiveness of Self-Instructional Video vs. Classroom Teaching Method on Focused Assessment With Sonography in Trauma Among House Officers in University Hospital

*Mohd Hisham Isa[1], Kristina Lim[2], Mohd Johar Jaafar[1] and Ismail Mohd Saiboon[1]**

[1] Department of Emergency Medicine, Faculty of Medicine, Universiti Kebangsaan Malaysia, Kuala Lumpur, Malaysia,
[2] Emergency and Trauma Department, Hospital Raja Permaisuri Bainun, Ipoh, Malaysia

OPEN ACCESS

Edited by:
Hakan Kulacoglu,
Ankara Hernia Center, Turkey

Reviewed by:
Ulf Kessler,
Hirslanden Clinique Cecil, Switzerland
Kamarul Aryffin Baharuddin,
Universiti Sains Malaysia
(USM), Malaysia

***Correspondence:**
Ismail Mohd Saiboon
fadzmail69@yahoo.com.my

Specialty section:
This article was submitted to
Visceral Surgery,
a section of the journal
Frontiers in Surgery

Received: 22 April 2021
Accepted: 23 July 2021
Published: 17 August 2021

Citation:
Isa MH, Lim K, Jaafar MJ and Mohd Saiboon I (2021) The Effectiveness of Self-Instructional Video vs. Classroom Teaching Method on Focused Assessment With Sonography in Trauma Among House Officers in University Hospital.
Front. Surg. 8:698774.
doi: 10.3389/fsurg.2021.698774

Background: The aim of this study was to compare the effectiveness of self-instructional-video (SIV) and classroom training method (CTM) in learning Focus-Assessment with Sonography-in-Trauma (FAST) among house officers (HO).

Method: A randomized controlled study involving house officers working in the university hospital in Malaysia was conducted where participants were randomized into SIV group (intervention) and CTM group (control). Each group had to undergo a 4 h hands-on training. The intervention group has undergone self-training using the video material without any facilitation while the control group received lecture and hands-on training with facilitators. Participants' performance was assessed using a validated Objective Structured Clinical Examination checklist for landmark identification and interpretation of images generated. Learning preference and confidence level were also assessed.

Result: A total of 33 HO were enrolled in this study. Marks obtained in image acquisition by the intervention and control were 25.3 (SD = 5.3) and 25.6 (SD = 2.3) $p > 0.05$, respectively. While in image interpretation, the mean score for the intervention and control group was 10.3 (SD 1.7) and 9.8 (SD = 1.7) $p > 0.05$, respectively. Overall performance assessment, showed the intervention group obtained 35.6 (SD = 5.9) compared to control 35.3 (SD = 3.4), $p > 0.05$. Based on pre-specified determinant these scores difference falls within the 10% of non-inferiority margin. The absolute difference between both groups was 0.3 (CI = −3.75 to 3.21, $p = 0.871$), which proves non-inferiority but not superiority. In terms of learning preference and confidence to perform FAST, most of the participants preferred the control group approach.

Conclusion: The SIV method is as effective as the CTM for learning FAST among the house officers and served as an alternative to classroom teaching. However, this technique needs improvement in promoting their confidence and preference. Perhaps incorporating a feedback session after going through the SIV would improve the confidence.

Keywords: focused assessment with sonography in trauma, education, self-directed learning, simulation, self-instructional video

INTRODUCTION

Focused Assessment with Sonography in Trauma (FAST) is a protocol used to detect hemoperitoneum and hemopericardium using ultrasonography in trauma cases (1). It has long been used as an adjunct in primary survey and even adapted in the Advanced Trauma Life Support (ATLS) algorithm since 2007 (2, 3). Although ultrasonography is not the gold standard for diagnosing intra-abdominal injury, it became popular due to its portability, ease of use and capability to be performed repeatedly without concerns of radiation exposure (4, 5). FAST is routinely done for trauma cases in the emergency department (1, 5).

Currently most ultrasound courses are conducted face-to-face in a classroom with hands-on practice. The classroom teaching method (CTM) requires a qualified instructor to deliver a didactic classroom session followed by hands-on training using patients with findings or simulated patients without findings. Incorporating simulation as a teaching modality is the way by which health educators can bridge the existing gaps (6). An ultrasound simulator may be used to conduct such training, but it is expensive. FAST usually requires long hours of training and is not easy to arrange for a large crowd, especially when time and resources are limited. Besides that, participants may be pressured to keep up with their peers' pace in a classroom teaching since it is usually done only once (7, 8). Hence some might find it challenging to fully benefit from classroom learning, especially when it involves participants from different educational backgrounds and experiences such as doctors from different specialities, nurses and paramedics. Lack of a clinical instructor to teach the skill is also another problem (9). Due to the increasing need for healthcare professional manpower, the ratio of instructor to trainees has increased, placing more burden on the instructor in terms of time and responsibility (10).

There are newer teaching modalities that has been proposed such as incorporating the use of video-assisted learning through self-instructional video (SIV) with ultrasound simulators for hands-on training to teach sonographic skills (7, 8). The impact of this method is not limited to reducing the need for the instructor's presence, but also enabling participants to review the video for learning at their own time and pace, allowing a more relaxed learning environment (10, 11). Hence, participants do not have to worry about keeping up with the instructor's or the other participants' pace during the lecture (7, 12). The impact is enhanced during the COVID-19 pandemic, when it is harder to conduct a classroom training course due to strict measures laid down by the authorities in line with lockdowns or Movement Control Orders (13). SIV is also gaining better acceptance as a tool for learning sonographic skills as evidenced by the use of videos in online courses. The technology is readily available and can be easily accessed and viewed from gadgets such as laptops and smartphones (14, 15).

Several studies have been conducted to evaluate the effectiveness of SIV in teaching clinical procedures where the main benefit lies in its flexibility (8, 10). The module is also easily repeatable and can compensate for the lack of instructor and time (8, 12). A previous study showed that an animated video can be an effective teaching tool (16). SIV has been used to teach senior doctors or specialists of certain specialties such as anaesthesiology and pediatric emergency medicine (8, 17). However, teaching sonographic procedures such as FAST via SIV to junior house officers or doctors has not been thoroughly investigated. In our study, we aim to evaluate the effectiveness of teaching FAST using SIV compared with face-to-face CTM among house officers. It is hoped that more healthcare professionals can be trained effectively to perform FAST using SIV.

METHODS

We conducted a prospective randomized interventional study in a university hospital in Kuala Lumpur, Malaysia from 1st June 2019 to 30th January 2020. We enrolled house officers from various departments in the hospital except from the emergency department. None of them had undergone formal training for FAST or abdominal ultrasonography. In this study we developed a self-directed-learning-package (SDLP) for FAST and evaluated the effectiveness of the FAST SDLP in terms of confidence and preference using a validated questionnaire. Psychomotor skills were evaluated using Objective Structured Clinical Examination (OSCE).

The Intervention

Development of Self-Directed Learning Package

The SDLP consists of a video lecture and a self-instructional video (SIV). The video lecture introduces the ultrasound machine, learning objectives, knobology, and the ultrasound probes. The SIV, on the other hand, shows the psychomotor skills involved in performing FAST, and interpretation of the images. These videos were developed by a team from our department of emergency medicine. The videos were then edited using VideoPad Video Editor V10.04 (NCH Software, Canberra Australia). Simulation of the FAST was performed on a simulated patient. The same content was also prepared in PowerPoint slides for the classroom learning group. Both learning material were validated by senior lecturers and emergency physicians from the university hospital who are trainers for the FAST course in emergency medicine faculty.

Assessment Tools

The questionnaire evaluates the participants' socio-demography, confidence in performing FAST, and preference of learning FAST. For the confidence, a 5-point Likert scale was used whereas a close ended question was for the preferences. The content of the questionnaire was validated by senior emergency physicians. Internal consistency reliability testing was done using statistical analysis and the alpha score obtained for our questionnaire was 0.75. The OSCE checklist used for assessing the participants' proficiency in performing FAST was created based on standard FAST protocol. It was reviewed and validated by an expert panel comprising of two emergency physicians.

Participant Enrolment

An invitation to participate in this study was forwarded to all house officers ($n = 235$) in HCTM from 6 departments (internal medicine, surgery, orthopedic, pediatric, and anaesthesiology). Those that agreed to join the study were given instructions via email on how to proceed with the study. Those who undergone formal ultrasound training for FAST or abdominal ultrasound or who did not give consent were excluded. Selected participants were then randomized into two parallel groups: the SIV group (intervention) and, the CTM group (control). The randomization was done using table of random numbers. Allocation of the participants into the 2 groups was done via a sealed envelope by the investigator (LK).

Study Protocol

Participants in the intervention group was given the video on FAST after they were assigned to their smaller groups. They were advised to go through the video from the beginning until the end at least once before they proceed with hands-on training. They were allocated 4 h in the training room to learn and practice using the video given on all five simulated patients for that day. There were no facilitators assigned to guide the intervention group participants. The intervention duration was decided based on our literature review and actual courses conducted for FAST (4, 18).

Meanwhile, the control group received a lecture delivered by an emergency medicine resident, followed by hands-on training on 5 simulated patients. Image acquisition and interpretation were guided by facilitators. The participants must perform on all 5 simulated patients. The total time allocated for teaching and practice was 4 h.

Assessment was done on the same day as the practice using the validated OSCE and questionnaire. Two stations were prepared. Station 1 was to test their ability to obtain the four images in FAST (the hepatorenal view, splenorenal view, pelvic view, and subxiphoid view) while station 2 was to test their ability to interpret the FAST images (normal and abnormal). The test was performed on the same stimulated patients that were used for the hands-on training. The assessors were blinded from the teaching method that the participants received. Each station was allocated 10 min for the participants to complete their tasks. Upon completion of the OSCE, the participants were given a post-test questionnaire to complete and allowed home. The participants on the first day were strongly advised not to share any information with their peers that were attending the next day. Participants for both days were mixed of the intervention and control groups.

Outcome Measurement

The primary outcome measures were the ability of the participants to obtain the four images in FAST, and their ability to interpret the images with normal and abnormal findings. Both outcomes were measured based on the OSCE checklist. Secondary outcome measures were the participants' learning preference and the confidence level to perform FAST. The scores were based on a five-point Likert scale. The maximum score for the OSCE was 32 marks, whereas for image acquisition it was 14 marks.

Sample Size

The sample size was calculated based on the non-inferiority trials with continuous variables (Sealed Envelope Ltd, 2012), using a significance level of 5%, power of 90%, standard deviation, σ of 9.3 and a non-inferiority limit δ of 10%. This gave a sample size of 15 per arm. In order to adjust for an estimated dropout rate of 20%, we aimed to recruit 18 participants per arm. The standard deviation was based on results from a previous study on video-based learning (12). The non-inferiority limit was based on similar studies (8, 12).

Calibration of Assessors

The OSCE assessors comprised emergency physicians and senior emergency medicine residents trained and certified to perform FAST in their daily practice. They were invited to join the inter-rater calibration session conducted prior to the assessment. The examiners were briefed on the study objective, their roles and the OSCE checklist. After the briefing, they were shown images and video clips of other medical interns performing FAST and asked to evaluate the videos based on the checklist given. Upon completion, the results and crucial steps were discussed to clear any confusion and ensure unanimity among their evaluation during data collection. The intra-class correlation (ICC) score calculated for all five assessors was 0.69 with confidence interval set at 95%.

Statistical Analysis

Statistical analysis was carried out using Statistical Packages for Social Science (SPSS), version 22.0 (IBM Armonk, NY). The data obtained from the questionnaire were analyzed using descriptive statistics. Mann Whitney U-test was applied for questions with the Likert scale. We defined a p-value of <0.05 as statistically significant. Normality of the variable distributions was determined using Shapiro-Wilk test. Descriptive analyses were done on the OSCE results and expressed as mean and standard deviation. The scores from both groups were compared using independent Students t-test and Mann Whitney U-test. To determine the non-inferiority of the video intervention group, the results were plotted in a graph to compare the upper bound of the confidence interval to the non-inferiority margin. The non-inferiority margin was set at 10% based on previous studies to compare classroom-based learning with video-based learning (8, 12).

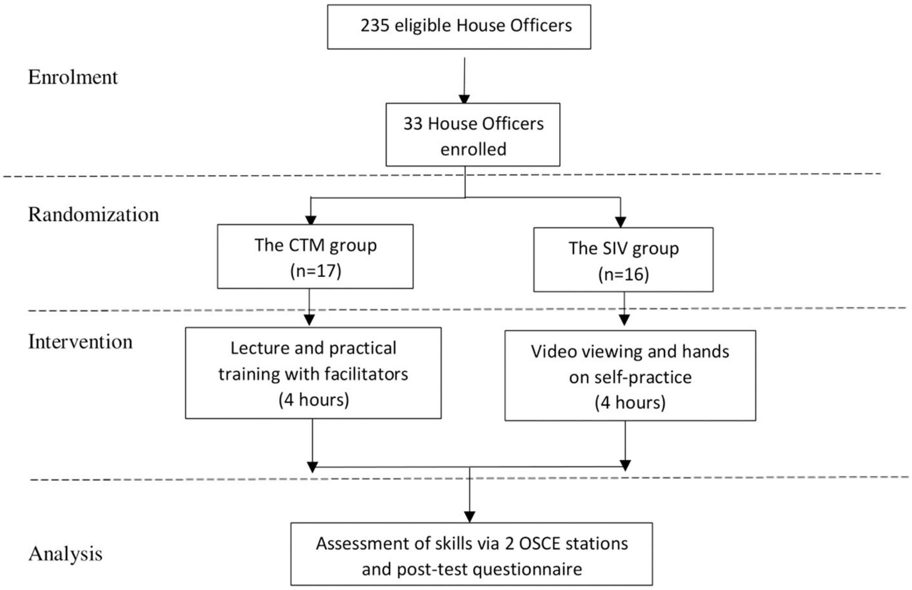


FIGURE 1 | Study flow chart according to CONSORT guidelines.

TABLE 1 | Baseline characteristics of participants from both groups.

Variable	SIV group (N = 16) n (%)	CTM group (N = 17) n (%)	p-value
Gender			
Male	8 (50)	6 (35)	0.491
Female	8 (50)	11 (65)	
Work experience			
1st year HO	10 (63)	15 (88)	0.118
2nd year HO	6 (37)	2 (12)	
Prior experience with video learning			
Yes	15 (94)	12 (71)	0.175
No	1 (6)	5 (29)	
Prior exposure to ultrasound training			
Yes	2 (13)	2 (12)	1.000
NO	14 (87)	15 (88)	

SIV, self-instructional video; CTM, conventional training method; HO, House-officer.

TABLE 2 | Assessment of OSCE results after intervention.

	SIV group (n = 16)	CTM group (n = 17)	p-value[b]	Mean score difference
Mean Station 1[a] performing FAST (SD) [Total marks 31]	25.3 (5.3)	25.6 (2.3)	0.845	0.3
Mean Station 2[a] interpret images (SD) [Total marks 14]	10.3 (1.7)	9.8 (1.7)	0.359	0.5
Mean Total OSCE score[a] (SD) [Total marks 45]	35.6 (5.9)	35.3 (3.4)	0.871	0.3

SIV, self-instructional video; CTM, conventional training method; OSCE, objective structured clinical examination; FAST, focused assessment with sonography in trauma.
[a]Data reported as mean score (standard deviation).
[b]P-value is reported with 95% confidence interval.

RESULTS

Out of 235 potential recruits, 38 house officers volunteered to participate. Only 33 were enrolled based on inclusion and exclusion criteria of this study. Sixteen were in the intervention and 17 in the control groups (**Figure 1**). The participants were between 25 and 35 years of age. Four out of 33 participants (12%) had prior exposure to ultrasound courses covering obstetric ultrasound and vascular access but did not fulfill the exclusion criteria. None of our participants had prior learning on FAST or prior experience performing FAST. There were no significant demographic differences between these two groups with the $p > 0.05$ as shown in **Table 1**.

For FAST performance in image acquisition (**Table 2**), the control group mean score was 25.6 (SD = 2.3) while the intervention group scored 25.3 (SD = 5.3). However, there was no significant difference between groups ($p > 0.05$). In image interpretation, the intervention group mean score was 10.3 (SD = 1.7) and 9.8 (SD = 1.7) for the control with no statistically significant difference ($p > 0.05$). Total mean scores for the intervention and control groups were 35.6 (SD = 5.9) and 35.3 (SD = 3.4), respectively. The absolute difference between the mean score of the two groups was 0.3 (CI = −3.75 to 3.21, $p = 0.871$), hence according to **Figure 2**, it only proves non-inferiority but not superiority between the two groups.

In terms of learning method preference, 22 (67%) participants favored the control group. The details of

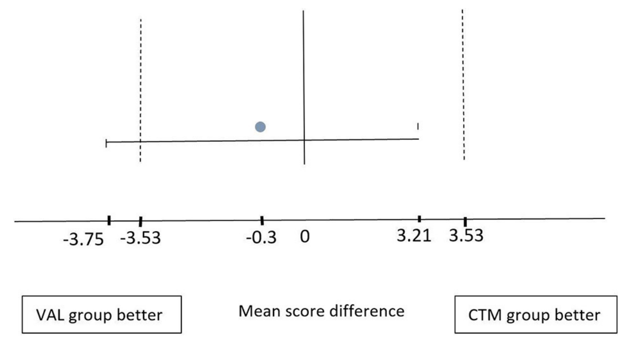


FIGURE 2 | Mean-score difference graph demonstrating that the 10% confidence interval (CI) mean score of the control group is between −3.53 and 3.53 (dotted line). The absolute difference of the mean score between both groups is negative −0.3 (gray bullet). The intervention group mean score CI is between −3.75 and 3.21 (continuous line). The upper bound of CI is within the 10% difference margin. This shows the non-inferiority of the OSCE score of the intervention group compared to control.

TABLE 3 | Summary of response from participants regarding their confidence level and preferred learning method.

	SIV group (n = 16) n (%)	CTM group (n = 17) n (%)	p-value
Preferred learning method[c]			
Classroom	12 (80)	10 (84)	
Video	2 (13)	1 (8)	1.000
Both	1 (7)	1 (8)	
Not applicable [a]	1	5	
Possibility to learn skills through video[c]			
Yes	15 (94)	14 (82)	0.229
No	0 [b]	3 (19)	
My knowledge level on FAST is adequate after training[d]			
Disagree	0	0	**0.014**
Neutral	5 (31)	2 (12)	
Agree	11 (69)	9 (53)	
Strongly agree	0	6 (35)	
I am confident in performing FAST after training[d]			
Disagree	1 (6)	0	**0.002**
Neutral	6 (38)	0	
Agree	8 (50)	11 (65)	
Strongly agree	1 (6)	6 (35)	
I am confident in interpreting images obtained in FAST[d]			
Disagree	2 (13)	0	
Neutral	8 (50)	2 (12)	**0.002**
Agree	5 (31)	10 (59)	
Strongly agree	1 (6)	5 (29)	
I will perform FAST on real patients[d]			
Disagree	0	0	
Neutral	4 (25)	0	0.720
Agree	7 (44)	8 (47)	
Strongly agree	5 (31)	9 (53)	

[a] *5 participants did not answer this question because they never had video learning and 1 missing data, these 6 samples were not included in the analysis.*
[b] *1 missing data.*
[c] *Fisher Exact test.*
[d] *Mann Whitney U-test.*

findings in the control and intervention groups are shown in **Table 3**.

All participants in the control group were confidence to perform FAST as compared to only 9 (56%) in the intervention group. In the control group, the majority (15, 88%) were confident to interpret the images obtained while performing FAST, whereas only 6 (38%) in the intervention group expressed confidence. The differences in confidence to perform FAST and to interpret images between the two groups were statistically significant ($p < 0.05$) (**Table 3**).

All participants (100%) in the control group and 12 (75%) in the intervention group were willing to perform FAST on real patients, however this difference was not statistically significant ($p > 0.05$) (**Table 3**).

DISCUSSION

Video learning has been used in various medical fields to teach clinical procedures and impart knowledge with good outcomes (19, 20). Our findings reaffirm previous reports. In this study, the intervention group showed similar efficacy compared to the control group for learning FAST. This leads us to conclude that SIV made it possible for house officers to learn FAST, indicated by non-inferior marks on their performance as compared to the control group. The OSCE score in both learning groups was within the 10% difference margin pre-specified before the intervention. In fact, the marks in the intervention group were higher than the control group, although the difference was not statistically significant. The comparable OSCE results between these two groups shows that, despite a shorter course duration and the absence of on-site instructor guidance, the intervention group was still capable of performing within the allocated time.

Our evidence is in keeping with results obtained from various studies that compared traditional classroom learning with video learning of sonographic skills (21, 22), indicating that it is possible for medical instructors to incorporate video learning into their curriculum. Many studies have clearly demonstrated that modern teaching techniques facilitate training and student achievement (23, 24). Students are given more responsibility to ensure their learning is complete and they share the instructors' burden. They are provided the opportunity to do this at their own pace and in the environment of their choice (10, 12). This is beneficial especially for house officers with long working hours and inflexible schedules. A study by Woodham et al. (25) reported that both trainees and tutors felt that video learning delayed the learning process. Conversely, in our study, the two groups underwent learning within the same time frame and produced similar results, which means that SIV does not necessarily prolong the learning process.

In the survey among our participants, 82% stated their preference for CTM over SIV although they had prior experience with video learning for other skills during their undergraduate years. Even among our intervention SIV group, 75% participants still preferred CTM. Interestingly, 92% of those with video learning experience agreed that it is possible to learn skills using SIV although the majority preferred CTM.

Based on these findings, we present three important points. Firstly, SIV is ubiquitous (26). This is implied from the widespread availability of the internet, hence all information and resources are easily accessible through gadgets such as computers and smartphones. Our participants were house officers who are mostly in their late twenties, hence they are most likely to be familiar with the use of the internet to gain information, being digital natives. Furthermore, many medical universities have embedded video learning or e-learning into their curriculum (14). Our participants were likely to have been exposed to these alternative learning methods as medical undergraduates.

Secondly, performing FAST is a complex learning procedure. Despite that, SIV was capable of imparting psychomotor skills to the participants as shown by the marks obtained, which were better than the control group albeit statistically insignificant. This evidence was previously supported by the advantage of SIV in teaching the complex skills of endotracheal intubation among medical students (27).

Thirdly despite being receptive to video learning, most participants prefer CTM for gaining new skills. Soon et al. (8) postulated that their participants favored CTM because they were mostly of older age with a median of 7 years' work experience. The actual age range was, however, not stated. Interestingly, our findings were different from theirs. Our participants were of a younger age with only 1–2 years' work experience, yet their preference was CTM. We attributed this finding to the lack of confidence in SIV.

Based on our questionnaire results, the intervention group was less confident in performing FAST and interpreting the images as compared to the control group. However, we did not reveal the assessment outcome of both groups to the participants. We did not explore the possibility of them changing their perception if they had known the primary outcome of this study. Similarly, we did not explore the reason why our participants preferred classroom learning over video learning. We postulated that it might be due to lack of feedback from an instructor, making the intervention group participants unsure if they were performing correctly. Students often use feedback they received in order to guide further learning direction and effort, especially from their tutors or instructors (28). As other authors have observed, the use of feedback correlates positively with exam scores (29). Sekiguchi et al. (11) also emphasized the importance of hands-on training with supervision because their participants scored lower than expected prior to training with supervision. This differs from the findings in other studies. Soon et al. (8) reported that the comfort level was similar in both intervention arms post-test. Back et al. (7), reported a significant increase in confidence score after ultrasound video tutorial. However, their study did not have a comparison arm. We looked into the literature for other obstacles that might be the reason for our participants' preference for CTM over SIV. In a qualitative study on teaching clinical skills to nurses, students highlighted the need to talk to a tutor or instructor especially when learning a new skill (29, 30).

Video learning is largely dependent on the students themselves. They need to analyze and extract information from the video themselves, which may make the learning process more challenging compared to classroom learning by a tutor (29, 30). Overall, most participants in our study were receptive toward video learning and agreed that video was a good learning tool especially for skills and procedures. There are weaknesses in video learning, including the need for customization to suit students' needs (31). For example, our video had visual and audio prompts, and labeling on the images, but no closed captioning. The use of closed captioning might improve audience understanding of the content.

The strength of our study is the full utilization of the video material to test its effectiveness. Participants were not given any other guidance to learn FAST until after the data collection was completed. We standardized the learning conditions between the intervention and control groups, including the learning material, time for learning the material given, the venue, and the ultrasound scanner, in order to allow a fair comparison. We selected participants who are not skilled in performing FAST in order to get a homogenous sample. This allowed us to better evaluate the effect of the learning methods used with fewer confounding factors.

Limitations

There were several limitations in this study. Firstly, the participants' satisfaction level, perception of SIV for training of sonographic skills, and their reasons for preference for the learning method, were all not explored. A mixed methods study might reveal a better understanding of the participants' response. Further study to glean such information will enable medical instructors to better cater for students' needs. Secondly, the small sample size was contributed by difficulties in enrolment of house officers into the study. We found the majority of them had already learned FAST through on-job-training. Another contributing factor was the limited time available among house officers and the inflexibility of their work schedule. Future studies with a larger sample size are needed to provide a more generalizable interpretation of results. Finally, this study used an asynchronous non-feedback video teaching approach, therefore participants could not air or voice their queries or concern.

CONCLUSION

Our study showed that SIV is as effective as face-to-face classroom method in teaching house officers to perform FAST. However, this learning tool needs improvement in order to promote house officers' confidence and preference. Perhaps the inclusion of a feedback session after going through the SIV would help improve their confidence in performing FAST and interpreting the images.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Medical Ethic and Research Committee of Universiti Kebangsaan Malaysia (Ethic Approval no: JEP-2019-269. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

IMS involved in the study concept, data interpretation, and writing. MHI involved in the study concept, data collection, data interpretation, and writing. KL involved in data collection, data interpretation, and writing. MJJ involved in conceptual and data interpretation. All authors contributed to the article and approved the submitted version.

FUNDING

This study was funded by the Fundamental Research grant of PPUKM. The research grant number is FF-2019-284.

ACKNOWLEDGMENTS

The authors would like to acknowledge staff of the Department of Emergency Medicine HCTM for their support toward accomplishing this study and the Faculty of Medicine, Universiti Kebangsaan Malaysia, for funding this study through a short-term grant (FF-2019-284).

REFERENCES

1. Beck-Razi N, Gaitini D. Focused assessment with sonography for trauma. *Ultrasound Clin.* (2008) 3:23–31. doi: 10.1016/j.cult.2007.12.009
2. Richards JR, McGahan JP. Focused assessment with sonography in trauma (FAST) in 2017: what radiologists can learn. *Radiology.* (2017) 283:30–48. doi: 10.1148/radiol.2017160107
3. Salen PN, Melanson SW, Heller MB. The focused abdominal sonography for trauma (FAST) examination: considerations and recommendations for training physicians in the use of a new clinical tool. *Acad Emerg Med.* (2000) 7:162–8. doi: 10.1111/j.1553-2712.2000.tb00521.x
4. Mohammad A, Hefny AF, Abu-Zidan FM. Focused assessment sonography for trauma (FAST) training: a systematic review. *World J Surg.* (2014) 38:1009–18. doi: 10.1007/s00268-013-2408-8
5. Pearl WS, Todd KH. Ultrasonography for the initial evaluation of blunt abdominal trauma: a review of prospective trials. *Ann Emerg Med.* (1996) 27:353–61. doi: 10.1016/S0196-0644(96)70273-1
6. Mahdy ZA, Maaya M, Atan IK, Abd Samat AH, Isa MH, Saiboon IM. Simulation in Healthcare in the Realm of Education 4.0 (Simulasi dalam Penjagaan Kesihatan di Alam Pendidikan 4.0). *Sains Malaysiana.* (2020) 49:1987–93. doi: 10.17576/jsm-2020-4908-21
7. Back SJ, Darge K, Bedoya MA, Delgado J, Gorfu Y, Zewdneh D, et al. Ultrasound tutorials in under 10 minutes: experience and results. *Am J Roentgenol.* (2016) 207:653–60. doi: 10.2214/AJR.16.16402
8. Soon AW, Toney AG, Stidham T, Kendall J, Roosevelt G. Teaching point-of-care lung ultrasound to novice pediatric learners: web-based e-learning versus traditional classroom didactic. *Pediatr Emerg Care.* (2020) 36:317–21. doi: 10.1097/PEC.0000000000001482
9. Baribeau Y, Sharkey A, Chaudhary O, Krumm S, Fatima H, Mahmood F, et al. Handheld point-of-care ultrasound probes: the new generation of POCUS. *J Cardiothorac Vasc Anesth.* (2020) 34:3139–45. doi: 10.1053/j.jvca.2020.07.004
10. Mohd Saiboon I, Jaafar MJ, Ahmad NS, Nasarudin NM, Mohamad N, Ahmad MR, et al. Emergency skills learning on video (ESLOV): A single-blinded randomized control trial of teaching common emergency skills using self-instruction video (SIV) versus traditional face-to-face (FTF) methods. *Med Teach.* (2014) 36:245–50. doi: 10.3109/0142159X.2013.857013
11. Sekiguchi H, Bhagra A, Gajic O, Kashani KB. A general Critical Care Ultrasonography workshop: results of a novel Web-based learning program combined with simulation-based hands-on training. *J Crit Care.* (2013) 28:217.e7–12. doi: 10.1016/j.jcrc.2012.04.014
12. Chenkin J, Lee S, Huynh T, Bandiera G. Procedures can be learned on the Web: a randomized study of ultrasound-guided vascular access training. *Acad Emerg Med.* (2008) 15:949–54. doi: 10.1111/j.1553-2712.2008.00231.x
13. Isa M, Abd Samat AH, Mohd Saiboon I. The preparation, delivery and outcome of COVID-19 pandemic training program among the Emergency Healthcare Frontliners (EHFs): the Malaysian teaching hospital experience. *Med Health*. (2020). 15:250–65. doi: 10.17576/MH.2020.1501.23
14. Rasmussen K, Belisario JM, Wark PA, Molina JA, Loong SL, Cotic Z, et al. Offline eLearning for undergraduates in health professions: a systematic review of the impact on knowledge, skills, attitudes and satisfaction. *J Glob Health.* (2014) 4:010405. doi: 10.7189/jogh.04.010406
15. Wutoh R, Boren SA, Balas EA. eLearning: a review of Internet-based continuing medical education. *J Contin Educ Health Prof.* (2004) 24:20–30. doi: 10.1002/chp.1340240105
16. Isa M, Shamsuriani M, Afliza A, Tan T, Dazlin Masdiana S, Fadzlon M, et al. Comparing teachers and medical students as trainers of cardiopulmonary resuscitation (CPR) among secondary school students. *Med Health.* (2019) 14:180–8. doi: 10.17576/MH.2019.1402.16
17. Edrich T, Stopfkuchen-Evans M, Scheiermann P, Heim M, Chan W, Stone MB, et al. A comparison of web-based with traditional classroom-based training of lung ultrasound for the exclusion of pneumothorax. *Anesth Analg.* (2016) 123:123–8. doi: 10.1213/ANE.0000000000001383
18. McCallum J, Vu E, Sweet D, Kanji HD. Assessment of paramedic ultrasound curricula: a systematic review. *Air Med J.* (2015) 34:360–8. doi: 10.1016/j.amj.2015.07.002
19. Tarpada SP, Hsueh WD, Gibber MJ. Resident and student education in otolaryngology: a 10-year update on e-learning. *Laryngoscope.* (2017) 127:E219–e24. doi: 10.1002/lary.26320
20. Assadi T, Mofidi M, Rezai M, Hafezimoghadam P, Maghsoudi M, Mosaddegh R, et al. The comparison between two methods of basic life support instruction: video self-instruction versus traditional method. *Hong Kong J Emerg Med.* (2015) 22:291–6. doi: 10.1177/102490791502200505
21. Bertran S, Boby H, Bertrand PM, Pereira B, Perbet S, Lautrette A. Comparison of video-based learning and lecture-based learning for training of ultrasound-guided central venous catheterization: a randomized controlled trial. *Br J Anaesth.* (2017) 118:628–30. doi: 10.1093/bja/aex059
22. Eimer C, Duschek M, Jung AE, Zick G, Caliebe A, Lindner M, et al. Video-based, student tutor- versus faculty staff-led ultrasound course for medical students - a prospective randomized study. *BMC Med Educ.* (2020) 20:512. doi: 10.1186/s12909-020-02431-8
23. Ganyaupfu EM. Teaching methods and students' academic performance. Int J Humanit Soc Sci Invent. (2013) 2:29–35.
24. Moqaddam PS. Investigating the effect of modern teaching methods on students' educational progress (Case Study: Sama1 Boys Elementary School, Ghaemshahr City). *Mediterranean J Soc Sci.* (2016) 7:253. doi: 10.5901/mjss.2016.v7n3s3p253
25. Woodham LA, Ellaway RH, Round J, Vaughan S, Poulton T, Zary N. Medical student and tutor perceptions of video versus text in an interactive online virtual patient for problem-based learning: a pilot study. *J Med Internet Res.* (2015) 17:e151. doi: 10.2196/jmir.3922
26. Kugali SN, Natekar DS, Nandeshwar S, Prabhu R, Panduranga A, Pavitra B, et al. An effectiveness of self instructional module on knowledge regarding effects of computer vision among office staff working in selected organization of B.V.V. Sangha Bagalkot. *Int J Innov Sci Res Technol.* (2019) 4:254–60.

27. Saiboon IM, Musni N, Daud N, Shamsuddin NS, Jaafar MJ, Hamzah FA, et al. Effectiveness of self-directed small-group-learning against self-directed individual-learning using self-instructional-video in performing critical emergency procedures among medical students in Malaysia: a single-blinded randomized controlled study. *Clin Simul Nurs*. (2021) 56:46–56. doi: 10.1016/j.ecns.2021.02.006
28. Taras M. The use of tutor feedback and student self-assessment in summative assessment tasks: towards transparency for students and for tutors. *Assess Eval Higher Educ.* (2001) 26:605–14. doi: 10.1080/02602930120093922
29. Brown GT, Peterson ER, Yao ES. Student conceptions of feedback: impact on self-regulation, self-efficacy, and academic achievement. *Br J Educ Psychol.* (2016) 86:606–29. doi: 10.1111/bjep.12126
30. Barisone M, Bagnasco A, Aleo G, Catania G, Bona M, Gabriele Scaglia S, et al. The effectiveness of web-based learning in supporting the development of nursing students' practical skills during clinical placements: a qualitative study. *Nurse Educ Pract.* (2019) 37:56–61. doi: 10.1016/j.nepr.2019.02.009
31. Roshier AL, Foster N, Jones MA. Veterinary students' usage and perception of video teaching resources. *BMC Med Educ.* (2011) 11:1. doi: 10.1186/1472-6920-11-1

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

frontiers in Medicine

DATA REPORT
published: 20 September 2021
doi: 10.3389/fmed.2021.742071

Data Report: "Health care of Persons Deprived of Liberty" Course From Brazil's Unified Health System Virtual Learning Environment

Janaína Valentim[1,2], Eloiza da S. G. Oliveira[1,3], Ricardo A. de M. Valentim[1], Sara Dias-Trindade[4], Aline de Pinho Dias[1], Aliete Cunha-Oliveira[2,5], Ingridy Barbalho[1], Felipe Fernandes[1], Rodrigo Dantas da Silva[1], Manoel Honorio Romão[1], César Teixeira[6] and Jorge Henriques[6]*

[1] Laboratory of Technological Innovation in Health, Federal University of Rio Grande Do Norte, Natal, Brazil, [2] Univ Coimbra, Centre for Interdisciplinary Studies of the 20th Century, Coimbra, Portugal, [3] Multidisciplinary Institute for Human Development With Technologies, State University of Rio de Janeiro (UERJ), Rio de Janeiro, Brazil, [4] Univ Coimbra, Centre for Interdisciplinary Studies of the 20th Century (CEIS20), Faculty of Arts and Humanities (DHEEAA), Coimbra, Portugal, [5] Health Sciences Research Unit: Nursing (UICISA: E), School of Nursing of Coimbra (ESEnfC), Coimbra, Portugal, [6] Univ Coimbra, Centre for Informatics and Systems of the University of Coimbra, Department of Informatics Engineering, Coimbra, Portugal

OPEN ACCESS

Edited by:
Zaleha Abdullah Mahdy, National University of Malaysia, Malaysia

Reviewed by:
Daniel Rainkie, Qatar University, Qatar
Seng Fah Tong, National University of Malaysia, Malaysia

****Correspondence:***
Janaína Valentim
janaina.lrsv@lais.huol.ufrn.br

Specialty section:
This article was submitted to Healthcare Professions Education, a section of the journal Frontiers in Medicine

Received: *15 July 2021*
Accepted: *25 August 2021*
Published: *20 September 2021*

Citation:
Valentim J, Oliveira EdSG, Valentim RAdM, Dias-Trindade S, Dias AdP, Cunha-Oliveira A, Barbalho I, Fernandes F, Silva RDd, Romão MH, Teixeira C and Henriques J (2021) Data Report: "Health care of Persons Deprived of Liberty" Course From Brazil's Unified Health System Virtual Learning Environment. Front. Med. 8:742071. doi: 10.3389/fmed.2021.742071

Keywords: sexually transmitted infections, persons deprived of liberty, prisional system, education, SUS—Brazilian national health system

1. INTRODUCTION

The Brazilian prison system has a history of shortcomings related to lack of investments and infrastructure, leading to severe consequences for the entire prison population, such as problems related to fundamental guarantees of human rights, the lack of health care, and the rise in criminality rates (1–3). With almost the third-largest prison population (4), Brazil accumulates critical issues such as overcrowding, high internal violence indexes, and disease spread (5–7). Data from January to June 2019, from the National Survey of the Penitentiary Information System (Infopen)—Brazil's system of statistical information regarding correctional facilities, published by the National Penitentiary Department (8)—pointed out that the Brazilian prison population was 752,277. Thus, 31,742 people had some condition, 8,523 were HIV-positive, 6,920 had syphilis, 9,113 had tuberculosis, and 7,186 had other diseases.

We present a set of factors that characterize the population deprived of liberty as a vulnerable group to Sexually Transmitted Infections (STIs) (9). Among those that most affect this highly invisible population, Syphilis, HIV, and Tuberculosis are most prominent due to their fast spread and the challenges for diagnosing and accessing treatment (10–12). Yet, in this discouraging spectrum, hope still lingers. It is represented by public policies that genuinely serve such a population and human education aiming to develop its potential fully, including individuals who permeate the prison system in its totality, both those deprived of their liberty and professionals who work there.

Brazilian Prison System, we find such diseases, as mentioned above, quite often. Nevertheless, we believe this scenario can be changed. We believe in a scenario where those conditions can be efficiently avoided and their dissemination rate reduced. We consider that the development of educational resources is a strategy toward human education in health, both for professionals and the community in general. Our investment in education and training strategies is based on studies that indicate the need for educational measures to prevent and promote health care for people deprived of their liberty (13, 14). Taking into account that, besides the high prevalence of these infections in the prison system, we also face knowledge deficits on the subject, misperceptions, and peculiar conditions of imprisonment, which result in at-risk behaviors.

At the core of our observation, the first problem question arises: can a technology-based educational activity train professionals for syphilis and other STIs demands within the prison system? As an answer, we have established the first goal: constructing a data report through an object that combines the two previously mentioned strategies. Thus, (1) a public policy that emphasizes the Virtual Learning Environment of the Unified Health System (AVASUS, in Portuguese: Ambiente Virtual de Aprendizagem do Sistema Único de Saúde) and (2) the course on "Health care of Persons Deprived of Liberty" (15). AVASUS is a virtual learning space for healthcare professionals, students, and general society to enhance SUS training, management, and care. As for the course "Health care of Persons Deprived of Liberty" (ASPPL, in Portuguese: Atenção à Saúde da Pessoa Privada de Liberdade), its learning objectives are characterizing the prison population and introducing the central public policies aimed at this population, with substantial reflections for primary care practitioners. Together, these two resources develop skills that allow for comprehensive care for the person deprived of liberty.

Based on universality, equity and integrity, the ASPPL self-instructional course encompasses the legal and historical contexts of health care of the Brazilian prison population. Its 30-h workload is organized into four units. It focuses on the national prison assistance scenario, the main problems, and specific needs that affect incarcerated people, and the attributions of the Family Health Strategy team—ESF, in Portuguese: Estratégia de Saúde da Família—as to the welcoming and care of people deprived of liberty. The course methodology is based on a proposal of active learning through Problem-Based Learning, simulating real-life situations to stimulate the student's motivation to search for solutions as a starting point for acquiring and integrating new knowledge. In addition to problems, several resources are used, such as texts, animations, interactive timelines, infographics, videos, and games. Thus, it presents a training structure for health professionals to get to know and work in the Brazilian prison system and for the general population to get acquainted with the reality of the penitentiary system, chiefly actions developed in this context.

With the perspective of providing the appropriate content for health professionals and the general population, the course syllabus was produced by a team composed of experts in the field of knowledge and with great practical experience, selected through public notice and submitted to training specific. In the production process, the course was subjected to moments of quality assessment: (a) Technical-scientific assessment; (b) Pedagogical assessment; (c) Brazilian Association of Technical Standards (ABNT, in Portuguese: Associação Brasileira de Normas Técnicas) assessment (standardization) and Portuguese language; (d) Instructional design assessment; (e) Communication assessment; (f) Final evaluation of content writer. AVASUS' pedagogical team accompanies the content writer throughout the course's preparation process until its completion and availability on the platform, ensuring the balance of educational content for access by the target audience.

Then, a second question emerges: with the data of this course participants, is it feasible to measure or map trained professionals for the healthcare demands in the Brazilian prison system in Brazil? The data report we present to answer such question purposes to perform a descriptive analysis of ASPPL's data and provide a repository containing the set of participants' data so that the scientific community may contribute with further research. This repository contributes to the definition of scenarios that enable assessing the quality of health care in the Brazilian prison system and visualizing essential characteristics, such as profile and geographic location, related to the participants who took the course and to the health care facilities. In addition, it allows crossover with epidemiological data on STIs, enabling the analysis of the subject's causal relationship. Finally, the study of this dataset can also help adopt preventive measures that consequently contribute to a decrease in the transmission rate of STIs.

2. MATERIALS AND METHODS

2.1. Data Acquisition

The original data of the ASPPL course participants were extracted from AVASUS (15). Since course enrollment is continuously available, data collection comprises from the course's start date to the day of data collection, 06/07/2018 to 05/25/2021, respectively. Initially, the dataset is composed of 14 attributes and 4,861 instances. The attributes, except the unique identifier of the instances (id), correspond to the personal information of the course participants. These are as follows: gender; Brazilian Occupational Classification (CBO, in Portuguese: Classificação Brasileira de Ocupações); participant's occupation through CBO; occupation declared by the participant; course completion percentage; evaluation of the course in free text and on a satisfaction level scale ranging from 1 to 5; geographic location (Municipality and State); employment relationship(s); type(s) of health establishment(s), and whether these are linked or not to the prison system. Attribute types vary, i.e., they are multivalued, and 11 of them have missing values.

2.2. Data Processing

Original data was pre-processed through the pipeline described below. In addition, an organized version of the dataset suitable for exploratory data analysis by the scientific community was created. The executed pipeline for data processing, supported by the Python programming language and classical libraries from the data science field, is composed of the following steps: (i) data retrieval and standardization; (ii) treatment of missing data; (iii) data transformation; and (iv) feature selection. The new dataset, formatted as a comma-separated values (.csv) file named "asppl-dataset.csv," comprises 33 attributes and 4,861 instances. A detailed description of the dataset is available for public consultation at the repository (available at: https://zenodo.org/record/5095518#.YO3gshNueLo).

In the pipeline's first stage, data recovery and standardization (i), work focused on the recovery of missing data on the "gender" and type(s) of health establishment(s) attributes. In the original dataset, 36.65% (1,782) of the instances did not have values referring to participants' gender. After consulting the database of the Permanent Integration System of Education Strategies of the Ministry of Health of Brazil, Sabiá, developed by LAIS/UFRN,

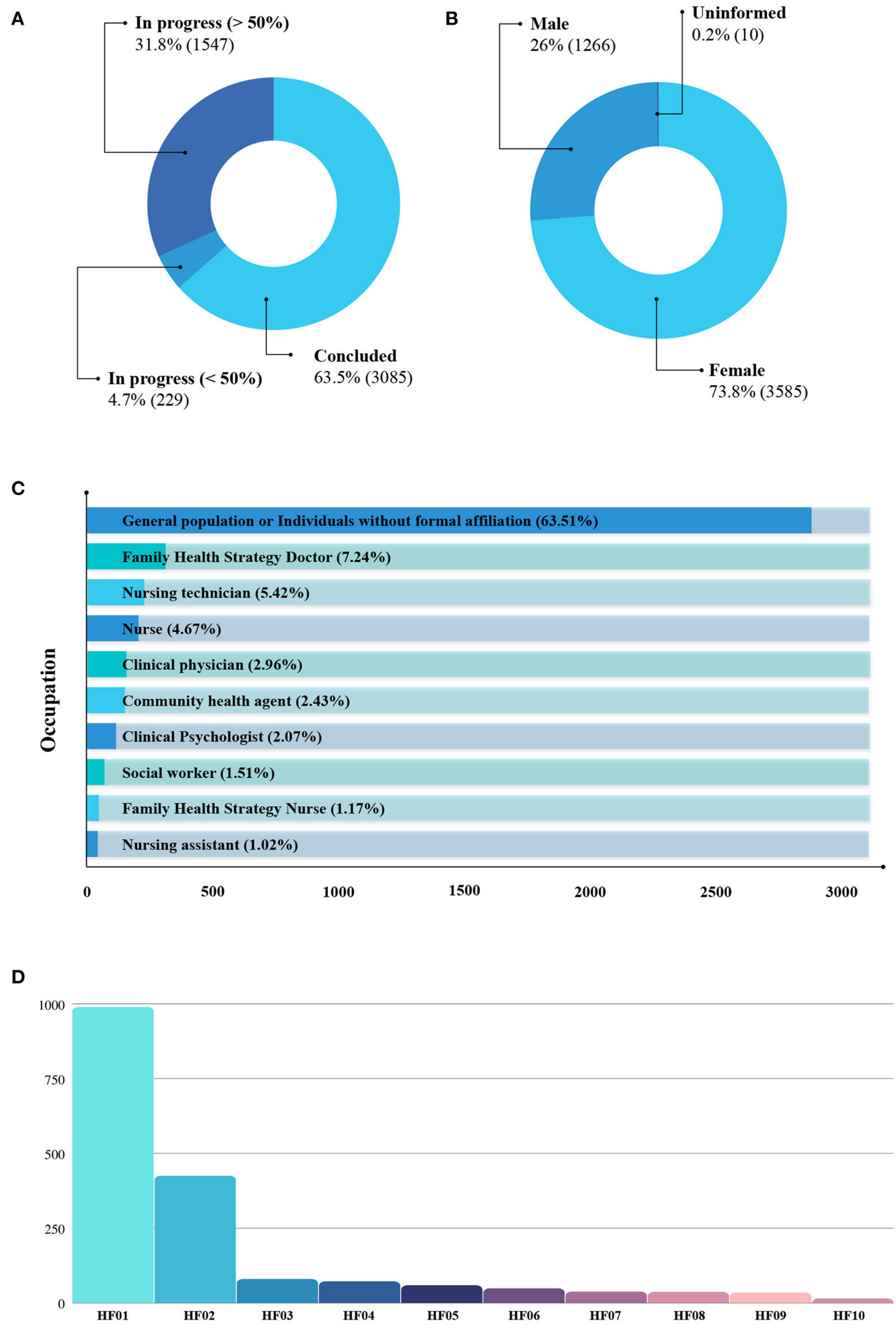


FIGURE 1 | "asppl-dataset.csv" analysis of repository data. **(A)** Number of participants who completed the course. **(B)** Number of participants by Gender. **(C)** Number of occupations of the participants. **(D)** Number of health facilities where participants work. HF01, Health Center/Primary Unit; HF02, General Hospital; HF03, Specialty Clinic/Center; HF04, Health Center; HF05, Health Management Center; HF06, Specialized hospital; HF07, Prompt service; HF08, Polyclinic; HF09, Psychosocial care center; HF10, Isolated office.

approximately 99.44% (1,772) of missing data on the "sex" attribute were retrieved. Continued the recovery process, the instances of the attribute "type(s) of work establishment(s)" to which there was no relevant data were 61.16% retrieved through the National Registry of Health Establishments (CNES, in Portuguese: Cadastro Nacional de Estabelecimentos de Saúde) (16). In standardization, data conventions were created for the following attributes: gender, CBO, State, and employment(s).

For handling the missing data (step ii), missing values of the gender, CBO, and region attributes (see step iii) were replaced. For missing data values of the gender attribute, the term "Not Informed" was assigned, as it was impossible to retrieve the data in step (i) of the pipeline. As per the section 1, the ASPPL course is also open to healthcare students and society in general. That is, anyone, with or without professional registration, can take the course. With this premise in mind, the term "General Population" was assigned to the values absent in the CBO. For missing values for the region attribute, the term "Not Informed" was assigned. The missing values for other attributes were kept to preserve the originality and coherence of instances.

A series of data (pipeline step iii) was replaced and transformed through mappings on secondary sources based on specific attributes from the original dataset. Besides, new relevant attributes were added to the "asppl-dataset.csv" dataset. For the CBO attribute, the numeric code entered by each participant when enrolling in the course was converted into a text that describes the corresponding profession (17). New attributes were also created to store data referring to participants who registered more than one employment and health establishment to avoid loss of information. Furthermore, a new corresponding attribute was created for each employment record (based on CBO) and establishment (based on CNES). According to Brazil's political-administrative and regional division (18) and the attribute referring to the participant's State (Federative Unit, UF), the region attribute was set up. It allows grouping participants into one of the five major regions of Brazil: North, Northeast, Midwest, Southeast, and South.

Conversely, the declared occupation attribute was removed to avoid redundancy and conflicts (pipeline step iv) between official data, registered in the Government database, and informal data. Such data can be consulted through CBO, to which the course participant has also added. Further, to promote more transparency to this pre-processing data stage, we shall indicate the main weakness of the dataset: within the scope of "General Population," it is possible to create labels, such as "healthcare students" or other occupations. However, due to the technology's limitation, it is not mandatory to declare one's profession.

3. DESCRIPTIVE ANALYSIS

The data were analyzed for all 4,861 ASPPL course participants, as available in the "asppl-dataset.csv" dataset, with the aid of the Python programming language. In this pilot study, we mainly analyzed the profile, geographic location, and percentage of course completion of participants. Based on the latter, a total of 3,085 (63.46%) people have completed the course, and 1,776 (36.54%) are currently taking it. Of these, 229 (4.71%) participants attended more than 50% of the program, and 1,547 (31.83%) less than 50%, as depicted in **Figure 1A**. Out of the group of participants who completed the course, 92.93% (2867) provided an evaluation, ascribing a score from 0 to 5, related to the degree of satisfaction. Therefore, the arithmetic mean of the course evaluations is approximately 4.92, with a 0.38 standard deviation and median equal to 5.0.

Regarding participants' gender, a predominance of females was detected, with a total of 3,585 (73.8%) women

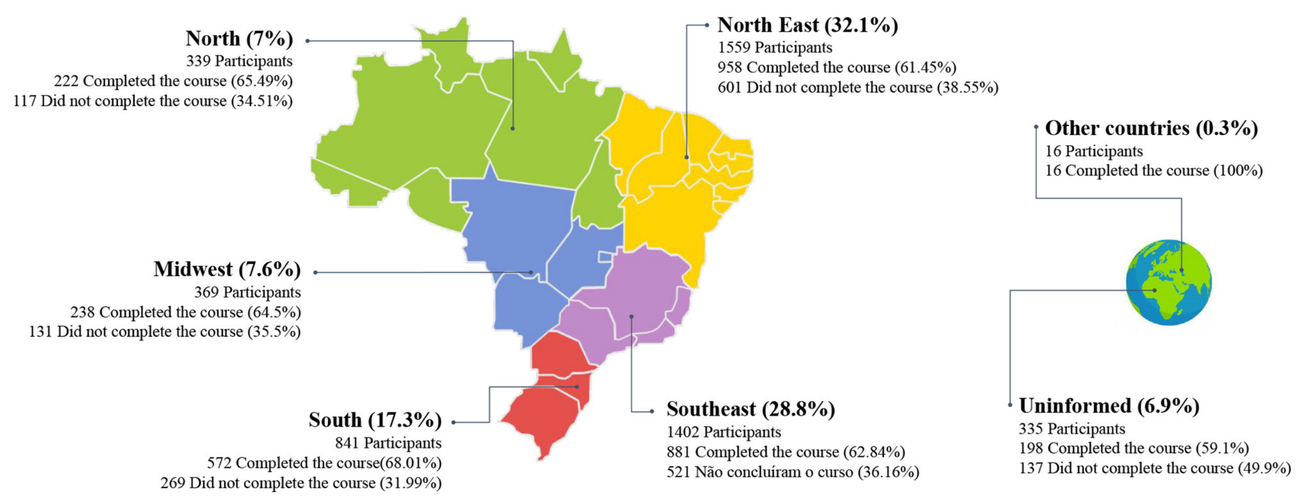


FIGURE 2 | Analysis of participants by region.

participants, as shown in **Figure 1B**. On the other hand, males are 1,266 (26%) participants. Lastly, those who did not provide gender information and did not have their data retrieved, then called "Not informed," add up to 10 (0.2%).

We nominally and quantitatively list the first 10 target items to synthesize the occupations and health establishments of the participants who most frequent the course. **Figure 1C** shows the most frequent occupations. Likewise, we present commercial establishments in **Figure 1D**. According to the guidelines established by the Ministry of Health, in Brazil, health establishments are categorized by level of care (primary, secondary, and tertiary). Hence, based on these data available in "asppl-dataset.csv," it is possible to group health establishments and analyze which level of care have trained professionals who meet the health care demands for dealing with STIs in the prison system.

For a clearer view of the geographic distribution of course participants, **Figure 2** depicts a synthesis of participants by Brazilian region. The course attracted entries from participants from all five of Brazil's regions and their states. In addition to Brazil, it was identified that the ASPPL course had a total of 16 (0.3%) participants residing in other countries. A total of 6.9% (335) of the participants did not inform their place of residence. As for Brazil, it can be observed that the Northeast is the region with the most participants, with a total of 1,559 (32.1%), followed by the Southeast region, with 1,402 (28.8%), South region, 841 (17.3%), Midwest, 369 (7.6%), and the North region, with 339 (7%). **Figure 2** reveals the number of participants who completed the course by region.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

JV, EO, FF, IB, and MR structured and wrote the manuscript. JV, FF, IB, RV, and RS analyzed the data and contributed with descriptive analysis. SD-T, AD, AC-O, CT, and JH reviewed the manuscript. FF, IB, RV, and RS organized the repository. All authors contributed to manuscript revision, read, and approved the submitted version.

FUNDING

This work was funded by Ministry of Health Brazil.

ACKNOWLEDGMENTS

We kindly thank the Laboratory for Technological Innovation in Health (LAIS) of the Federal University of Rio Grande do Norte (UFRN) and the Ministry of Health Brazil for supporting this research.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmed.2021.742071/full#supplementary-material

REFERENCES

1. Machado NO, Guimarães IS. A realidade do sistema prisional brasileiro e o princípio da dignidade da pessoa humana. *Revista Eletrônica de Iniciação Científica*. (2014) 5:566–81. Available online at: https://www.univali.br/graduacao/direito-itajai/publicacoes/revista-de-iniciacao-cientifica-ricc/edicoes/Lists/Artigos/Attachments/1008/Arquivo%2030.pdf
2. Kallas M. A Falência do sistema prisional brasileiro. *Direito em Movimento*. (2019) 17:62–89. Available online at: http://emerj.com.br/ojs/seer/index.php/direitoemmovimento/article/view/76/volume17_numero1_51.pdf
3. Machado FHB, Silva LS, Costa PAD, Rodrigues AS, Miranda ML. Health in prison: characterization and perception of inmates. *Eur J Public Health*. (2020) 9:30. doi: 10.1093/eurpub/ckaa166.793
4. Beato Filho C, Maria Silveira A, Mendonça Lopes Ribeiro L, Lacerda Siveira Rocha R, Lopes Souza R, Neiva e Oliveira V. Percepções Sociais sobre o Sistema Prisional Brasileiro:: um estudo quantitativo. *Revista Brasileira de Execução Penal*. (2020) 1:279–305. Available online at: http://rbepdepen.depen.gov.br/index.php/RBEP/article/view/139
5. Nascimento FDS. A Superlotação a crise do sistema prisional Brasileiro. *Captura Criptica Direito Politica Atualidade*. (2019) 8:114–25. Available online at: https://ojs.sites.ufsc.br/index.php/capturacriptica/article/view/3543
6. Quirino Filho J, Rolim Neto ML, do Nascimento VB. Incarcerated people in prisons: a public health priority in resource-poor settings. *Forensic Sci Int Mind Law*. (2020) 1:100007. doi: 10.1016/j.fsiml.2019.100007
7. Lopes RL, Cavalcante A, Melo J, Cavalcante G, Oliveira A, Weslânnya P. Ocorrência de doenças infectocontagiosas em pessoas privadas de liberdade no sistema prisional. *Interfaces Científicas Saúde e Ambiente*. (2019) 7:53–60. doi: 10.17564/2316-3798.2019v7n2p%p
8. Brasil. *Levantamento Nacional de Informações Penitenciárias*. Departamento Penitenciário Nacional (2021). Available online at: https://www.gov.br/depen/pt-br/sisdepen/sisdepen
9. Batista MIHM, Paulino MR, Castro KS, Gueiros LAM, Leão JC, Carvalho AAT. Alta prevalência de sífilis em unidade prisional feminina do Nordeste Brasileiro. *einstein*. (2020) 18:1–6. doi: 10.31744/einstein_journal/2020AO4978
10. Oliveira ESG, Valentim RAM, Trindade SD, Coutinho KD, Dias AP, Valentim JLRS, et al. Capítulo 9: A sífilis no sistema prisional Brasileiro, desafio para a saúde: uma análise baseada em dados. In: Gonçalves MNP, de Freitas IK, editors. *Pesquisas Aplicadas No Panorama das Ciências da Saúde No Brasil*. Rio de Janeiro (2021). p. 102–14.
11. Cadamuro ACGA, Andrade RLP, Lopes LM, Neves LAS, Catoia EA, Monroe AA. Coordenação do cuidado às pessoas que vivem com HIV no sistema prisional. *Acta Paulista de Enfermagem*. (2020) 33:1–8. doi: 10.37689/acta-ape/2020AO02676
12. Alves KKAF, Borralho LM, Bernardino IM, Figueiredo TMRM. Análise temporal da incidência da tuberculose na populao privada de liberdade. *Arch Health Investig*. (2020) 9:655–60. doi: 10.21270/archi.v9i6.4907

13. Nascimento JR, Barbosa KMG, Vieira MCA. Abordando infecções sexualmente transmissíveis com mulheres reclusas: um relato de experiência. *Extramuros Revista de Extensão da Univasf*. (2019) 7:104–14. Available online at: https://www.periodicos.univasf.edu.br/index.php/extramuros/article/view/1012
14. Benedetti MSG, Nogami ASA, Costa BB, Fonsêca HIF, Costa IS, Almeida IS, et al. Infecções sexualmente transmissíveis em mulheres privadas de liberdade em Roraima. *Revista de Saúde Pública*. (2020) 54:105. doi: 10.11606/s1518-8787.2020054002207
15. Brasil. *Ambiente virtual de aprendizagem do SUS - AVASUS*. Atenção à Saúde da Pessoa Privada de Liberdade (2021). Available online at: https://avasus.ufrn.br/local/avasplugin/cursos/curso.php?id=114
16. Brasil. *CNES - Cadastro Nacional de Estabelecimentos de Saúde* (2021). Available online at: http://cnes.datasus.gov.br/
17. Brasil. *CBO - Classificação Brasileira de Ocupações* (2021). Available online at: http://www.mtecbo.gov.br/cbosite/pages/home.jsf
18. EducaIBGE. *Divisão Politico-Administrativa e Regional* (2021). Available online at: https://educa.ibge.gov.br/jovens/conheca-o-brasil/territorio/18310-divisao-politico-administrativa-e-regional.html

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

frontiers in Medicine

ORIGINAL RESEARCH
published: 23 September 2021
doi: 10.3389/fmed.2021.732054

Pharmacist-Led Education for Final Year Medical Students: A Pilot Study

Sophie Mokrzecki[1,2]*, *Tilley Pain*[1,3], *Andrew Mallett*[4,5] and *Stephen Perks*[1,2]

[1] College of Public Health, Medical and Veterinary Sciences, James Cook University, Townsville, QLD, Australia, [2] Pharmacy Department, Townsville University Hospital, Townsville, QLD, Australia, [3] Allied Health Department, Townsville University Hospital, Townsville, QLD, Australia, [4] College of Medicine and Dentistry, James Cook University, Townsville, QLD, Australia, [5] Institute of Health Research and Innovation, Townsville University Hospital, Townsville, QLD, Australia

Background: Prescribing is a core skillset for medical officers. Prescribing errors or deficiencies can lead to patient harm and increased healthcare costs. There is an undefined role for pharmacist-led education to final year medical students to improve prescribing skills.

Aim: Assess if pharmacist-led education on prescription writing improves the quality and safety of final year medical students' prescribing skills.

Method:

Participants and Intervention: Final year medical students were randomised into tutorial (TG) or non-tutorial groups (NTG) and assessed pre- and post- intervention. TG received education by a clinical pharmacist and pharmacy educator using case-based learning. NTG received no additional training as per usual practice. Following the pre-test, all students completed a 3-week tertiary hospital medical ward placement. Students completed the post-test following placement and after the TG participated in the intervention.

Student Assessment: Assessment included writing Schedule 4 (S4, prescription only), Schedule 8 (S8, controlled drug), S4 streamline (S4SL), and Mixed case (S4 and S8) prescriptions.

Results: At baseline, there were no significant differences between TG and NTG for overall scores or proportion of passes. Post intervention scores significantly improved in TG ($p = 0.012$) whereas scores significantly decreased in the NTG ($p = 0.004$). The overall proportion of passes was significantly higher in the TG than NTG ($p < 0.001$).

Conclusion: Education by a clinical pharmacist improved short-term prescribing skills of final year medical students in this study. Students learning primarily experientially from peers and rotational supervisors showed decreased prescribing skills. We propose pharmacist-led education on prescription writing should be further evaluated in larger studies across more student cohorts and for longer periods of follow up time to clarify whether such an educational model could be included in future medical school curricula.

Keywords: pharmacist, medical education, medical students, prescribing skills, drug prescriptions, prescriptions, drug legislation

OPEN ACCESS

Edited by:
Michelle A. Kelly,
Curtin University, Australia

Reviewed by:
Shaista S. Guraya,
Royal College of Surgeons in Ireland, Bahrain
Nurhanis Syazni Roslan,
Universiti Sains Malaysia Health Campus, Malaysia

Correspondence:
Sophie Mokrzecki
sophie.mokrzecki@health.qld.gov.au

Specialty section:
This article was submitted to Healthcare Professions Education, a section of the journal Frontiers in Medicine

Received: *28 June 2021*
Accepted: *31 August 2021*
Published: *23 September 2021*

Citation:
Mokrzecki S, Pain T, Mallett A and Perks S (2021) Pharmacist-Led Education for Final Year Medical Students: A Pilot Study. Front. Med. 8:732054. doi: 10.3389/fmed.2021.732054

INTRODUCTION

Medications are the most common health intervention worldwide (1). In Australia, almost 300 million prescriptions are covered by the Government per year under the Pharmaceutical Benefit Scheme (PBS) or Repatriation Pharmaceutical Benefit Scheme (2). If medication prescriptions are documented incorrectly or unclearly, this may lead to substantial patient harm (1, 3). Pharmacists are specifically educated and trained in the many aspects of safe and legal prescribing. This structured education means pharmacists are well-placed to provide education to future and current prescribers.

In 1994, the World Health Organization (WHO) published the Guide to Good Prescribing (GGP), where in 2001 the Teacher's Guide to Good Prescribing followed. The GGP is a 6-step model for rational prescribing aimed at undergraduate medical students and their teachers. Many places around the world have based their medical student or graduate learning and teaching on this model, including; the Netherlands, Canada, Spain, and Turkey (9). The National Prescribing Service (NPS) in Australia online modules on prescribing standards were developed based on the GGP. This web-based interactive prescribing module outlines competencies required to prescribe medicines (10). The NPS module is not compulsory in Australian medical school curriculum, however it must be completed by medical interns prior to working in a Queensland Health facility. Many online modules do not individually assess each legal component of a prescription or allow for interaction with an educator. The relative and potentially significant role of subsequent experiential learning is neither captured nor clarified. The UK have developed a compulsory online national Prescribing Safety Assessment (PSA) for final-year medical students based on a similar framework (10-step) (9). The differences in the delivery of medical education within and between European countries could impact students results on the PSA, thus supporting EACPT suggestion to create a uniform core curriculum for European medical schools (7).

In Australia, medical officers can prescribe once registered by the Australian Health Practitioner Regulation Agency and are bound by the Medical Board of Australia's Code of Practice (4). The Australian Medical Council sets standards for assessment and accreditation of primary medical programs. The Graduate Outcome Statement stipulates that upon entry into professional practice medical practitioners should prescribe medications safely and effectively (5, 6). The Medical Board of Australia's Code of Practice simply states that doctors must comply with State and Territory legislation (4). Frameworks for attainment of these regulatory requirements are somewhat implied though still unclear, including education for safe and legal prescription writing within medical degree programs for future medical practitioners to write prescriptions compliant with Australian legislation (5). Similarly, in most European countries, junior doctors are expected to have the baseline knowledge and skills as learnt in medical school in order to write prescriptions effectively and safely (7). The European Association of Clinical Pharmacology and Therapeutics (EACPT) aims to promote high professional standards in prescribing medications (8). However, like Australia, the methods of how this is achieved is unclear.

Interns and junior doctors write the highest proportion of medication prescriptions in hospital settings globally and it is therefore highly desirable for them to become proficient prescribers (3, 7, 11, 12). However, prescriptions written by medical interns may not be of high quality and may contain errors due to a multitude of factors (3, 7, 11–15). Prescribers in Australia must understand and follow the legal requirements of a prescription using state and territory guidelines; for example, in Queensland, the Health Drugs (and Poisons) Regulation (HDPR), 1996. There is potential jurisdictional incongruence however, as the Australian Curriculum framework for Junior Doctors only stipulates that junior doctors must document a medication prescription accurately (16). The framework implies but does not outline core competencies to safely prescribe, nor does it stipulate the need to adhere to local legal requirements.

It is essential we provide medical graduates with the skills needed to write a safe and legal prescription effectively prior to graduating. This study aims to assess if a pharmacist-led education session on prescription writing for final year medical students improves their subsequent short-term prescribing skills regarding safety and legality requirements.

METHODS

Participants

All James Cook University (JCU) final year (sixth year) medical students in third term (June 18th to August 24th, 2018) at Townsville University Hospital (TUH) were invited to participate ($N = 33$). Medical students at other JCU medical student training sites, from other universities, or in years one to five were excluded. Other students from terms one, two and four were excluded due to time constraints of the study. Final year medical students were recruited as they are anticipated to transition into their internship within the next year, at which time they will apply medication prescribing skillsets. Therefore, it is predicted they would be more engaged in the content given approaching requirements for its application. All participants provided written informed consent and were advised they could withdraw at any time. Participants were randomly allocated into either non-tutorial group (NTG/control, standard education provided via university) or tutorial group (TG, provided an additional education session by a pharmacist). Randomisation was performed using Microsoft Excel randomisation tool.

The overarching research design and participant flow diagram is presented in **Figure 1**.

Intervention

One month after orientation week, participants in the TG received one 1.5-h structured education session delivered by a clinical pharmacist and pharmacy educator. Session content included legal and safety requirements of writing prescriptions. Resources were demonstrated to the students, including HDPR 1996, PBS, Australian Medicines Handbook, Therapeutic guidelines and Monthly Index of Medical Specialties. The education format was case-based learning (CBL) which

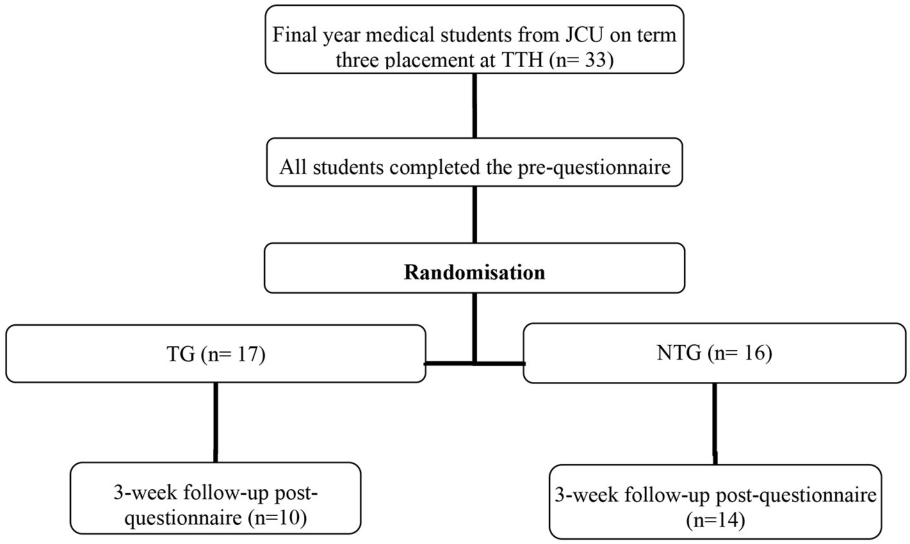


FIGURE 1 | Research design and participant flow. N. B. Students in the TG ($n = 7$) and NTG ($n = 2$) were lost to follow-up due to placement requirements.

provided students with an opportunity to learn relevant material and apply knowledge in different situations (17). During the session, students were given sample questions to practice writing scripts and encouraged to engage with the educators.

Control

Participants in the NTG completed the pre- and post-questionnaires but were provided with no additional prescribing education, by a pharmacist or otherwise, as per the standard educational practice employed for their medical ward rotation. Both groups were likely to receive prescribing mentoring during their medical ward rotation by supervising medical staff. Neither the TG nor NTG were encouraged by the educating pharmacists to seek further information on prescription writing. The TG were not provided with hard-copy materials outside of the education session. Students may have undertaken their own self-directed learning; however, this variability was not assessed in this study.

Student Assessment

Four types of cases generating five medication prescriptions were assessed. Cases were: Schedule 4 (S4), prescription only medication; Schedule 8 (S8), controlled drug; Schedule 4 streamline (S4SL); and a combined S4 and S8 case (mixed case where students were required to write two prescriptions). During the development phase of the assessment, each case was reviewed by pharmacy staff and an early career prescribing medical officer to determine the appropriateness. Different cases were used in the pre- and post-test, however both with the same types of cases generating five medication prescriptions.

Each prescription was assessed against compliance to 17 types of errors (see **Appendix 1**). However, the total score using the 17 legal and safety criteria for all four cases together was 70. The data collection tool allowed all errors to be identified and more than one error accounted for per case. The two educating pharmacists independently assessed the prescriptions and, where necessary, discussed to arrive at consensus for final marks.

Statistical Analysis

Two levels of analyses were performed. One level looked at the number of errors on each prescription type (case). The other assessed an overall pass or fail of the entire case. For example, a student may receive a total mark of 66 out of 70, but if the prescription doesn't contain all the legal requirements according to the HDPR, in this study it was considered a fail for that case. The rationale for this type of assessment is that a pharmacist cannot legally dispense the prescription.

Data was collated in Microsoft Excel and imported to IBM SPSS Statistics (Version 25, IBM Corporation) for statistical analysis. An independent samples t-test was used to compare the overall change scores. Mann–Whitney U-tests were used to compare change scores for individual cases (the variables were not normally distributed so non-parametric tests were used) and to compare the overall number of cases passed. Mann–Whitney U-tests were also used to investigate differences in number of cases passed, post-test compared to pre-test, between the TG and NTG. Paired t-tests were used to analyse differences between pre-test total score and post-test total score within each group.

Ethics

Townsville Hospital and Health Service Human Research and Ethics Committee approved this study (HREC/18/QTHS/142) and it was endorsed by the JCU Townsville Ethics Committee. Site Specific Approval was granted to conduct the study at TUH with final-year medical school students from JCU. The College of Medicine at JCU and Medical Placement coordinators at TUH provided approval and support for this study. All final year medical students (from terms one to four in 2018) were provided the opportunity to receive the education session after the pilot study was completed, meeting ethical standards of TUH HREC.

RESULTS

There were no significant differences at baseline for the scores or proportion of passes between TG and NTG.

TABLE 1 | Mean and standard deviation of pre- and post-test scores for NTG and TG.

	Pre-	Post-	Difference	*P*-value
NTG	61.8 ± 5.2	58.0 ± 5.3	−3.8 ± 4.7	0.012
TG	61.2 ± 6.0	66.6 ± 4.0	5.5 ± 4.5	0.004

TABLE 2 | Mean individual case scores pre- and post-test for the TG and NTG.

Case	Group	Pre-test (mean ± sd)	Post-test (mean ± sd)	Mann–Whitney U-statistic	*p*-value
S4	TG	9.90 ± 1.10	10.80 ± 0.42	20.0	0.002
	NTG	10.21 ± 0.98	9.64 ± 0.75		
S8	TG	18.05 ± 2.52	19.90 ± 1.79	17.0	0.002
	NTG	17.96 ± 1.65	17.14 ± 2.03		
S4SL	TG	10.50 ± 0.97	11.20 ± 0.79	21.5	0.004
	NTG	10.71 ± 1.14	9.64 ± 1.08		
Mixed	TG	22.70 ± 2.31	24.70 ± 1.95	22.5	0.008
	NTG	22.69 ± 2.90	21.54 ± 2.30		
Total	TG	61.15 ± 5.99	66.60 ± 4.01	*T*-test: $t = 4.775$, df = 21	<0.001
	NTG	61.85 ± 5.18	58.00 ± 5.32		

Pre-test characteristics showed 25 students were aged 22–25 years and 6 students were over the age of 26, compared to 19 and three, respectively, post-test (two student did not answer both pre- and post-test). Three students had trained or worked in a health profession prior to their medical degree. One of these students was randomised to TG, and the other two were lost to follow-up.

Overall Score

Students in the TG performed better overall in the post-test compared the NTG. Paired *t*-tests demonstrated the TG group significantly improved their score from pre- to post-test whereas the NTG overall score significantly decreased (**Table 1**).

Individual Case Scores

The mean individual case scores for all prescription types significantly improved in the TG, while NTG scores significantly decreased (**Table 2**).

Pass vs. Fail

A Mann–Whitney *U*-test showed a significantly greater number of cases passed overall in the TG compared to the NTG ($p < 0.001$). Out of a possible 5, the average number of passes post-test was 2.7 (range 0–5) in the TG and 0 in the NTG. Comparing the number of cases passed between TG and NTG found a significant difference pre- to post-test ($p < 0.001$), with an average increase of 1.6 passes for TG and average decrease of 1.3 passes for NTG (**Figure 2**).

Error Types

Common errors included: prescriber's qualifications not documented, no streamline code, no units on the drug strength, the formulation of the medication not clear, quantity not written in words and items not numbered for S8 case and items not on separate scripts for the mixed case.

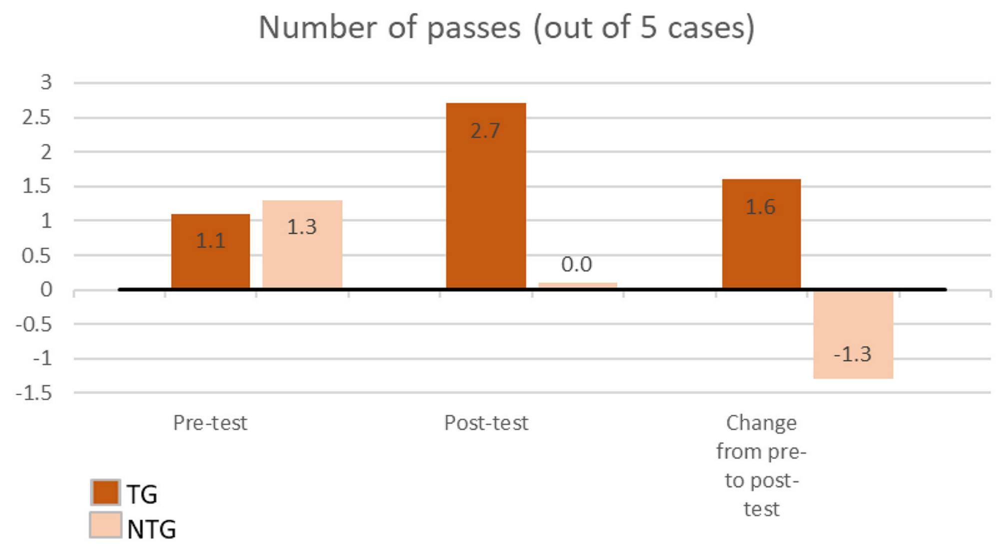


FIGURE 2 | Pre- and Post-test passes for students, assessing the change between TG and NTG.

DISCUSSION

This study investigated if prescribing skills of final year medical students changed following a structured pharmacist-led education intervention. Those randomised to receive the educational intervention significantly improved their prescribing skills whereas those randomised to standard medical ward rotation training were observed to exhibit significantly worsened prescribing skills. The change in scores between the randomised groups were consistent regardless of comparing overall or individual case scores. It is likely that improvements in the intervention group (TG) were due to the prescribing-specific education provided by the pharmacists. The apparent decrease in skills in the control group (NTG) was concerning and potentially a result of inconsistent prescribing-specific experiential teaching and learning. Previous studies have demonstrated that instilling poor skills and habits amongst medical students early in their clinical development is avoidable with appropriate training by informed educators (18, 19).

The salient result of this study is the pass/fail rate representing the number of students' cases which complied with all legal and safety requirements. The overall number of cases passed was significantly more in the TG compared to the NTG. We extrapolate that an increased number of legal and safe prescriptions may reduce future adverse events and costs to the health sector, though assessment of such medium-long term impacts was not possible in this pilot study. In a fourth-year medical students' response to Newby et al., they believe that positive habits in prescription writing would form with pharmacist-led education being established as a longitudinal theme, revised and regularly updated (20).

Prescribing errors relating to legal and safety requirements of a prescription are common, occurring at a rate of four to five per patient on paper-based prescriptions (1). Increased education on prescription writing for medical students may decrease the number of errors and therefore decrease these adverse events, improving patient outcomes (14). Many of the errors identified in this study originated from lack of knowledge and familiarity around legal requirements of prescriptions in Queensland. For example, requesting a 7-day supply of a controlled drug in the questionnaire assessed knowledge of safety specifically for a Queensland regulatory context. Whilst the PBS allows 14 days supply under federal regulation; students were required to supply a quantity lasting 7 days and those whose scripts reflected the PBS quantity were marked down. Our reasoning was that safe script writing must be a component taught with the legal requirements of prescribing within the specific local jurisdiction in which it is hierarchically applied.

There is no global standard for prescriptions as per the WHO GGT (21). However, it states the most important requirement is for the prescription to be clear and legible. Furthermore, it is the legal duty of a prescriber to produce an unambiguous prescription (21). All the prescriptions assessed in this study were legible. Good legibility was anticipated as the assessments were performed in a controlled environment without outside stimuli or time pressures that heuristically may otherwise influence student handwriting abilities.

Most students in this study sat an additional education session during their medical rotation through the palliative care centre. This education consisted of a specialist practicing physician educating students specifically on "controlled drug" prescription writing. Comparing educators was not the purpose of this study. However, a number of articles have demonstrated pharmacists have a positive influence on prescribing behaviours of prescribers (18, 19, 21, 22). Given that all students, except one, received this education from a prescribing physician it is unlikely to represent a confounder to our findings. Further, given that we observed superior prescribing skillset performance only amongst the group randomised to receive pharmacist-led education, we conclude the pharmacist-led education on script writing was effective in an additive compared to the alternative model of physician education. It has previously been observed that physicians in the role of educators may at times overlook some required knowledge and skills (18, 19). We hypothesise that students potentially felt more comfortable asking a pharmacist questions rather than a senior colleague to spare criticism or judgement given the traditionally hierarchical nature of medical workforce structures. Tittle et al. identified that students highly regarded pharmacists as teachers, finding them knowledgeable and approachable (22). The findings in this study support Tittle et al.'s conclusions.

Newby et al. also found that pharmacist-led education to medical students had a positive influence on their learning (3). Interprofessional learning creates an environment similar to professional practice which may prepare students for the holistic care provided to patients in a team-based scenario. A clinical pharmacist presented the education session using CBL. CBL offers an ideal opportunity to learn relevant material and apply knowledge in different situations. Our results demonstrate CBL and establishing a relationship with pharmacists allowed the TG to learn during the intervention, apply their knowledge and develop further during the subsequent 3-week placement, leading to improved results at post-test.

Engraining positive prescribing habits and teaching students through CBL on the legal and safety requirements of prescription writing during their final year of medical school may encourage short-term retention of knowledge as students' progress toward their intern year. Further research using the same students in a yearlong follow-up period will be required to confirm this hypothesis and begin to explore medium- and longer-term impacts. The engaging format used by the clinical pharmacist was another strength of this study. The session was formatted to be interactive, avoiding long learning segments and encouraging students to participate in practice prescription writing. Using the research design of a randomised controlled trial and having a control group to compare the pre- and post-results reduced bias and was a strength of this study. Limitations of this study were that it was only performed at a single site, using a small cohort of students, with one education session. The characteristics of those not recruited were not collected and assessment marking was not blinded due to time constraints and available pharmacists. A larger cohort and consistent student follow-up will be necessary to corroborate the study results, including delivery by multiple different pharmacist educators with sufficient powering to overcome confounding effects. Blinded marking of the assessment should be used in future studies to remove the risk of bias in the measurement of the outcome.

Future studies should address these limitations and follow-up students in their intern year to assess retention and application of knowledge in real world settings. For example, one model may be to conduct the intervention in a simulated clinical environment mimicking a real-life ward setting to replicate factors that contribute to prescribing errors. We propose future investigation and research should incorporate clinical knowledge into assessment, as this can greatly influence a student's and subsequent prescriber's ability to generate effective, appropriate and safe prescriptions.

CONCLUSIONS

This study demonstrates that education to final year medical students by a clinical pharmacist on the legal and safety factors of prescriptions is beneficial in terms of their prescribing skills over a short time frame. We propose pharmacist-led education models be further studied and investigated to assess potential for incorporation into medical school curricula. Further improvement may be needed in the future on standards put forth on prescription writing by such institutions as the Australian Medical Council and Medical Board of Australia. Elaboration should be made on what, and how, teaching is delivered and assessed and a requirement to have handwritten prescriptions compliant with local legislation. We postulate that proximity of education to the intern year aids retention of knowledge, as students may be more interested in the education sessions, knowing they will use the skills the following year. Results showing poor prescribing skills acquired solely from standard ward rotation experiential and peer learning (NTG) suggests that experienced prescribers may also benefit from future pharmacist-led prescribing educational models.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because data set has not been anonymized. Requests to access the datasets should be directed to sophie.mokrzecki@health.qld.gov.au.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Townsville Hospital and Health Service Human Research and Ethics Committee and endorsed by the James Cook University Townsville Ethics Committee. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

SM created the concept and design of the research project and conducted the intervention, analysed and interpreted the data. Writing of the manuscript, and drafting and coordination of edited versions were managed by SM. TP and AM critically analysed the paper which was highly important for the intellectual content of the paper. TP assisted with analysis and interpretation of data, while AM assisted in the guidance and direction of the paper. SP assisted SM in finalising the research design and conducting the intervention, acted as a second reviewer of data for SM, and provided guidance for data presentation. SP also provided critical analysis when drafting the paper and offering different intellectual content. All authors have provided final approval for publishing and was held accountable for all aspects of the work and ensure accuracy and integrity of each part of work.

ACKNOWLEDGMENTS

The authors wish to thank and acknowledge all participants and stakeholders involved in this study, including the JCU College of Medicine, Dentistry and Pharmacy and Townsville Hospital and Health Service.

REFERENCES

1. Roughead L, Semple S, Rosenfeld E. Australian Commission on Safety and Quality in Health Care. *Literature Review: Medication Safety in Australia*. ACSQHC, Sydney (2013).
2. Australian Institute of Health and Welfare. *Australia's Health 2018*. Canberra, ACT: Australian Government (2018).
3. Newby DA, Stokes B, Smith AJ. A pilot study of a pharmacist-led prescribing program for final-year medical students. *BMC Med Educ.* (2019) 19:54. doi: 10.1186/s12909-019-1486-1
4. Medical Board of Australia. *Good Medical Practice: A Code of Conduct for Doctors in Australia*. Canberra, ACT: AHPRA (2020).
5. Australian Medical Council. *Standards for Assessment and Accreditation of Primary Medical Programs*. Australian Medical Council (AMC) (2012).
6. Morris S, Coombes I. The right to prescribe: towards core prescribing competencies for all prescribers. *Australian Prescriber.* (2011). 34:126–7. doi: 10.18773/austprescr.2011.067
7. Brinkman DJ, Tichelaar J, Schutte T, Benemei S, Böttiger Y, Chamontin B, et al. Essential competencies in prescribing: a first European cross-sectional study among 895 final-year medical students. *Clin Pharmacol Therapeut.* (2017). 101:281–9. doi: 10.1002/cpt.521
8. Böttiger Y, Zeitlinger M, Coleman J, Agtmael M, Rongen G, Backman J, et al. 14th Congress of the European Association for Clinical Pharmacology and Therapeutics (EACPT). *Eur J Clin Pharmacol.* (2019) 75:743–50. doi: 10.1007/s00228-019-02685-2
9. Tichelaar J, Richir MC, Garner S, Hogerzeil H, de Vries ThPGM. WHO guide to good prescribing is 25 years old: quo vadis? *Eur J Clin Pharmacol.* (2020). 76:507–13. doi: 10.1007/s00228-019-02823-w
10. National Prescribing Service (NPS), editor. *Competencies Required to Prescribe Medicines: Putting Quality Use of Medicines Into Practice*. Sydney, NSW: National Prescribing Service Limited (2012).
11. Heaton A, Webb DJ, Maxwell SR. Undergraduate preparation for prescribing: the views of 2413 UK medical students and recent graduates. *Br J Clin Pharmacol.* (2008) 66:128–34. doi: 10.1111/j.1365-2125.2008.03197.x

12. Kennedy MB, Haq I, Ferns G, Williams SE, Okorie M. The role of undergraduate teaching, learning and a national prescribing safety assessment in preparation for practical prescribing: UK medical students' perspective. *Brit J Clin Pharmacol.* (2019). 85:2390–8. doi: 10.1111/bcp.14058
Celebi N, Weyrich P, Riessen R, Kirchhoff K, Lammerding-K6ppel M.
13. Celebi N, Weyrich P, Riessen R, Kirchhoff K, Lammerding-Köppel M. Problem-based training for medical students reduces common prescription errors: a randomised controlled trial. *Med Educ.* (2009) 43:1010−8. doi: 10.1111/j.1365-2923.2009.03452.x
14. Hilmer SN, Seale JP, Le Couteur DG, Crampton R, Liddle C. Do medical courses adequately prepare interns for safe and effective prescribing in New South Wales public hospitals? *Internal Med J.* (2009) 39:428–34. doi: 10.1111/j.1445-5994.2009.01942.x
15. Sandilands EA, Reid K, Shaw L, Bateman DN, Webb DJ, Neeraj Dhaun, et al. Impact of a focussed teaching programme on practical prescribing skills among final year medical students. *Br J Clin Pharmacol.* (2011) 71:29–33. doi: 10.1111/j.1365-2125.2010.03808.x
16. Confederation of Postgraduate Medical Education Councils. *Australian Curriculum Framework for Junior Doctors*. In: Health Do, editor. Melbourne, VIC: Confederation of Postgraduate Medical Education Councils (CPMEC) (2012).
17. Srinivasan M, Wilkes M, Stevenson F, Nguyen T, Slavin S. Comparing problem-based learning with case-based learning: effects of a major curricular shift at two institutions. *Acad Med J Assoc Am Med Coll.* (2007) 82:74–82. doi: 10.1097/01.ACM.0000249963.93776.aa
18. Akici A, Gören MZ, Aypak C, Terzioğlu B, Oktay S. Prescription audit adjunct to rational pharmacotherapy education improves prescribing skills of medical students. *Eur J Clin Pharmacol.* (2005). 61:643–50. doi: 10.1007/s00228-005-0960-3
19. Javadi M, Khezrian M, Sadeghi A, Hajimiri SH, Eslam K. An interprofessional collaboration between medicine and pharmacy schools: designing and evaluating a teaching program on practical prescribing. *J Res Pharmacy Pract.* (2017). 6:178–81. doi: 10.4103/jrpp.JRPP_17_16
20. Lloyd N. Pharmacist-led teaching as a longitudinal theme for medical school curriculums - a solution for reducing prescribing errors in junior doctors? *BMC Med Educ.* (2019). 19:173. doi: 10.1186/s12909-019-1632-9
21. De Vries TPGM, Henning RH, Hogerzeil HV, Fresle DA. Guide to good prescribing : a practical manual. Geneva: World Health Organization, (1994).
22. Tittle V, Randall D, Maheswaran V, Webb A, Quantrill S, Roberts M. Practical prescribing course. A student evaluation. *Clin Teach.* (2014). 11:38–42. doi: 10.1111/tct.12106

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

APPENDICES

Appendix 1: All possible errors identified on a prescription.

1. Patient factors
   - Name
   - Address
   - [Additional to above] Date of birth on a controlled drug prescription
2. Prescriber factors
   - Name
   - Qualifications
   - Signature
   - NOTE: The place of practice address was already pre-printed on the prescription copy
3. Drug factors
   - Name of drug
   - Strength of drug (with unit e.g., mg)
   - Clear directions for a pharmacist to dispense and a patient to understand
   - Quantity in figures
   - Quantity in words and figures (for a controlled drug)
   - Indication in repeats box (either crossed out/nil/0 or a number generally coinciding with PBS written)
   - Streamline if required
4. Legal factors
   - Date the script was written
   - If two controlled drugs on one prescription, each drug is numbered
   - If two controlled drugs on one prescription, a line under the last item
   - Where a drug from another case is written on the safe prescription as another case, it must still be legal (eg. schedule 4 prescriptions only together, not written with a schedule 8 medication)
5. Safety factors (variable not calculated into error types but noted)
   - Clear and legible
   - No ambiguity

frontiers in Surgery

ORIGINAL RESEARCH
published: 01 October 2021
doi: 10.3389/fsurg.2021.746837

Remote Training of Functional Endoscopic Sinus Surgery With Advanced Manufactured 3D Sinus Models and a Telemedicine System

*Masanobu Suzuki[1,2], Erich Vyskocil[1], Kazuhiro Ogi[1], Kotaro Matoba[3], Yuji Nakamaru[2], Akihiro Homma[2], Peter J. Wormald[1] and Alkis J. Psaltis[1]**

[1] Department of Surgery–Otorhinolaryngology Head and Neck Surgery, Central Adelaide Local Health Network and the University of Adelaide, Adelaide, SA, Australia, [2] Department of Otolaryngology-Head and Neck Surgery, Faculty of Medicine and Graduate School of Medicine, Hokkaido University, Sapporo, Japan, [3] Department of Forensic Medicine, Faculty of Medicine and Graduate School of Medicine, Hokkaido University, Sapporo, Japan

OPEN ACCESS

Edited by:
Zaleha Abdullah Mahdy, National University of Malaysia, Malaysia

Reviewed by:
Irfan Mohamad, Universiti Sains Malaysia Health Campus, Malaysia
Farah Dayana Zahedi, National University of Malaysia, Malaysia

****Correspondence:***
Alkis J. Psaltis
alkis.psaltis@adelaide.edu.au

Specialty section:
This article was submitted to Otorhinolaryngology - Head and Neck Surgery, a section of the journal Frontiers in Surgery

Received: *24 July 2021*
Accepted: *06 September 2021*
Published: *01 October 2021*

Citation:
Suzuki M, Vyskocil E, Ogi K, Matoba K, Nakamaru Y, Homma A, Wormald PJ and Psaltis AJ (2021) Remote Training of Functional Endoscopic Sinus Surgery With Advanced Manufactured 3D Sinus Models and a Telemedicine System. Front. Surg. 8:746837. doi: 10.3389/fsurg.2021.746837

Objective: Traditionally, cadaveric courses have been an important tool in surgical education for Functional Endoscopic Sinus Surgery (FESS). The recent COVID-19 pandemic, however, has had a significant global impact on such courses due to its travel restrictions, social distancing regulations, and infection risk. Here, we report the world-first remote (Functional Endoscopic Sinus Surgery) FESS training course between Japan and Australia, utilizing novel 3D-printed sinus models. We examined the feasibility and educational effect of the course conducted entirely remotely with encrypted telemedicine software.

Methods: Three otolaryngologists in Hokkaido, Japan, were trained to perform frontal sinus dissections on novel 3D sinus models of increasing difficulty, by two rhinologists located in Adelaide, South Australia. The advanced manufactured sinus models were 3D printed from the Computed tomography (CT) scans of patients with chronic rhinosinusitis. Using Zoom and the Quintree telemedicine platform, the surgeons in Adelaide first lectured the Japanese surgeons on the Building Block Concept for a three Dimensional understanding of the frontal recess. They in real time directly supervised the surgeons as they planned and then performed the frontal sinus dissections. The Japanese surgeons were asked to complete a questionnaire pertaining to their experience and the time taken to perform the frontal dissection was recorded. The course was streamed to over 200 otolaryngologists worldwide.

Results: All dissectors completed five frontal sinusotomies. The time to identify the frontal sinus drainage pathway (FSDP) significantly reduced from 1,292 $\pm$ 672 to 321 $\pm$ 267 s ($p = 0.02$), despite an increase in the difficulty of the frontal recess anatomy. Image analysis revealed the volume of FSDP was improved (2.36 $\pm$ 0.00 to 9.70 $\pm$ 1.49 ml, $p = 0.014$). Questionnaires showed the course's general benefit was 95.47 $\pm$ 5.13 in dissectors and 89.24 $\pm$ 15.75 in audiences.

Conclusion: The combination of telemedicine software, web-conferencing technology, standardized 3D sinus models, and expert supervision, provides excellent training outcomes for surgeons in circumstances when classical surgical workshops cannot be realized.

Keywords: surgical training, functional endoscopic sinus surgery (FESS), 3D printer, building block concept, frontal sinusotomy, social distancing regulation

INTRODUCTION

Functional Endoscopic Sinus Surgery (FESS) is the standard surgical procedure for chronic rhinosinusitis (1). To guarantee safe and consistent surgical outcomes of FESS, a clear and complete understanding of the three dimensional (3D) anatomy of paranasal sinuses is required (2). The frontal sinus is the most complicated and difficult of all sinuses and has a significant anatomical variation (2–4). As the frontal sinus is adjacent to critical structures such as the orbit and skull base, the risk of complications is higher compared to other sinuses. The Building Block Concept (BBC) has been proposed as an excellent tool for surgeons to preoperatively understand the anatomy of the frontal sinus (5). It allows the surgeon to identify each cell in the frontal recess as well as the frontal sinus drainage pathway (FSDP), thereby facilitating a structured surgical approach to this region.

Besides a clear understanding of the anatomy, surgical technique has to be taught, practiced and acquired to achieve consistent and safe outcomes. Along with literature, textbooks, and training in theater, surgical training courses are the mainstay of teaching surgery. Traditionally, courses and workshops are conducted in person with cadaveric specimens. This is associated with significant direct costs from the cadaveric material and indirect costs from travel and time away from one's surgical practice. Cadaveric specimens also carry an infection risk and may have undergone previous sinonasal surgery and have unpredictable sinus anatomy which can all affect the training experience. The recent COVID- 19 pandemic has had a significant global impact on the ability to conduct such courses due to its restrictions on travel, social distancing regulations, and the infection risk.

Recent advanced 3D printing techniques permit the creation of 3D sinus models based on Computed tomography (CT) scans of the paranasal sinuses. As the quality of the printing materials used, continues to improve, the tactile, "real-life" feel of the tissues make such models attractive alternatives to cadavers. Furthermore, they have the advantage of predictable anatomy and the lack of human tissue means that these courses can be outside of cadaveric facilities.

Here, we report the world-first remote FESS training course between Japan and Australia, utilizing the novel 3D sinus models in combination with telemedicine software enabling a real time supervision of step-by-step dissections. We also examined the educational effect of the remote surgical training system.

MATERIALS AND METHODS

3D Sinus Model

Three advanced manufactured 3D sinus models were used in the course (Fusetech, Adelaide, South Australia, **Table 1**). The models were printed from the axial CT scans of patients with chronic rhinosinusitis who had later undergone surgery by the senior authors. Currently, eight different models (Model 1 to Model 8) are available, all of differing degrees of complexity. Prior to the course, three of the models (Model 2, Model 6, and Model 8) were chosen by the Adelaide team based on their differing degrees of frontal sinus anatomy complexity as outlined in the international consensus papers by Wormald et al. international frontal sinus anatomy classification (1, 2). These models were printed and shipped to Japan from Australia, prior to the course. The exact same models were prepared in Adelaide for demonstration by the instructors. Because only the 3D sinus models were used in this study, ethical approval for this study was waived by the ethical board of Hokkaido University Hospital.

TABLE 1 | Anatomical characteristics of the advanced manufactured 3D sinus models used in the course.

Training round	Model	Anterior cells	Posterior cells	Medial cells	AP-diameter (mm)	Difficulty grade	FSDP
Round 1	Model 2 Lt	ANC, SAFC	BE, SBC		10.9	2	AM
Round 2	Model 2 Rt	ANC,SAFC	BE, SBC		8.2	2	PL
Round 3	Model 6 Rt	ANC, SAFC	BE, SBFC		12.8	3	AM
Round 4	Model 8 Lt	ANC, SAFC	BE	FSC	6.6	4	AM
Round 5	Model 8 Rt	ANC, SAFC	BE, SBFC	FSC	7.5	4	AM

Lt, left; Rt, right; ANC, agger nasi cell; SAFC, supra agger frontal cell; BE, bulla ethmoidalis; SBC, supra bulla cell; SBFC, supra bulla frontal cell; FSC, frontal septal cell; AP-diameter, anterior-posterior-diameter; FSDP, frontal sinus drainage pathway; AM, anterior-medial; PL, posterior-lateral.

Surgical Stations

Three surgical training station were prepared in the conference room of the Department of Otolaryngology-Head and Neck Surgery, Hokkaido University, Japan. Each station was equipped with endoscope and sinus surgical equipment provided by Karl Storz (Tuttlingen, Germany), a microdebrider (Medtronic, Jacksonville USA), Telepacks (Karl Storz, Tuttlingen, Germany), a Fusion image guidance system (Medtronic, Jacksonville USA), and a windows PC. The endoscope monitor was connected to the USB port of each window PC through two conversion cables (DVI to HDMI and HDMI to USB). The three endoscopic images during dissection were simultaneously shared with 2 rhinologists based in Adelaide, Australia, on an encrypted telemedicine platform, Quintree (Michigan, USA).

Surgical Training

Prior to dissecting three Japanese surgeons were trained by the Adelaide Rhinologists AJP and PJW to assess the frontal recess anatomy and evaluate the FDSP using the computerized Scopis "Building Block Software" (Stryker, Michigan, USA). The Japanese surgeons were then asked to plan and conduct the frontal sinus dissection for the left side of Model 2, beginning with uncinectomy, followed by resections of the anterior wall of ANC, identification of FSDP, and resection of all cells in the frontal recess. Sharing the three endoscopic views, the instructors in Adelaide directly supervised the dissectors in Japan performing the surgical procedures and gave them real-time feedback and instruction using the Quintree platform. Following completion of their first dissection, the participating surgeons watched the instructors perform the dissection on the exact same 3D sinus model (the left side of Model 2) in Australia. At the end of the model dissection a video-recording of the actual real-life surgery of the patient from whom the model had been printed was shown. This process was repeated for each of the remaining four dissections with increasing frontal recess complexity on each dissection (right side of Model 2, right side of Model 6, and left and right sides of Model 8, **Table 1**). All the dissectors conducted the dissection of the same models. As a next step the endoscopic modified Lothrop procedure (EMLP, frontal drillout) was conducted by the participating surgeons using model 2, following the demonstration of the procedure by the instructors. The course was broadcasted worldwide to over 200 otolaryngologists' personal computers using the web-conferencing platform Zoom (California, USA). Social distancing of all involved was possible and enforced.

The Time to Identify FSDP

During the course, the time to identify the FSDP was measured. It was defined as the time interval from starting the resection of the anterior wall of ANC until the insertion of the tip of a malleable sinus probe or suction curette into the FSDP. The time was standardized as a relative value to the time taken for the instructors in Adelaide to perform the same dissection.

Measurement of Volume of FSDP in the Models Before and After the Training

CT examinations of the 3D sinus models before and after the training were performed using a 16-slice multidetector-row CT scanner (Hitachi, Tokyo, Japan) with collimation of 0.63 mm at 120 kV and 200 mA or less and a rotation time of 1.0 s. Coronal and sagittal multiplanar reconstruction (MPR) images were obtained from the axial images. 3D computed graphic images of FSPD were created, and the volume of FSDP from the level of the superior edge of 3D sinus models to the level of the floor of ANC was quantified by 3D image analysis system, SYNAPSE VINCENT (Fujifilm, Tokyo, Japan, **Supplementary Figure 1**). For model 2 (EMLP plus bilateral FSDP), the total volume of bilateral FSDP was calculated and compared before and after the surgeries. For model 6 and 8 frontal sinusotomy without frontal drillout was performed and the volume of each side of FSDP were compared before and after the frontal sinusotomy.

Questionnaires for the Trainers and Audiences

During the course, subjective data was collected from the three dissectors using a visual-analog (VAS) scale. The data included (1) subjective difficulty of the surgeries during the frontal sinusotomy, (2) subjective completeness of frontal sinusotomy, and (3) confidence in performing a frontal sinusotomy in general.

After the course, a questionnaire survey was performed on dissectors and audiences, to evaluate the usefulness of instruction, the quality of the telemedicine platform, and the educational value. Each response was converted to the VAS score (0–100).

Statistical Analysis

All data is expressed as the mean ± Standard Deviation (SD). The continuous variables were compared with a two-tailed Student's t-test. P-values of <0.05 were considered statistically significant. All analyses were performed using the JMP® 11 (SAS Institute Inc., Cary, NC, USA).

RESULTS

Course and Dissectors

The course was held over 2 days in February 2021 in the conference room of the Department of Otolaryngology-Head and Neck Surgery, Hokkaido University, in Japan. The experience years of the Japanese Otolaryngologists was 9.7 ± 7.6 years. Two were officially certified board members of the Japanese Otolaryngology Society, and the other was an otolaryngology registrar yet certified. None of them were trained rhinologists. Their operative experience in performing FESS and frontal sinusotomies was 101.7 ± 60.1 and 21.7 ± 18.9 sides, respectively. The registrar had no experience in performing frontal sinusotomies before the course. None of the three dissectors had performed a frontal drillout before. All dissectors performed five frontal sinusotomies and one frontal drillout under the supervision and real-time feedback by the instructors in Adelaide (**Figure 1** and **Supplementary Video 1**).

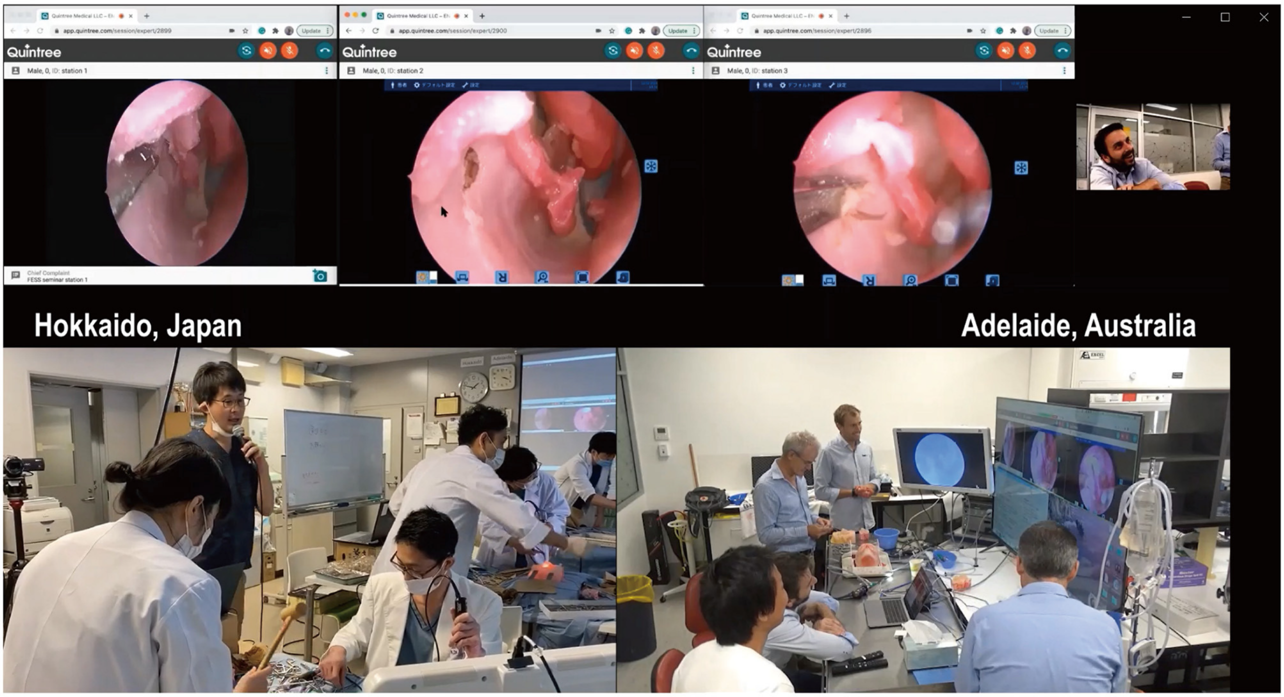


FIGURE 1 | The remote endoscopic surgery training course was conducted between Hokkaido, Japan, and Adelaide, Australia, and broadcasted worldwide. The course was held over 2 days in February 2021. Three otolaryngologists in Hokkaido were trained to perform frontal sinus dissections on 3D sinus models printed from CT scans of patients. Two rhinologists based in Adelaide, 8,000-km away from Hokkaido, simultaneously viewed the surgeries and provided real-time feedback using a telemedicine platform, Quintree. The course was also broadcast worldwide to over 200 otolaryngologists' personal computers.

The Remote Endoscopic Surgery Training Course Was Objectively and Subjectively Beneficial in Improving the Dissectors' Skills

To evaluate the educational impact of the course, we examined how long it took for the dissectors to identify the FSDP. The duration from starting to resect the anterior wall of ANC to identify and insert a malleable probe or frontal sinus curette into the FSDP was measured. In the first round, the dissectors needed 1,292 ± 672 s to identify the FSDP. As the course proceeded, the time to identify FSDP decreased and to 321 ± 267 s at the final side despite the most complexity anatomy (**Figure 2A**, $p = 0.017$). The time was also expressed as relative time to the instructor's demonstration. The relative time also has significantly shortened (from 4.77 ± 2.48-fold at the first round to 1.71 ± 1.42-fold, $p = 0.034$, **Figure 2B**), even though the difficulty of anatomies has increased (**Figure 2**).

The CT images of 3D sinus models before and after the training were taken and the volume of FSDP was calculated and compared. Image analysis showed the volume of FSDP increased significantly after the frontal sinusotomy (Model 6 Rt; 1.20 ± 0.00 ml vs. 5.53 ± 0.29 ml, $p = 0.002$, Model 8 Lt; 1.39 ± 0.00 ml vs. 4.59 ± 0.93 ml, $p = 0.027$, and Model 8 Rt; 0.83 ± 0.00 ml vs. 3.82 ± 0.61 ml, $p = 0.014$, **Figures 3A,B**). The total volume of bilateral FSDP after frontal drillout was significantly improved from 2.36 ± 0.00 to 9.70 ± 1.49 ml postoperatively (Model 2, $p = 0.014$, **Figures 3C,D**).

The subjective difficulty of surgeries perceived by the dissectors during the dissections did not significantly change throughout the course (the first dissection; 78.60 ± 20.45, the last dissection; 65.91 ± 9.47, $p = 0.53$, **Figure 2C**) despite an increase in the difficulty of preoperative comprehension of the anatomies (**Supplementary Figure 2**). The subjective completeness of frontal sinusotomy was quickly increased and reached the plateau (**Figure 2D**). The confidence to perform a frontal sinusotomy in significantly increased throughout the course (before the course; 8.39 ± 9.17, after the course; 63.88 ± 12.29, $p = 0.025$, **Figure 2E**).

The Remote Endoscopic Surgery Training Course Is Beneficial Not Only for Dissectors but Also for Audiences Away From the Training Room

The questionnaires were answered by the three dissectors (100%) and 79 of the 200 audience members (38.73%). The course's perceived general benefit to improve surgical skills was 95.47 ± 5.13 in the dissectors and 89.24 ± 15.75 in the audience (0: not at all to 100: extremely beneficial). The usefulness of instruction provided by the Adelaide supervisors was 96.97 ± 5.25 in the dissectors and 82.26 ± 15.73 in the audience (0: never to 100:

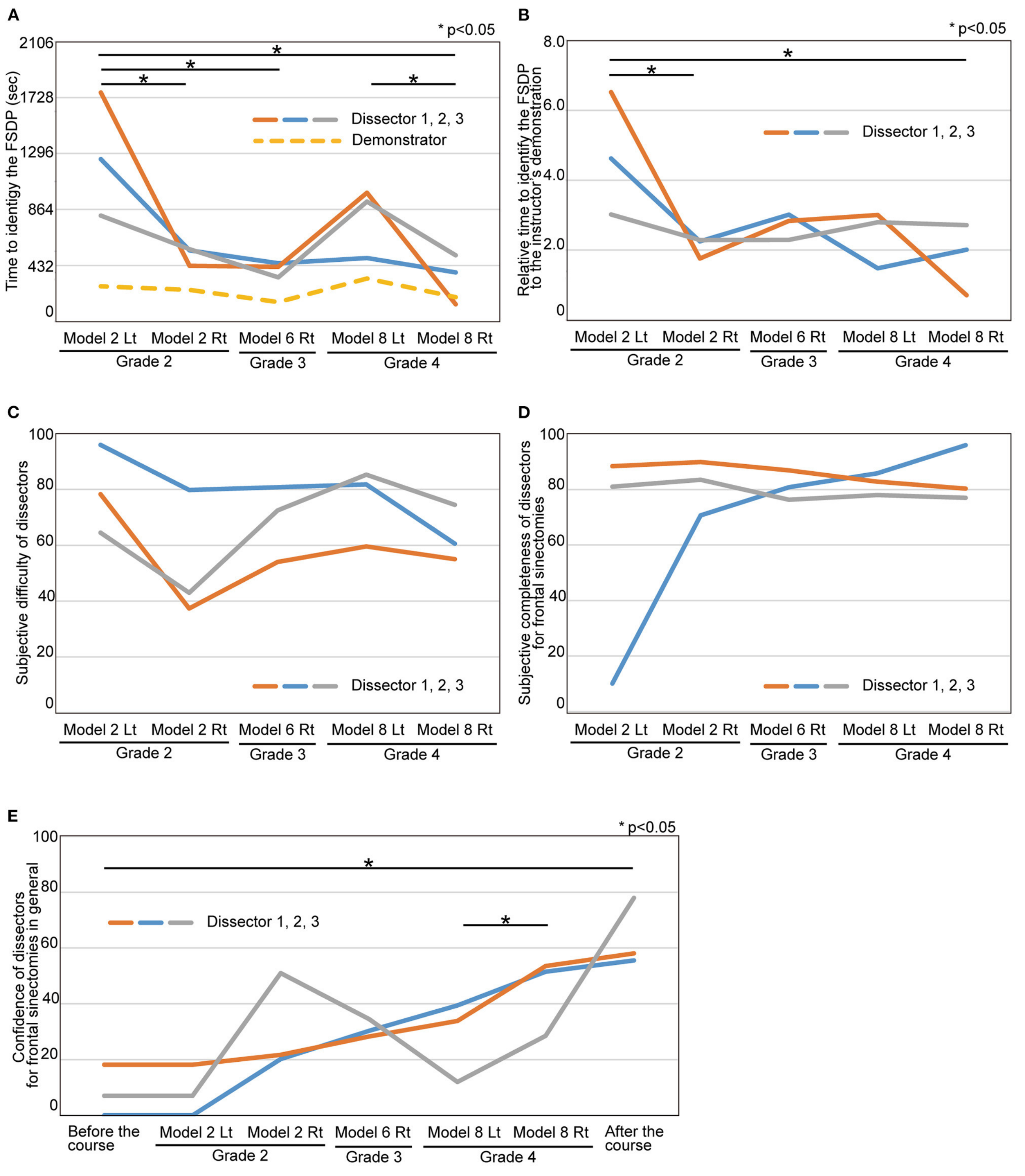


FIGURE 2 | The remote endoscopic surgery training course was objectively and subjectively beneficial in improving the dissectors' surgical techniques. **(A)** The time to identify the FSDP. It was defined as the time interval from starting to resect the anterior wall of ANC to identify and insert a ball probe tip to FSDP at the height of the top of ANC. *P*-values for indicated comparisons were determined by *t*-test. $^{*}p < 0.05$. **(B)** The relative time to identify the FSDP to the instructor's demonstration. *P*-values for indicated comparisons were determined by *t*-test. $^{*}p < 0.05$. **(C)** The subjective difficulty of the surgeries that the dissectors were perceiving during the dissection. **(D)** The subjective completeness of frontal sinusotomy during the dissection. **(E)** The confidence for frontal sinusotomy in general before, during, and after the course. *P*-values for indicated comparisons were determined by *t*-test. $^{*}p < 0.05$.

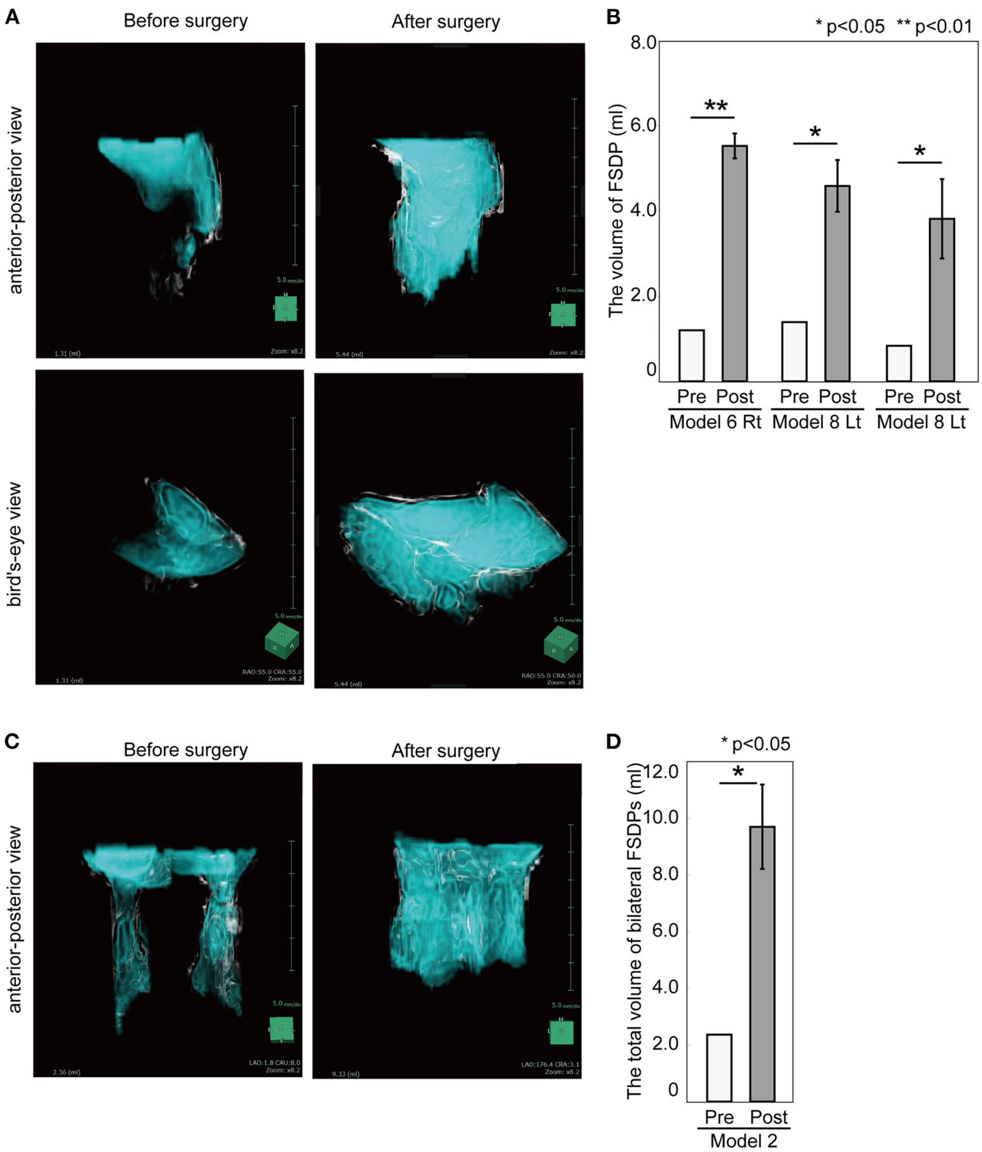


FIGURE 3 | The volume of FSDP before and after the frontal sinusotomies and the frontal drill out. **(A)** 3D computed graphic images of right FSDP in the model 6 before and after the sinusotomies. **(B)** The volume of FSDP in 3D sinus models was significantly improved after the frontal sinusotomies than before the procedure. *P*-values for indicated comparisons were determined by *t*-test. *$p < 0.05$, **$p < 0.01$. **(C)** 3D computed graphic images of bilateral FSDP in the 3D sinus models before and after the frontal drillout (the model 2). **(D)** The total volume of bilateral FSDPs was also significantly improved after the frontal drillout. *P*-values for indicated comparisons were determined by *t*-test. *$p < 0.05$.

excellent). Subjective distance from Adelaide (How far they felt from the Adelaide team) was 18.13 ± 2.40 in the dissectors and 35.90 ± 16.31 in the audience, respectively (0: felt as if the instructors were in the training room in Hokkaido to 100: far away). The dependency on the language translation provided by the first author for those who couldn't understand English was 91.96 ± 2.40 in the dissector and 85.90 ± 16.31 in the audience (0: completely independent to 100: perfect dependent) (**Figure 4**).

We also evaluated how the dissectors perceived the models. The surgical likeness of the model to the tissue feel anatomy of a real sinonasal cavity was 66.72 ± 15.04 in the dissectors (0: not at all to 100: completely reproduced). Similarly, the audience was asked how realistic the anatomy of the 3D sinus models looked compared to typical endoscopic sinonasal anatomy that they are accustomed to seeing in their practice. The reproduction of the 3D sinus model watched on the monitor was 75.32 ± 18.12 in the audiences (0: not at all to 100: completely reproduced). Obviously the tissue feel of the 3D sinus models could not be commented on by the non-dissecting audience members.

The perceived necessity of needing to use cadavers for similar surgical training after participating in this course was 25.24 ± 19.21 in the dissectors and 51.28 ± 23.31 in the audiences (0: not at all to 100: absolutely necessary) (**Figure 4**).

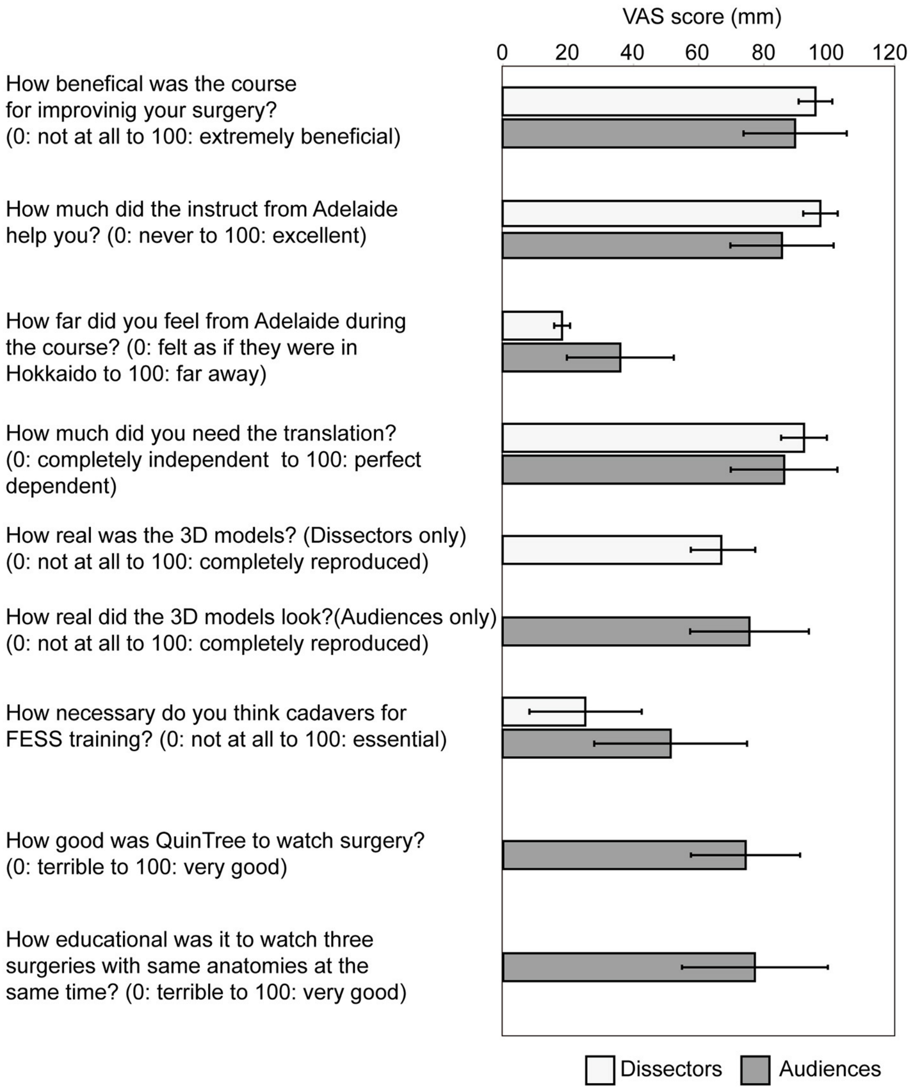


FIGURE 4 | The result of questionnaire from the dissectors and the audiences on educational benefits of the remote FESS training course. A questionnaire survey was performed on dissectors and audiences, including the following topic; the general benefit of the course to improve the surgical skills (0: not at all to 100: extremely beneficial), the usefulness of instructions from Adelaide (0: not at all to 100: excellent), subjective distance from Adelaide (0: felt as if they were in Hokkaido to 100: far away), the dependency on the translation between English and Japanese (0: completely independent to 100: perfect dependent), the reproducibility of the 3D sinus models to the real nasal cavity and paranasal sinuses (0: not at all to 100: completely reproduced, for dissectors only), the reproducibility of the 3D sinus models to the real nasal cavity and paranasal sinuses when watched on monitors (0: not at all to 100: completely reproduced, for audiences only), the necessity of using cadavers for the similar surgical training (0: not at all to 100: essential), the quality of the communication by Quintree (0: terrible to 100: very good), and the educational effect of watching the three surgeries with same anatomies at the same time by Quintree (0: terrible to 100: very good). Data were gathered by visual-analog scale and expressed as the mean ± SD.

The quality of the telemedicine platform provided by Quintree was as high as 73.42 ± 16.57 (0: terrible to 100: very good). The educational value to the non-dissecting audience of simultaneously watching the three surgeons performing the same surgery on three identical frontal sinus models was 76.27 ± 22.11 (0: terrible to 100: very good) with 84.81% of the audience considering the educational effect of the three simultaneous dissections as higher compared to watch only one dissection (**Figure 4**).

DISCUSSION

This study documents, for the first time, the feasibility of performing a remote endoscopic sinus surgical course using non-cadaveric advanced material 3D sinus models in conjunction with an encrypted telemedicine platform. Post-course evaluation demonstrated that in addition to such a course being possible, it objectively and subjectively improved surgeon's frontal sinus surgical skill in terms of efficiency and completeness of dissection. Participants and observers described a degree of post-course satisfaction in terms of learning opportunity.

With advanced in 3D printing technology and manufacturing many 3D organ models have been developed for surgical training, including temporal bone (6–8), paranasal sinuses (9–12), skull base (9, 13–16), kidney, renal pelvis, and ureter (17), mandibular (9), aorta (18), and heart (19). In addition, some models successfully reproduce the organs with pre-existing pathology such as cerebral aneurysms (20, 21) and basilar invagination (22). Studies assessing the use of 3D printed models for surgical training have generally supported their benefits for surgical education (23) and recently in the field of veterinary medicine, Kelly reported the use of 3D models to teach students surgical anatomy remotely (24). Several additional small studies assessing remote training for surgical skills have also been reported. These generally involve the teaching of basic surgical skills using box trainers such as peg transfer, knot tying, and suturing techniques under laparoscopy (25, 26). Recently a course utilizing remote guidance of actual endovascular surgery using augmented reality (AR), has also been published (27). To our knowledge, our study is the first remote course to assess the utility of using 3D-printed models for a complex surgical procedure in human based models.

3D sinus models hold several advantages over cadavers in surgical training. There is no risk of infectivity from the specimens, the courses can be held outside of designated anatomical institutions required for housing cadavers, and there is an elimination of the ethical issues that would accompany the transmission of cadaveric pictures on a telemedicine platform. Furthermore, such models are much cheaper than cadavers, ∼1/10 of the cost, meaning that course costs can be kept lower, and candidates can have the opportunity to dissect more frontal sinuses during a course than they have historically been able to do with cadaver.

Another major advantage of using advance material 3D sinus models over cadavers is the ability to print standardized anatomy, that allows both instructors and students to teach and learn in a predictable and graduated fashion as we saw in this course. From an instructor's perspective, pre-existing knowledge of the anatomy is likely to translate into more effective and efficient teaching. From a student's perspective, the student can gain knowledge, familiarity and confidence from performing more simple frontal sinus dissections before attempting more difficult ones. Furthermore, they can also learn from watching surgery performed by the expert's on exactly the same anatomy.

The successful completion of this course by all three surgeons validates the initial objective of this study, which was to see if it was possible to use encrypted telemedicine software to remotely teach and observe sinus surgery in a structured environment. Furthermore, it confirmed that surgery as complex as frontal recess dissection, could be taught in a step-wise and structured manner, using the building block concept, to surgeons of differing levels of sinus surgical experience, including a trainee that had never performed a sinus procedure prior. Of even greater significance, and further supporting this way of teaching, was the objective evidence that despite an increase in the difficulty of frontal sinus anatomy, surgical time and complete of dissection both improved as the course went on.

The results from the feedback questionnaire obtained from both the dissectors and the general audience confirmed the high level of satisfaction the participants obtained from attending the course. In terms of the specific questions of the questionnaire, the physical distance between the delegates and instructors did not pose a problem due to the clear instruction of the instructors facilitated by the innovative telemedicine technology utilized. There was a general consensus that the 3D sinus models were a suitable alternative to the cadaveric models particularly from the dissectors who were able to directly work with the model. A distinct advantage of the 3D sinus model as outlined by the responses of both the dissectors and the general audience, was the predictability and reproducibility of the model when compared to cadaveric specimens. The importance of well-performed translation was identified by over half of the Japanese audience as a significant factor contributing to their satisfaction with the course. This is obviously of critical importance when the native language of the delegates is not that of the remote instructors.

In addition to the high level of delegate and audience satisfaction from the course, both instructors (AJP and PJW) also reported high level of satisfaction with the ease of which they were able to teach (data not shown). Using the Quintree telemedicine platform they were able to visualize the endoscopic images of all three candidates on the same screen simultaneously, and so were in direct contact with each of the candidates for their duration of their dissection. This allowed them to tailor the extent and level of their instruction to the need of the candidate. This is not possible with one-on-one supervision required during face-face in person courses.

The obvious limitations of this study include the small number of dissecting surgeons assessed and the varying surgical experience of the dissectors and the audience. We recognize that this has the protentional to create bias in some of the responses evaluating the utility of the course. With this said, the primary aim of the course was to assess whether we could address the issues of conducting educational surgical courses, posed by the COVID-19 pandemic. With the promising results obtained from the feedback from this course, we plan to conduct a much larger course with more surgical dissectors whereby factors such as the relationship of surgical experience to learning benefit from such courses can be more adequately assessed.

CONCLUSION

To the best of our knowledge, this is the first study to report on a remotely conducted FESS training course using advanced 3D sinus models with different grades of complexity. This study demonstrated that remote courses and the use of non-cadaveric material may provide a suitable alternative to the traditional cadaveric/in person courses. This is particularly relevant in the current environment of the COVID-19 pandemic.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The patients/participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

AUTHOR CONTRIBUTIONS

MS, EV, and PW designed the project. AH and AP supervised the project. MS, EV, and KO set up the course. PW and AP supervised the training. KM and YN analyzed CT images. MS, EV, and AP wrote the draft. All authors provided feedback on the manuscript.

FUNDING

This study was supported by JSPS KAKENHI Grant Number 18KK0444, Itoiyaku Gakuzyutsu Zaidan, and Suginome Kinen Kai for MS.

ACKNOWLEDGMENTS

We are thankful to Dr. Aya Honma, Dr. Akira Nakazono, Dr. Shogo Kimura, Shizuka Sugawara, Yuka Masuta, Yumiko Kimura, and Minoru Ishida, for their support in the surgical training course. We appreciate Prof. Adam Folbe for his providing the Quintree platform. We are grateful to the members of the CAST committee at the Hokkaido University Hospital for their support. We are also thankful to Medtronic, KARL STORZ, Stryker, and Neilmed for their providing and setting up the surgical equipment, endoscopes, the Building Block software, and the web-conferencing platform.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsurg.2021.746837/full#supplementary-material

Supplementary Figure 1 | Measurement of the volume of the frontal sinus drainage pathway. **(A)** 3D sinus models used in the course. The anatomy is identical to that of humans as they are printed from the axial CT scans of patients with chronic rhinosinusitis. The materials mimic human tissue found in the nasal cavity and sinuses. **(B–D)** CT images of the 3D sinus models were acquired before and after the dissection. 3D computed graphic images of FSPD (sky blue) were created by a 3D image analysis system, SYNAPSE VINCENT with different transparency of the 3D sinus models from 0% **(B)** to 100% **(D)**. The volume of FSDP from the level of the superior edge of 3D sinus models to the level of the floor of ANC was quantified.

Supplementary Figure 2 | Subjective difficulty of preoperative comprehension of anatomies of frontal recess in each difficulty grade. The subjective difficulty of prediction of FSDP with the Building Block Concept was increased with the higher difficulty grade. *P*-values for indicated comparisons were determined by *t*-test. $^{*}p < 0.05$, $^{**}p < 0.01$.

REFERENCES

1. Fokkens WJ, Lund VJ, Hopkins C, Hellings PW, Kern R, Reitsma S, et al. European position paper on rhinosinusitis and nasal polyps 2020. *Rhinology*. (2020) 58(Suppl.S29):1–464. doi: 10.4193/Rhin20.601
2. Wormald P-J. *Endoscopic Sinus Surgery*. Stuttgart, New York, NY: Thieme (2018). doi: 10.1055/b-0038-149997
3. Naidoo Y, Wen D, Bassiouni A, Keen M, Wormald PJ. Long-Term results after primary frontal sinus surgery. *Int Forum Allergy Rhinol.* (2012) 2:185–90. doi: 10.1002/alr.21015
4. Wormald PJ. Surgery of the frontal recess and frontal sinus. *Rhinology.* (2005) 43:82–5.
5. Wormald PJ. The agger nasi cell: the key to understanding the anatomy of the frontal recess. *Otolaryngol Head Neck Surg.* (2003) 129:497–507. doi: 10.1016/S0194-5998(03)01581-X
6. Chien WW, da Cruz MJ, Francis HW. Validation of a 3d-Printed human temporal bone model for otology surgical skill training. *World J Otorhinolaryngol Head Neck Surg.* (2021) 7:88–93. doi: 10.1016/j.wjorl.2020.12.004
7. Da Cruz MJ, Francis HW. Face and content validation of a novel three-dimensional printed temporal bone for surgical skills development. *J Laryngol Otol.* (2015) 129(Suppl.3):S23–9. doi: 10.1017/S0022215115001346
8. Mooney MA, Cavallo C, Zhou JJ, Bohl MA, Belykh E, Gandhi S, et al. Three-dimensional printed models for lateral skull base surgical training: anatomy and simulation of the transtemporal approaches. *Oper Neurosurg.* (2020) 18:193–201. doi: 10.1093/ons/opz120
9. Chan HH, Siewerdsen JH, Vescan A, Daly MJ, Prisman E, Irish JC. 3D rapid prototyping for otolaryngology-head and neck surgery: applications in image-guidance, surgical simulation and patient-specific modeling. *PLoS ONE.* (2015) 10:e0136370. doi: 10.1371/journal.pone.0136370
10. Chang DR, Lin RP, Bowe S, Bunegin L, Weitzel EK, McMains KC, et al. Fabrication and validation of a low-cost, medium-fidelity silicone injection molded endoscopic sinus surgery simulation model. *Laryngoscope.* (2017) 127:781–6. doi: 10.1002/lary.26370
11. Alrasheed AS, Nguyen LHP, Mongeau L, Funnell WRJ, Tewfik MA. Development and validation of a 3d-printed model of the ostiomeatal complex and frontal sinus for endoscopic sinus surgery training. *Int Forum Allergy Rhinol.* (2017) 7:837–41. doi: 10.1002/alr.21960
12. Barber SR, Jain S, Son YJ, Chang EH. Virtual functional endoscopic sinus surgery simulation with 3d-printed models for mixed-reality nasal endoscopy. *Otolaryngol Head Neck Surg.* (2018) 159:933–7. doi: 10.1177/0194599818797586
13. Tai BL, Wang AC, Joseph JR, Wang PI, Sullivan SE, McKean EL, et al. A physical simulator for endoscopic endonasal drilling techniques: technical note. *J Neurosurg.* (2016) 124:811–6. doi: 10.3171/2015.3.JNS1552
14. Hsieh TY, Cervenka B, Dedhia R, Strong EB, Steele T. Assessment of a patient-specific, 3-dimensionally printed endoscopic sinus and skull base surgical model. *J Am Med Assoc Otolaryngol Head Neck Surg.* (2018) 144:574–9. doi: 10.1001/jamaoto.2018.0473
15. Zheng JP Li CZ, Chen GQ, Song GD, Zhang YZ. Three-Dimensional printed skull base simulation for transnasal endoscopic surgical training. *World Neurosurg.* (2018) 111:e773–82. doi: 10.1016/j.wneu.2017.12.169
16. Ding CY, Yi XH, Jiang CZ, Xu H, Yan XR, Zhang YL, et al. Development and validation of a multi-color model using 3-Dimensional printing technology for endoscopic endonasal surgical training. *Am J Transl Res.* (2019) 11:1040–8. doi: 10.3171/2019.6.FOCUS19294
17. Cheung CL, Looi T, Lendvay TS, Drake JM, Farhat WA. Use of 3-Dimensional printing technology and silicone modeling in surgical simulation: development and face validation in pediatric laparoscopic pyeloplasty. *J Surg Educ.* (2014) 71:762–7. doi: 10.1016/j.jsurg.2014.03.001
18. Hussein N, Honjo O, Barron DJ, Yoo SJ. Supravalvular aortic stenosis repair: surgical training of 2 repair techniques using 3d-printed models. *Interact Cardiovasc Thorac Surg.* (2021) 2021:ivab198. doi: 10.1093/icvts/ivab198

19. Yildiz O, Köse B, Tanidir IC, Pekkan K, Güzeltaş A, Haydin S. Single-center experience with routine clinical use of 3d technologies in surgical planning for pediatric patients with complex congenital heart disease. *Diagn Interv Radiol.* (2021) 27:488–96. doi: 10.5152/dir.2021.20163
20. Mashiko T, Kaneko N, Konno T, Otani K, Nagayama R, Watanabe E. Training in cerebral aneurysm clipping using self-made 3-dimensional models. *J Surg Educ.* (2017) 74:681–9. doi: 10.1016/j.jsurg.2016.12.010
21. Nagassa RG, McMenamin PG, Adams JW, Quayle MR, Rosenfeld JV. Advanced 3d printed model of middle cerebral artery aneurysms for neurosurgery simulation. *3D Print Med.* (2019) 5:11. doi: 10.1186/s41205-019-0048-9
22. Narayanan V, Narayanan P, Rajagopalan R, Karuppiah R, Rahman ZA, Wormald PJ, et al. Endoscopic skull base training using 3d printed models with pre-existing pathology. *Eur Arch Otorhinolaryngol.* (2015) 272:753–7. doi: 10.1007/s00405-014-3300-3
23. Langridge B, Momin S, Coumbe B, Woin E, Griffin M, Butler P. Systematic review of the use of 3-dimensional printing in surgical teaching and assessment. *J Surg Educ.* (2018) 75:209–21. doi: 10.1016/j.jsurg.2017.06.033
24. Thieman Mankin KM, Cornell K, Peycke L, Dickerson V, Scallan E. Adaptation of a hands-on veterinary surgical training course from a traditionally taught laboratory to a remotely taught laboratory during a global pandemic. *Vet Surg.* (2021) 50:494–506. doi: 10.1111/vsu.13584
25. Quaranto BR, Lamb M, Traversone J, Hu J, Lukan J, Cooper C, et al. Development of an interactive remote basic surgical skills mini-curriculum for medical students during the covid-19 pandemic. *Surg Innov.* (2021) 28:220–5. doi: 10.1177/15533506211003548
26. Sloth SB, Jensen RD, Seyer-Hansen M, Christensen MK, De Win G. Remote training in laparoscopy: a randomized trial comparing home-based self-regulated training to centralized instructor-regulated training. *Surg Endosc*. (2021) 7:1–12. doi: 10.1007/s00464-021-08429-7
27. Hassan AE, Desai SK, Georgiadis AL, Tekle WG. Augmented reality enhanced tele-proctoring platform to intraoperatively support a neuro-endovascular surgery fellow. *Interv Neuroradiol.* (2021). doi: 10.1177/15910199211035304

Conflict of Interest: MS: receiving royalties from Igakushoin. PW: consultant for Fusetec, Neilmed and receiving royalties from Medtronic, Fusetec, and Integra. Shareholder for Chitogel. AP: consultant for Fusetec, Medtronic, Tissium, and ENT technologies. Shareholder for Chitogel and Speakers Bureau for Sequiris.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Medicine

ORIGINAL RESEARCH
published: 05 November 2021
doi: 10.3389/fmed.2021.772956

Curiosity in Online Video Concept Learning and Short-Term Outcomes in Blended Medical Education

Cheng-Maw Ho [1,2], Chi-Chuan Yeh [1,3], Jann-Yuan Wang [2,4,5], Rey-Heng Hu [1,2]* and Po-Huang Lee [1,2,6]**

[1] Department of Surgery, National Taiwan University Hospital, Taipei, Taiwan, [2] School of Medicine, College of Medicine, National Taiwan University, Taipei, Taiwan, [3] Department of Medical Education, National Taiwan University Hospital, Taipei, Taiwan, [4] Department of Internal Medicine, National Taiwan University Hospital, Taipei, Taiwan, [5] Center of Faculty Development and Curriculum Integration, College of Medicine, National Taiwan University Hospital, Taipei, Taiwan, [6] Department of Surgery, E-Da Hospital, I-Shou University, Kaohsiung, Taiwan

OPEN ACCESS

Edited by:
Ismail Mohd Saiboon, National University of Malaysia, Malaysia

Reviewed by:
Jaroslav Kacetl, University of Hradec Králové, Czechia
Nurhanis Syazni Roslan, Universiti Sains Malaysia Health Campus, Malaysia

***Correspondence:**
Jann-Yuan Wang
jywang@ntu.edu.tw
Rey-Heng Hu
rhhu@ntu.edu.tw
Po-Huang Lee
pohuang1115@ntu.edu.tw

Specialty section:
This article was submitted to Healthcare Professions Education, a section of the journal Frontiers in Medicine

Received: *09 September 2021*
Accepted: *12 October 2021*
Published: *05 November 2021*

Citation:
Ho C-M, Yeh C-C, Wang J-Y, Hu R-H and Lee P-H (2021) Curiosity in Online Video Concept Learning and Short-Term Outcomes in Blended Medical Education. Front. Med. 8:772956. doi: 10.3389/fmed.2021.772956

Background: A student's level of curiosity in a subject after learning about it through online videos has not been addressed well in the medical education field. The purpose of this study, therefore, was to investigate online learning's effect on the stimulation of curiosity and short-term learning outcomes in a blended framework of precision medical education.

Methods: A mixed-methods research design was used. During the 2020 academic year, all fifth-year medical students who, prior to class, viewed 6 video clips that presented 6 core concepts were invited to complete a survey and self-reflection on their learning process to assess their level of curiosity in each concept. For each group of medical students, teaching assistants helped collect anonymous survey data and summative assessment scores representing the students' learning outcomes. Video-viewing patterns, attained through an action log transformation, were also coded for analysis. Mann–Whitney *U* and Kruskal–Wallis tests were employed to compare differences between groups, and multiple linear regression was used to select the factors affecting learning outcomes. Qualitative data were content-coded through a descriptive approach using thematic analysis.

Results: Of 142 medical students, 136 watched the online videos, 124 responded to the questionnaires, and 92 provided comments. Students' curiosity levels after learning about each concept through online videos significantly correlated with the degree to which a concept was learned. Medical students spent a median of 1.6 h online, and pause frequency correlated with curiosity in certain concepts. Aroused curiosity was associated with short-term learning outcomes in inconsistent effect sizes and directions. Students' feedback revealed various dimensions of curiosity, including novelty acknowledgment, recognition of an information gap, and information-seeking requests.

Conclusions: Curiosity can be induced through online video learning platforms and has a role in short-term learning outcomes in medical education.

Keywords: online video learning, curiosity, concept, learning outcome, medical education

INTRODUCTION

Curiosity can be broadly defined as the desire to acquire new knowledge and new sensory experiences, which motivates exploratory behavior (1–3). An individual's degree of curiosity varies according to their personality traits (2) and can be independently induced; for example, two people might be drawn to different aspects of the same stimulus (2, 3). In the medical education field, studies in cognitive psychology and education have suggested that common instructional practices may inadvertently suppress curiosity by conflating haste with efficiency, neglecting negative emotions, promoting overconfidence, and using teaching approaches that encourage passive learning (4). Attributes of the instructor that contribute to the development of a student's curiosity include patience, a habit of inquiry, emotional candor, intellectual humility, transparency, and recognition of the benefits of learning from peers (4). Specific educational strategies that can support curiosity in both classroom and clinical settings include the mindful pacing of teaching, modeling effective control of emotions, confronting uncertainty and overconfidence, using inquiry-based learning, helping students see familiar situations as novel, simultaneously contemplating multiple perspectives, and maximizing the value of small-group discussions (4).

THEORETICAL BACKGROUND AND IMPORTANCE OF CURIOSITY IN MEDICAL EDUCATION

George Loewenstein described curiosity as "a cognitive induced deprivation that arises from the perception of a gap in knowledge and understanding" (2). Epistemic curiosity is "the desire for knowledge that motivates individuals to learn new ideas, eliminate information gaps, and solve intellectual problems" (5). The development of deliberate, focused, and sustained epistemic curiosity should, therefore, be a core element of teaching and learning in medical education (6). Moreover, calls for self-reflection, critical thinking, and teamwork are meaningless in the absence of curiosity (4). Kidd and Hayden expanded information gap theory by proposing that studying the motivation behind information-seeking behavior in its ethological context is more productive than defining curiosity itself (7). This conceptualization indicates that online video learning using a threshold concept strategy (8) presents various opportunities for medical students to develop epistemic curiosity.

Although the importance of curiosity in medical education was perceived and critically reminded in literature for a long time (4, 9–12), relevant evidence was accumulated sluggishly. Stenernszus et al. found that trait curiosity (individual characteristic) is relatively stable across a 4-year undergraduate program of medical education whereas there is more variability in state curiosity (arousal of curiosity by the educational context), which is consistently lower than trait curiosity in each year (13). Medical students' state curiosity may not be optimally supported in the environment of medical education (13). Richards et al. demonstrated that students with high levels of trait curiosity tended to use learning strategies that promoted understanding rather than memorization (14). The need to evoke curiosity in medical education is highlighted, especially in the current setting of teaching which relies heavily on online learning and online video materials have become an integral part of instruction at universities.

We previously explored the possibility of practicing precision medical education based on cognitive load theory and the theory of multimedia learning (15–19). We summarized that implementing precision medical education in the blended medical education is feasible and online video learning is an ideal platform for balancing the dilemma between increasing cognitive load of class content and practice of precision medical education (15). In addition, inverse concept change was frequently documented among participants and students' feedback of online video learning experiences revealed aroused study interest and motivation (15). These observations were subtle signs of aroused curiosity which trigger us for further study. Therefore, we hypothesized that this instructional design could stimulate students' curiosity for online video learning of these concepts. This study examined students' levels of curiosity arousal after online video learning and investigated the association of curiosity with short-term learning outcomes.

METHODS

Research Type, Context, and Participants

This study involved a survey using cross-sectional mixed-methods study design (20). The survey consisted of questionnaires (quantitative part) and free comments (if any, qualitative part) (**Supplementary Table 1**). The qualitative component of this study was embedded to enhance a largely quantitative study (**Figure 1A**) (21). This embedded mixing facilitates quantitative and qualitative analyses to complement each other (21). Clinical teaching on the subject of acute liver failure is a section of a core compulsory course (including 23 sections) for surgery students in their first clinical (fifth) year (8). Almost all students were between 23 and 24 years of age, with few post-baccalaureate students in every school year. Each course section consists of a 1-h class, with 22–24 medical students enrolled in each round. Six rounds of teaching are conducted in 1 academic year at National Taiwan University Hospital. Between September 2020 and May 2021, 142 fifth-year medical students took the compulsory core course on surgery, and they were invited to participate in this survey. The Institutional Review Board of National Taiwan University Hospital approved this study as an exempt protocol (201809078W and 202006048W). Participation in the survey was considered implied consent from the participants.

The curriculum development committee assigned HCM to develop the curriculum for the acute liver failure section. HCM summarized 6 threshold concepts of acute liver failure according to the educational goals of the curriculum development committee and incorporated them into the course design and practice (8). A blended course section of acute liver failure was initiated and practiced beginning in 2018 (8, 15).

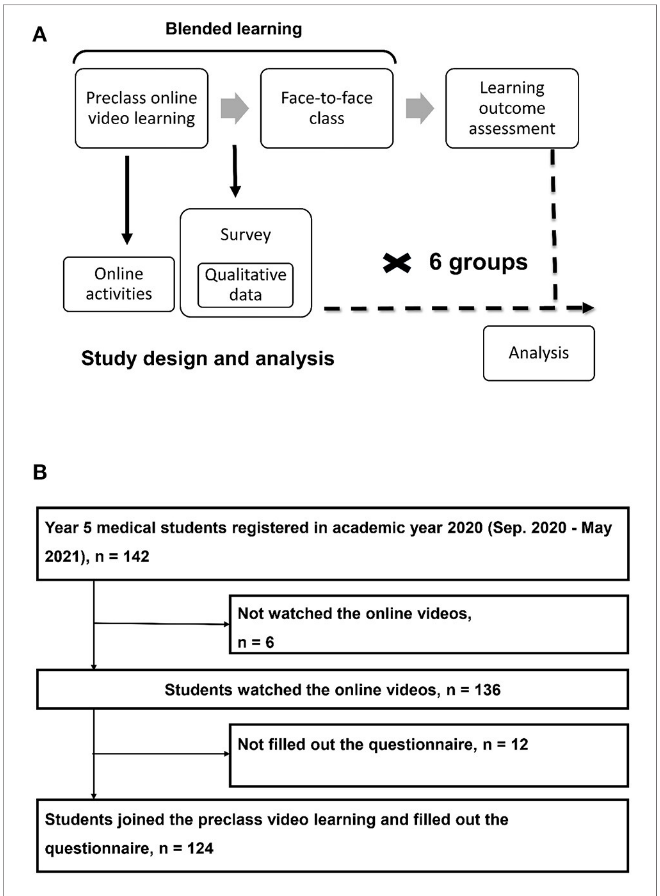


FIGURE 1 | Study design **(A)** and participants **(B)**.

The course content was divided into two stages: pre-class online video learning and face-to-face classroom instruction. When redesigning the classic course into a blended one, consideration was specifically given to dividing the learning materials in a manner such that they would retain a stimulating effect and be integrated at the end of the learning journey. The instructional methods for the online video portion of the course were based on the coherence (excluding extraneous material) and segmenting (message is presented in user-paced segments rather than as a continuous unit) principles of Mayer's multimedia learning (18, 19).

Previously, a 10-min online video for pre-class learning was developed to minimize the extraneous load by removing non-essential content, breaking content into smaller segments, and enabling learners to control the pace (15). In the 2020–2021 academic year, one 10-min online video was remade into 6 video clips, each lasting <2 min, for six individual concepts. A title with a short summary of each concept was added to arouse interest and curiosity. The clinical teacher (HCM) selected and uploaded the updated review literature to the webpage to make available optional additional reading. A list of chart numbers was provided on the intranet for a real-world clinical case analysis.

At the beginning of the surgery course, students were instructed to watch the online videos explaining the core concepts before the face-to-face class. Subsequently, they were free to respond to an online questionnaire (**Supplementary Table 1**) in the university intranet (22). Changes in the understanding of concepts were rated on a 5-point Likert scale ("totally changed," "largely changed," "changed and unchanged in equal measure," "mostly unchanged," and "totally unchanged"). The following categories were evaluated: curiosity induced in individual concepts; concepts that motivated medical students to learn more; concepts requiring further clarification during face-to-face classes; loading, difficulty, and satisfaction of online video learning prior to class; class style (teaching method) expectations for the upcoming face-to-face class; and comments or questions.

The survey listed the four class styles: complete and thorough introduction (subsequently referred to as thorough), concept orientation to stimulate study interest (concept), discussions between the teacher and students creating a learning experience (discussion), and self-learning and class presentations (presentation) (15). The teacher developed the face-to-face class style for each round of students based on the survey responses (15).

The outcome measurements in this study consisted of two summative assessments. The first was a written exam [total possible score: 100 marks (points)] taken at the end of the surgery course round, which included 3 points for a short essay question concerning the acute liver failure section. The second assessment was a clinical case-based analysis (total possible score: 100 marks that contribute to grade point average for the section course) that was submitted online prior to the completion of the surgery course. The clinical teacher (HCM) graded the medical students' work after they completed the surgery course.

Online Learning Activities and Patterns of Online Video-Viewing Behaviors

Cumulative website page views, webpage visit/browsing durations, and action logs of video viewing for each medical student were documented anonymously in the management platform at the end of the school year. The action logs of video viewing were transformed into visualization plots containing intensity (defined as peak times of viewing with a duration lasting more than 2 s), extensity (completeness, categorized as 1 of 3 types: viewing <50%, 50–90%, or more than 90% of the video), and pause frequency (the number of times the video was paused). HCM and WJY independently performed pattern coding and eventually reached consensus.

Data Collection

For each round of students, administrative teaching assistant (SKW) helped collect anonymous survey data before the class.

Demographic data, scores, and online activities, including action logs of the online video viewing, total webpage view counts, and webpage visit durations, were anonymously collected at the end of the school year by administrative teaching assistants.

Qualitative Data Analysis

Student comments were independently content-coded through a descriptive approach using thematic analysis (8, 15, 23) by HCM and WJY, who eventually reached consensus. Codes corresponding to learning experiences were previously developed by a team comprising a surgeon specialist (HCM), an experienced medical education specialist (YCC), and an administrative researcher (WJY) (15). Regular meetings were held to discuss and resolve all coding discrepancies and to combine codes (15). According to the survey responses in each round of students, the teacher in charge (HCM) answered questions posed by students, validated the codes that reflected their opinions through anonymous discussions in class, and adjusted the class style (15).

At the end of the school year, identified themes were combined and compared to generate a final set representing the range of student feedback on the online video learning process. The research questions were to identify clues of induced curiosity, learning interests, and self-reported learning outcomes, in order to complement the quantitative analysis. Each student comment could include several codes across various categories (general, infrastructure, curiosity, learning outcome, and miscellaneous).

Quantitative Data Analysis

Quantitative data were expressed as means, medians, or percentages, where appropriate. Scores were compared using Student's *t* test. Non-parametric tests were employed to compare group differences other than scores. The Mann–Whitney *U* and the Kruskal–Wallis tests were employed to compare the differences in continuous variables among quantitative outcome variables for 2 and 3 groups, respectively. Kendall's tau coefficient was used to measure the ordinal association between 2 measured quantities. The multiple general linear regression model with a backward elimination method was used to select potential factors associated with the assessment scores. A two-sided $P < 0.05$ was considered statistically significant. Statistical analyses were performed using SPSS version 21.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

Demographics and Curiosity Spectrum

Of the 136 fifth-year medical students (136/142, 95.8%) who participated in the online video learning, 124 (124/136, 91.2%) completed the survey and were enrolled in the study (**Figure 1B**). These participants were predominantly male (75%), felt "just fine" about the work load and difficulty of online video learning (82.3 and 90.3%), were satisfied with online learning (91.9%), and provided comments (74.2%; **Table 1**). More than half of the participants preferred a class style of "through" (55.6%). Participants spent an average of 1.6 h [interquartile range (IQR), 3720.5-8634.8 s] watching the videos, and the median number of webpage visits was 194.5 (144.5–263.8). The summative assessment results of short-term learning outcomes indicated an average score of 87.9 ± 12.4 for the clinical case-based analysis and 2.4 ± 0.9 for the essay question.

Half of the participants (63/124, 50.8%) reported curiosity in only 1 concept after online video learning, and 59 participants expressed curiosity for 2–6 concepts (**Figure 2**). Two participants did not report feeling curious about any concept. Focused (only 1 concept) and diverse (more than 1 concepts) curiosity did not significantly differ when compared between genders, groups, durations of time spent online, perceptions of loading, perceptions of difficulty, perceptions of satisfaction with video learning, class preferences, whether comments were provided, and learning assessments but did significantly differ for accumulated webpage view counts [focused vs. diverse: 172.0 (134.0–246.0) and 201.0 (179.0–291.0); **Table 1**].

Online Video-Viewing Patterns

The intensity, extensity, and pause frequency of online video-viewing patterns for 6 concepts among 124 participants are shown in **Figure 3**. Most participants watched more than 90% of the 6 online videos. The median values for the intensity pattern were between 50 and 90% for the six videos. Total pauses when viewing online videos for concepts 1 −6 were 22, 16, 16, 21, 10, and 10, respectively (**Figure 3**). Statistically, the patterns between the 6 online videos clips were nonsignificant in terms of intensity ($P = 0.082$), extensity ($P = 0.626$), and pause frequency ($P = 0.239$, Kruskal–Wallis test).

Correlation of Curiosity With Other Parameters

Table 2 displays the correlation of curiosity with other parameters in 6 core concepts. Positive significant correlations between the "most learnt" concepts and their specific curiosities were noted for all 6 concepts. Other self-reported parameters positively correlated with specific curiosities were noted for "expect more" (concept 4) and "teach more" (concept 4) and negatively for "agree with previous understanding" (concept 2 and concept 3; **Table 2A**). For objective video-viewing patterns, curiosity significantly correlated with extensity (concept 3) and pause frequency (concept 5; **Table 2B**). Borderline significance was noted in pause frequency for concepts 1 and 4 ($P = 0.061$ and $P = 0.072$).

Factors Associated With Short-Term Learning Outcomes in Multivariable Analysis

Table 3 displays the adjusted factors associated with short-term learning outcomes determined through summative assessments. Male gender, concepts that agreed with previous understanding (C1), concepts that aroused curiosity (C1, C4, C6), concepts that "were learnt most" (C5), and concepts that agreed with video watching patterns of extensity (C2, C6) and pause frequency (C1, C6), and providing comments were significantly associated with essay assessment scores. Concepts that agreed with previous understanding (C3), aroused curiosity (C1, C3), were learnt most (C1), and were associated with a request for more teaching (C3, C4) significantly correlated with case analysis assessment scores (**Table 3**). Specific curiosities for concepts 1, 4, and 6 and concepts 1 and 3 were significantly associated with scores for the essay question and case-based analysis, respectively. The effect of specific curiosities on short-term learning outcomes, however, was not positively associated for all factors. Factors related to concept 6 (curiosity, extensity, and pause frequency) were positively associated with essay scores. Factors related to concept 3 (curiosity, agreement with previous understanding,

TABLE 1 | Characteristics of Participants Taking Surveys (Mann–Whitney *U* or chi-square test).

		All, *n* = 124*	Focused curiosity, *n* = 63	Diverse curiosity, *n* = 59	*P*
Gender					0.684
Male (%)		93 (75)	48 (76.1)	43 (72.9)	
Female (%)		31 (25)	15 (23.8)	16 (27.1)	
Group					0.284
Semester 1	1	19	12	6	
	2	23	12	11	
	3	23	14	9	
Semester 2	4	20	6	14	
	5	22	10	11	
	6	17	9	8	
Webpage view counts, median (IQR)		194.5 (144.5–263.8)	172.0 (134.0–246.0)	201.0 (179.0–291.0)	0.031
Visit durations (sec), median (IQR)		5602.5 (3720.5–8634.8)	5597.0 (2767.0–9738.0)	5705.0 (3638.0–8616.0)	0.612
Subjective					
Loading of online video learning					0.254
Heavy (%)		8 (6.5)	3 (4.8)	5 (8.5)	
Just fine (%)		102 (82.3)	55 (87.3)	45 (76.3)	
Light (%)		13 (10.5)	5 (7.9)	8 (13.6)	
Difficulty					0.478
Hard (%)		3 (2.4)	2 (3.2)	1 (1.7)	
Just fine (%)		113 (90.3)	59 (93.7)	52 (88.1)	
Easy (%)		7 (5.6)	2 (3.2)	5 (8.5)	
Satisfaction					0.570
Satisfied (%)		114 (91.9)	58 (92.1)	55 (93.2)	
So so (%)		9 (7.3)	5 (7.9)	3 (5.1)	
Class style preference					0.146
Through (%)		69 (55.6)	31 (49.2)	36 (61.0)	
Concept (%)		36 (29.0)	21 (33.3)	15 (25.4)	
Discussion (%)		18 (14.5)	11 (17.5)	7 (11.9)	
Providing comments (%)		92 (74.2)	46 (73.0)	45 (76.3)	0.835
Overall assessment					
Objective scores					
Case analysis, mean (SD)		87.9/100 (12.4)	89.1 (4.5)	86.4 (16.8)	0.226^
Essay question, mean (SD)		2.4/3 (0.9)	2.5 (0.9)	2.3 (0.9)	0.484^

**2 participants did not complete the survey item on curiosity.*
^Student's t test.
IQR, interquartile range; SD, standard deviation.

most learnt, and request for more teaching) were associated with case analysis scores.

Student Feedback

Table 4 presents students' feedback after online video learning. Most common comments were coded in the category of "appreciation of considerate lesson preparation or course framework" followed by "general gratitude" and "good learning efficiency and self-reported outcome." In the dimension of curiosity, "novelty" and inducing "interest and/or curiosity" were cited frequently. Although participants sensed an information gap after online video learning and asked for specific content, they were satisfied that the online video learning process was concise and clear. Some participants strongly recommended applying this framework to other courses.

DISCUSSION

This study revealed 4 major findings. First, students spent a median of 1.6 h engaged in online activities, and most were satisfied with online video learning. Second, self-reported curiosity was individually associated with the most learnt concept, and pause frequency correlated with curiosity in certain concepts. Third, curiosity about studied concepts following the online video learning suggested various effects of variable sizes and directions on short-term learning outcomes. Finally,

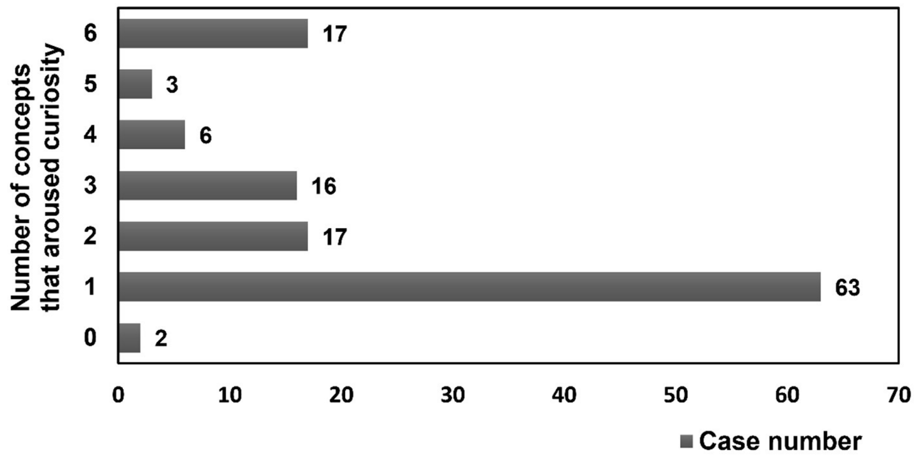


FIGURE 2 | Number of concepts that aroused curiosity in participants.

interpretation of the students' feedback reflected that the online video learning process cultivated curiosity.

Balance of Information Gap and Cultivating Curiosity in Medical Education

We observed aroused curiosity in the current study of online video learning, which could be explained by information gap theory. Besides, epistemic curiosity is useful to learn new ideas and solve intellectual problems, which were probed by quantitative questionnaires (**Supplementary Table 1**) and summative assessments, respectively. Loewenstein et al. (24) found that epistemic curiosity was greatest when participants had partial knowledge of a particular subject rather than no knowledge or full knowledge, a finding supported by Litman et al. (25) and Kang et al. (26). However, methods of managing the knowledge gap and potential consequences of varying degrees of gaps in knowledge (For example, a great knowledge gap may induce a loss of overall interest, and a gap that is too narrow may trigger satiety) require further investigation. Moreover, the instructional content designer must adjust the cognitive loads of online videos while simultaneously producing the most efficient learning environment.

Curiosity, Learning Motivation, and Learning Outcomes

Our study demonstrated that curiosity impacted short-term learning outcomes, with various effect sizes and directions, and led to an increased understanding of the role that certain intellectual, emotional, behavioral, physical, and social factors have in the student learning process and social development. The underlying causes and explanations that aroused curiosity to C1 was associated with scores of both essay and case base analysis were not clear. It may be attributed to the question selection or something different (e.g., a new concept to the students) as compared to other topics. Further study is needed to figure out the root cause. Nonetheless, we showed that sparkle curiosity was associated with the short-term learning outcome. A wide variety of studies on learning have revealed connections between non-cognitive factors or skills (e.g., motivation, interest, curiosity, responsibility, determination, perseverance, attitude, work habits, self-regulation, and social skills) and cognitive learning results (e.g., improved academic performance, test scores, information recall, and skill acquisition) (27). The impacts of these non-cognitive factors may be modified and diluted in an adult learning setting, especially that of medical education. Four dimensions of measurement (fear, assumptions, technology, and environment) for curiosity inhibitors, proposed by Hamilton in the Curiosity Code Index (28), can likely be applied to assess people working in clinical medical education.

Curiosity Online vs. Offline

We surveyed the extent of curiosity aroused in students just after they participated in the online video learning process. Sanjay analogized curiosity as the hunger of the brain, finding it, thus, to be a main element of a student's learning process (29). To spark curiosity through the online platform and develop expertise, Sanjay proposed helping students enter a state of mind conducive to questioning by assigning projects or asking questions online and then taking advantage of face-to-face class time by coaching and fine tuning. Our blended design is consistent with Sanjay's strategy and may also apply to other subjects, as one participant commented (**Table 4**).

Curiosity in Blended Learning

Blended learning is an educational process of the thoughtful integration of classroom face-to-face learning experiences with online learning experiences (30). Blended learning appears to be more effective than or at least as effective as non-blended instruction for knowledge acquisition in health professions (31, 32). When designed well, blended learning courses in medicine can facilitate students to improve themselves in self-learning, understanding, and problem solving, ultimately enhancing their learning efficiency (33–35). A potential pitfall of blended learning is the isolated nature of e-learning if the student interacts on an individual basis with the computer and not with a peer group, which can be overcome in part by online engagement

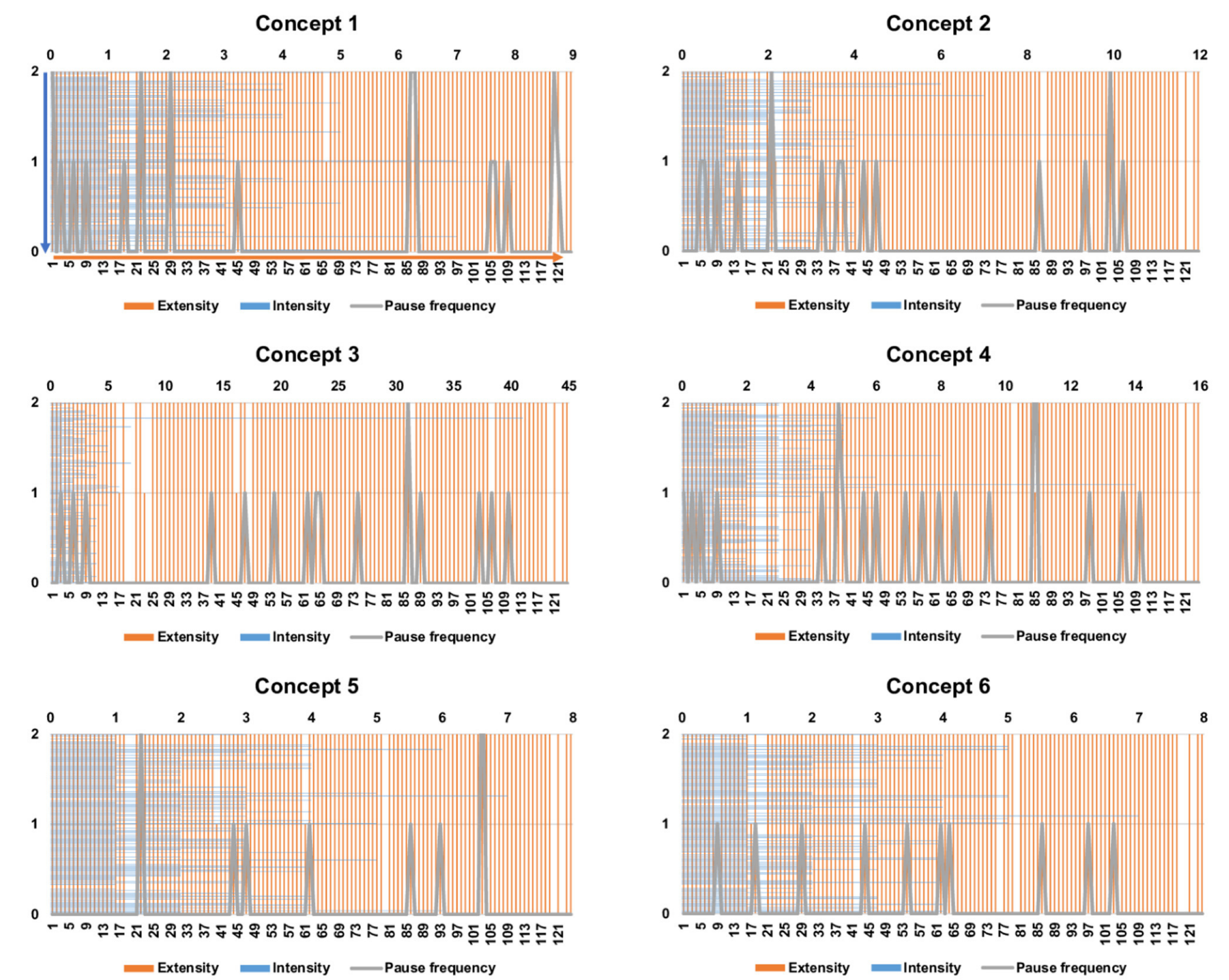


FIGURE 3 | Pre-class online video-viewing patterns (intensity, extensity, pause). (Upper X axis) Intensity (viewing times): Each blue line represents a case. Arrow shows the direction of cumulative cases. (Y axis, orange) Extensity (content completeness of video watching): 0, <50%; 1, 50–90%; 2, more than 90%. (Y axis, gray) Pause frequency during online video learning in each case. (Lower X axis): case number for extensity and pause frequency. Arrow shows the direction of cumulative cases.

through webinars and discussion boards (36). Moreover, the amount of work for the developers of the courses was much more than expected in the beginning and quite a big difference may exist in applying the concepts as proposed by different persons teaching the same course (36). Students may not be used to the new educational concepts and the success of a blended learning heavily relies on self-study phase of the students (37). In our study, 55.6% students preferred the through class style and hypothetically more students would prefer the concept style rather than thorough which is more spoon-fed. This observation might probably be associated with an overloaded and exhausting curriculum and time table, and the norm of transmitting knowledge and skills by teachers in Asian education culture (38). However, the online component is constantly being enhanced as new media technologies become available (36). The spread of blended learning during the COVID-19 pandemic has forced its widespread adoption and demonstrated its benefits to a large constituency (36). It is likely that it will remain a mainstay of healthcare education in the future (36). Clinical educators and instructional designers are encouraged to creatively cultivate curiosity into the blended learning approach by applying multiple strategies (39, 40).

Limitations

Applying no strict curiosity scales of measurement [e.g., epistemic curiosity vs. perceptual curiosity (3) or intellectual interest vs. information deprivation of Litman's Epistemic Curiosity Scale] (5) in the surveys limited this study. Whether these scales, along with a number of other non-cognitive factors, can be objectively assessed for medical students who are inundated with extensive medical knowledge is unclear. One participant's feedback stated that "The survey is too long and reductant. Please be as concise as possible." We conducted educational studies to help medical students improve their

TABLE 2 | Kendall's Tau-B correlation coefficient of curiosity with other parameters.

	Curious concept	Most learnt concept	*P*	Expect more	*P*	Teach more	*P*	Concept agreed with previous thought	*P*
(A) Self-reported factors									
C1	31	0.478	<0.001	0.114	0.205	0.013	0.886	0.013	0.882
C2	61	0.344	<0.001	0.063	0.488	0.081	0.371	−0.205	0.013
C3	58	0.405	<0.001	0.069	0.446	−0.069	0.445	−0.187	0.026
C4	52	0.292	0.001	0.200	0.027	0.240	0.008	−0.118	0.154
C5	47	0.216	0.017	0.145	0.107	0.091	0.312	−0.059	0.479
C6	37	0.508	<0.001	−0.028	0.755	0.078	0.389	−0.112	0.179

	Curious	Intensity	*P*	Extensity	*P*	Pause	*P*
(B) Objective video-viewing pattern							
C1	31	0.060	0.468	−0.028	0.753	−0.166	0.061
C2	61	0.119	0.147	−0.005	0.952	0.111	0.215
C3	58	−0.001	0.990	0.177	0.047	−0.053	0.559
C4	52	0.019	0.813	0.038	0.673	0.162	0.072
C5	47	0.109	0.180	0.022	0.803	0.237	0.008
C6	37	−0.010	0.905	−0.091	0.310	0.066	0.466

TABLE 3 | Variables associated with summative assessment of learning outcomes in multivariable general linear regression using backward selection.

Essay question scores	Coefficient	Standard error	*P*	Case-based analysis scores	Coefficient	Standard error	*P*
Male gender	−0.438	0.174	0.013				
Agree with previous understanding				**Agree with previous understanding**			
C1	0.285	0.099	0.005	C3	−2.606	1.216	0.034
C5	−0.120	0.066	0.072				
Difficulty	0.315	0.184	0.091				
Curiosity				**Curiosity**			
C1	−0.534	0.199	0.009	C1	7.233	2.963	0.016
C4	−0.332	0.167	0.049	C3	−4.890	2.439	0.047
C6	0.437	0.200	0.031				
Most learnt				**Most learnt**			
C5	0.358	0.165	0.032	C1	−8.705	2.798	0.002
Provide comments	0.409	0.177	0.022	C3	4.738	2.629	0.074
Online video watching pattern				Teach more			
Extensity				C3	−4.808	2.309	0.040
C2	−0.486	0.208	0.021	C4	5.447	2.276	0.018
C6	0.390	0.161	0.017				
Pause frequency							
C1	−0.380	0.166	0.024				
C6	0.591	0.292	0.045				

learning efficiency but did not intend to add to the loading burden. The effect of teaching in class was not controlled during the analysis, which was a possible confounder. Although the survey response was anonymous to the educators to minimize vulnerability issue between the participants, the study results might be biased by induced positive response. Through this study, we determined the role of cultivating curiosity in short-term learning outcomes in medical education. Additional work is needed to repeat this survey to get more respondents from classes of other topics. Expansion on the difference in using this approach to teach medical vs. other health care students are worthwhile. Further studies are required to validate our results.

TABLE 4 | Students' feedback.

Coding category	The number of code	Typical remarks and codes
General gratitude	26	Terrific and thank you. (general)
Infrastructure-wise		
Appreciate considerate lesson preparation or course framework	49	Perfect pre-class framework arrangement which prepares us for advanced learning in in-person class without overloading us. (framework, load)
Pre-class loading concern	9	Adequate amounts of content and sparkle learning interest. (load, interest)
Curiosity-wise		
Novel feeling and enjoyable reflection	7	The framework design is very novel and considerate for students. Topics are interesting! I enjoyed this style of learning key concepts and inductive learning which induce learning interests and enhance learning efficiency. (framework, interest, novel, efficiency)
Inducing interests and curiosity	8	Wonderful videos that remind us the important concepts and induce our curiosity! (curiosity)
Concise and clear	16	Concise content with depth; grab the key points in a short time without distraction; great innovation! (concise, novel)
Query for specific contents (information gap)	13	Understandable talking! I am interested in the pathophysiology part after the online video-learning but feel that the content can be involved more and want to know more about relevant clinical management guidelines. I expect clearer explanations in in-person class! (narration, query)
Learning outcome		
Learn a lot and good learning efficiency	19	Easily absorbable and effective learning! (efficiency)
Miscellaneous		
Suggesting modifications	7	Thanks for kind consideration in preparing the course. May add an overview introduction to integrate the video pieces. (framework, modification)
Suggest other courses imitation	2	I feel this teaching module is great! Apply this framework to other courses would benefit medical students a lot! (framework, imitation)
Good narration	3	Beautiful and clear narration! (narration)

CONCLUSIONS

Curiosity can be stimulated through pre-class online video learning in medical education. Such learning may induce medical students to further examine, either online or offline, other concepts about which information gaps were perceived through the learning process. As widespread applications of online technology are recruited for learning, the shifting role of in-person contacts would be toward coaching and mentoring in the future (41).

Aroused curiosity after online learning was associated with short-term learning outcomes in a blended framework of precision medical education. Curiosity also correlated with some features of the learning process, such as the most learnt concepts and watching pauses. Creating a "procuriosity" culture within the learning environment would foster learning efficiency and promote enjoyable learning experiences in medical education. Further investigation is required to determine the effect of this feature on long-term knowledge retention and to guide clinical career choices and development.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Institutional Review Board of National Taiwan University Hospital. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

C-MH drafted the manuscript. C-CY, R-HH, and P-HL designed the study. C-MH, J-YW, and C-CY conducted data processing. C-MH and J-YW performed data analysis. J-YW and R-HH were the directors responsible for general organization and instruction. All authors contributed to the article and approved the submitted version.

ACKNOWLEDGMENTS

We thank the student participants for providing feedback generously and the Center of Faculty Development, College of Medicine, and Center for Teaching and Learning Development, Digital Learning Center, National Taiwan University, for their technical assistance. We would also like to thank the administrative teaching assistants (Ms. Yu-Jung Lin and Ms. Kai-Wen Su) for their helpful efforts in data collection.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmed.2021.772956/full#supplementary-material

REFERENCES

1. Berlyne DE. Novelty and curiosity as determinants of exploratory behavior. *Br J Psychol*. (1950) 41:68–50. doi: 10.1111/j.2044-8295.1950.tb00262.x
2. Loewenstein G. The psychology of curiosity: a review and reinterpretation. *Psychol Bull*. (1994) 116:75–98. doi: 10.1037/0033-2909.116.1.75
3. Litman JA, Spielberger CD. Measuring epistemic curiosity and its diversive and specific components. *J Pers Assess*. (2003) 80:75–86. doi: 10.1207/S15327752JPA8001_16
4. Dyche L, Epstein RM. Curiosity and medical education. *Med Educ*. (2011) 45:663–8. doi: 10.1111/j.1365-2923.2011.03944.x
5. Litman JA. Interest and deprivation factors of epistemic curiosity. *Pers Indiv Differ*. (2008) 44:1585–95. doi: 10.1016/j.paid.2008.01.014
6. Ellaway RH. When I say ... epistemic curiosity. *Med Educ*. (2014) 48:113–4. doi: 10.1111/medu.12272
7. Kidd C, Hayden BY. The psychology and neuroscience of curiosity. *Neuron*. (2015) 88:449–60. doi: 10.1016/j.neuron.2015.09.010
8. Ho C-M, Wang J-Y, Yeh C-C, Hi R-H, Lee P-H. Experience of applying threshold concepts in medical education. *J Formos Med Assoc*. (2021) 120:1121–6. doi: 10.1016/j.jfma.2020.09.008
9. Rabinowitz D, Reis S, Van Raalte R, Alroy G, Ber R. Development of a physician attributes database as a resource for medical education, professionalism and student evaluation. *Med Teach*. (2004) 26:160–5. doi: 10.1080/01421590310001653955
10. Roman B. Curiosity: a best practice in education. *Med Educ*. (2011) 45:654–6. doi: 10.1111/j.1365-2923.2011.04017.x
11. Schattner A. Curiosity. Are you curious enough to read on? *J R Soc Med*. (2015) 108:160–4. doi: 10.1177/0141076815585057
12. Bugaj T. Did medical curiosity kill the cat? *MedEdPublish*. (2018) 7:23. doi: 10.15694/mep.2018.0000161.1
13. Sternszus R, Saroyan A, Steinert Y. Describing medical student curiosity across a four year curriculum: an exploratory study. *Med Teach*. (2017) 39:377–82. doi: 10.1080/0142159X.2017.1290793
14. Richards JB, Litman J, Roberts DH. Performance characteristics of measurement instruments of epistemic curiosity in third-year medical students. *Med Sci Educ*. (2014) 23:355–63. doi: 10.1007/BF03341647
15. Ho C-M, Yeh C-C, Wang J-Y, Hu R-H, Lee P-H. Preclass online video learning and class style expectation: patterns, association, and precision medical education. *Ann Med*. (2021) 53:1390–401. doi: 10.1080/07853890.2021.1967441
16. Sweller J. Cognitive load theory, learning difficulty, and instructional design. *Learn Instr*. (1994) 4:295–312. doi: 10.1016/0959-4752(94)90003-5
17. Sweller J. Cognitive load theory: recent theoretical advances. In: Plass J, Moreno R, Brünken R, editors. *Cognitive Load Theory*. Cambridge: Cambridge University Press (2010). p. 29–47. doi: 10.1017/CBO9780511844744.004
18. Mayer RE. *Multimedia Learning*. 2nd ed. Cambridge: Cambridge University Press (2009). doi: 10.1017/CBO9780511811678
19. Mayer RE, Moreno R. Nine ways to reduce cognitive load in multimedia learning. *Educ Psychol*. (2003) 38:43–52. doi: 10.1207/S15326985EP3801_6
20. Zheng M. Conceptualization of cross-sectional mixed methods studies in health science: a methodological review. *Int J Quantitat Qualitat Res Methods*. (2015) 3:66–87.
21. Plano Clark VL, Huddleston-Casas CA, Churchill SL, O'Neil Green D, Garrett AL. Mixed methods approaches in family science research. *J Fam Issues*. (2008) 29:1543–66. doi: 10.1177/0192513X08318251
22. *NTU COurses OnLine (NTU COOL)*. Available online at: https://cool.ntu.edu.tw/login/portal (accessed September 28, 2021).
23. Braun V, Clarke V. Using thematic analysis in psychology. *Qual Res Psychol*. (2006) 3:77–101. doi: 10.1191/1478088706qp063oa
24. Loewenstein G, Adler D, Behrens D, Gillis J. *Why Pandora Opened the Box: Curiosity as a Desire for Missing Information*. Pittsburgh: Carnegie Mellon University (1992).
25. Litman JA, Hutchins TL, Russon RK. Epistemic curiosity, feeling-of-knowing, and exploratory behaviour. *Cogn Emot*. (2005) 19:559–82. doi: 10.1080/02699930441000427
26. Kang MJ, Hsu M, Krajbich IM, Krajbich IM, Loewenstein G, McClure, SM, et al. The wick in the candle of learning: epistemic curiosity activates reward circuitry and enhances memory. *Psychol Sci*. (2009) 20:963–73. doi: 10.1111/j.1467-9280.2009.02402.x
27. Gutman LM, Schoon I. *The Impact of Non-Cognitive Skills on Outcomes for Young People. A Literature Review*. London: Education Endowment Foundation (2013).
28. Hamilton D. Developing and testing inhibitors of curiosity in the workplace with the Curiosity Code Index (CCI). *Heliyon*. (2019) 5:e01185. doi: 10.1016/j.heliyon.2019.e01185
29. Sanjay S, Luke Y. *Grasp: The Science Transforming How We Learn*. 1st ed. New York, NY: Doubleday (2020).
30. Garrison R, Kanuka H. Blended learning: uncovering its transformative potential in higher education. *Internet Higher Educ*. (2004) 7:95–105. doi: 10.1016/j.iheduc.2004.02.001
31. Liu Q, Peng W, Zhang F, Hu R, Li Y, Yan W. The effectiveness of blended learning in health professions: systematic review and meta-analysis. *J Med Internet Res*. (2016) 18:e2. doi: 10.2196/jmir.4807
32. McCutcheon K, Lohan M, Traynor M, Martin D. A systematic review evaluating the impact of online or blended learning vs. face-to-face learning of clinical skills in undergraduate nurse education. *J Adv Nurs*. (2015) 71:255–70. doi: 10.1111/jan.12509
33. Chen J, Zhou J, Wang Y, Qi J, Xia C, Mo G, et al. Blended learning in basic medical laboratory courses improves medical students' abilities in self-learning, understanding, and problem solving. *Adv Physiol Educ*. (2020) 44:9–14. doi: 10.1152/advan.00076.2019
34. Viljoen CA, Millar RS, Manning K, Burch VC. Effectiveness of blended learning versus lectures alone on ECG analysis and interpretation by medical students. *BMC Med Educ*. (2020) 20:488. doi: 10.1186/s12909-020-02403-y
35. Bock A, Kniha K, Goloborodko E, Lemos M, Rittich AB, Möhlhenrich SC, et al. Effectiveness of face-to-face, blended and e-learning in teaching the application of local anaesthesia: a randomized study. *BMC Med Educ*. (2021) 21:137. doi: 10.1186/s12909-021-02569-z
36. Leinster SJ, Pereira JH, Down S, Simpson AD. Blended learning in healthcare education. *Med Res Arch*. (2021) 9. doi: 10.18103/mra.v9i8.2527
37. van Moergestel L, Keijzer A, van der Stappen E. Tips and pitfalls with blended learning: redesigning a CS curriculum using IT. In: *Proceedings of the 12th International Conference on ICT in Education*. Kiev: Research and Industrial Applications (ICTERI) (2016). p. 273–83.
38. Kwan CY. Problem-based learning (PBL) in medical education in Taiwan: observations and a commentary. *J Med Health*. (2017) 6:1–12.
39. Heick T. *10 Strategies To Promote Curiosity In Learning*. Available online at: https://www.teachthought.com/learning/10-strategies-to-promote-curiosity-in-learning/ (accessed October 2, 2021).
40. Hege I, Tolks D, Adler M, Härtl A. Blended learning: ten tips on how to implement it into a curriculum in healthcare education. *GMS J Med Educ*. (2020) 37:Doc45. doi: 10.3205/zma001338
41. Emanuel EJ. The inevitable reimagining of medical education. *JAMA*. (2020) 323:1127–8. doi: 10.1001/jama.2020.1227

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

frontiers in Medicine

ORIGINAL RESEARCH
published: 15 November 2021
doi: 10.3389/fmed.2021.773806

Impact of COVID-19 on Continuing Medical Education—Results of an Online Survey Among Users of a Non-profit Multi-Specialty Live Online Education Platform

Tobias L. Schulte[1], Thilo Gröning[2], Babett Ramsauer[3], Jörg Weimann[4], Martin Pin[5], Karen Jerusalem[6] and Sami Ridwan[7]*

[1] Department of Orthopedics and Trauma Surgery, St. Josef-Hospital, Ruhr-University Bochum, Bochum, Germany, [2] Joint Practice for Gynecology, Moenchengladbach, Germany, [3] Department of Gynecology and Obstetrics, Vivantes Klinikum Berlin, Berlin, Germany, [4] Department of Anesthesiology and Interdisciplinary Intensive Care Medicine, Sankt Gertrauden Hospital, Berlin, Germany, [5] Emergency Department, Florence-Nightingale Hospital, Duesseldorf, Germany, [6] German Society of Emergency and Acute Medicine DGINA, Berlin, Germany, [7] Department of Neurosurgery, Klinikum Ibbenbueren, Ibbenbueren, Germany

OPEN ACCESS

Edited by:
Ismail Mohd Saiboon, National University of Malaysia, Malaysia

Reviewed by:
Hosam Eldeen Elsadig Gasmalla, Al-Neelain University, Sudan
Igor Nesteruk, National Academy of Sciences of Ukraine, Ukraine

***Correspondence:**
Sami Ridwan
sami.ridwan@yahoo.de

Specialty section:
This article was submitted to Healthcare Professions Education, a section of the journal Frontiers in Medicine

Received: 10 September 2021
Accepted: 12 October 2021
Published: 15 November 2021

Citation:
Schulte TL, Gröning T, Ramsauer B, Weimann J, Pin M, Jerusalem K and Ridwan S (2021) Impact of COVID-19 on Continuing Medical Education—Results of an Online Survey Among Users of a Non-profit Multi-Specialty Live Online Education Platform. Front. Med. 8:773806. doi: 10.3389/fmed.2021.773806

Background: The Coronavirus Disease-2019 (COVID-19) pandemic accelerated digitalization in medical education. Continuing medical education (CME) as a substantial component of this system was relevantly affected. Here, we present the results of an online survey highlighting the impact on and the role of online CME.

Methods: An online survey of 44 questions was completed by users of a German online CME platform receiving an invitation via newsletter. CME habits, requirements, personal perception, and impact of the pandemic were inquired. Standard statistical methods were applied.

Results: A total of 2,961 responders took the survey with 2,949 completed surveys included in the final analysis. Most contributions originated from Germany, Austria, and Switzerland. Physicians accounted for 78.3% (57.5% hospital doctors) of responses followed by midwives (7.3%) and paramedics (5.7%). Participating physicians were mainly board-certified specialists (69%; 55.75% hospital specialists, 13.25% specialists in private practice). Frequent online lectures at regular intervals (77.8%) and combined face-to-face and online CME (55.9%) were favored. A duration of 1–2 h was found ideal (57.5%). Technical issues were less a major concern since the pandemic.

Conclusion: A shift from face-to-face toward online CME events was expectedly detected since the outbreak. Online CME was accelerated and promoted by the pandemic. According to the perception of users, the CME system appears to have reacted adequately to meet their demand but does not replace human interaction.

Keywords: COVID-19, continuing medical education, online education, medical education, survey, online teaching

INTRODUCTION

Digitalization in healthcare had been pursued for the last decade and lies mainly in the hands of governments and healthcare systems (1). Digitalization has obviously moved into focus around the globe since the Coronavirus Disease-2019 (COVID-19) pandemic. Medical education also had to adapt to the implications of the pandemic and corresponding political measures. Prior to the outbreak of COVID-19, digital medical education was some kind of modern luxury and technical achievement in selected countries. Due to COVID-19, the digitalization of medical education was forced to move forward at an unprecedented pace, developing from a nice-to-have luxury to an absolutely essential tool (2–9).

No doubt, that the pandemic has raised the value of such platforms and educational formats, as physical presence is not required. Not only board-certified specialists but also trainees and medical students had to abandon well-established and familiar educational practices (10). Teachers and students, lecturers, and attendees were confronted by these facts similarly. The impact of the pandemic on in-hospital medical training and CME has already been picked up by recent literature, highlighting the processes and possibilities at hand (4, 9, 11).

MEDIZIN TO GO is a free of charge German continuing medical education (CME) platform offering online multi-specialty live educational lectures with approved medical certification and medical board CME accreditation since 2012 (**Table 1**). Thus, not only does it offer online medical lectures on relevant and up-to-date topics but also medical professionals are given the opportunity to obtain required continuing medical certification relevant for their practice without having to attend face-to-face lectures and conferences. Notably, a total of 250 CME accreditation points are mandatory for German board-certified physicians every 5 years. The main goal of the platform is to adequately prepare residents for board exams. However, the format also attracts medical students, experienced physicians, and related healthcare professions, such as midwives, nurses, physical therapists, or paramedics. MEDIZIN TO GO is independent of any industrial influence, medical society, or other stakeholders.

Continuing medical education plays a major role in maintaining up-to-date medical care. With CME being the sole mandatory source of education for German physicians after board certification, a significant impact of the pandemic and precautionary measures, such as social distancing, was to be expected. Being active since 2012, MEDIZIN TO GO with its wide reach (over 20,000 registered users) offered the possibility to analyze the perception of users concerning online CME in general during a broad time window, in addition to changes determined by the pandemic.

To better understand the specific impact of the pandemic on German CME, we conducted a platform-wide online survey. This survey investigated the role of online CME among German-speaking healthcare professionals. Additional focus was laid upon the impact of the COVID-19 pandemic on the perception of participants of CME in general and the online form in particular. Furthermore, the expectations and requirements of the participants regarding online medical education, in general, were highlighted. One of the main concerns of the authors was not only how to further improve CME especially adapted to the COVID-19 pandemic but also for the return of peacetime. Several publications described the impact of COVID-19 on medical education (2, 9, 12, 13); however, only very few formats or platforms allow a direct comparison before and after the onset of the pandemic. Only few published data on this topic exist for the German healthcare system (11, 14, 15).

METHODS

Study Setup, Survey Design, Validation, and Distribution

A questionnaire consisting of 44 questions was drafted to assess many aspects of online continuing medical education among German-speaking medical professionals and to further evaluate the impact of the COVID-19 pandemic (In the German language; translated version of the survey can be found as a **Supplementary Material**). The research goal was to investigate and record the impact of the first year of the pandemic on online continuing medical education through the acquisition of qualitative data.

Two experienced academic healthcare professionals with prior experience with healthcare surveys and online CME [SR (16) and TS] arranged the initial draft of the survey. KJ with a degree in education (Diplom Pädagogin) undertook further improvements and assisted with the final version of the survey. The design and internal validation stage was conducted during the second half of November 2020 in accordance with the existing literature (17, 18). A face validity index (FVI) of at least 0.83 was considered acceptable (19). External validation was conducted in a two-step approach. Pretesting was performed on a small sample of board-certified healthcare professionals ($N = 12$) followed by pilot testing on a larger cohort. The calculated S-FVIs were 0.98 and 0.91 based on the average method (S-FVI/Ave) and the universal agreement method (S-FVI/UA), respectively. The estimated completion rate according to SurveyMonkey was at 62%. Given that recently published surveys among healthcare professionals presented response rates between 3 and 5% when calculated using the distribution platforms (excluding social media) and had completion rates at about 70%, this study was intended to reach at least comparable response and completion rates (20, 21).

The final questionnaire was prepared and distributed using the online platform SurveyMonkey (https://www.surveymonkey.com, SurveyMonkey Inc., San Mateo, CA, USA) and was opened to responders on December 1, 2020. The survey was promoted during online lectures, and invitations were sent via E-mail to all 21,007 members of the platform with a newsletter subscription (the targeted population; sample frame $N = 21{,}007$). Additionally, a web link to the survey was continuously displayed on the website of the platforms (News) for a total of 5 consecutive weeks. Participants receiving the survey were encouraged to inform colleagues by disseminating the web link via social

TABLE 1 | Online continuing medical education on MEDIZIN TO GO (November 2020).

Format	Specialty	Online Since	Online Events/Year	Event Duration	Additional events
GYN TO GO	Gynecology, Obstetrics, Endocrinology and Senology	09/2011	45 early morning events* and 45 late night events + additional events	45 min.	4–5 Weekend events*/year (4 h)
NOW TO GO	Emergency Medicine	01/2017	45 early morning events and 45 late night events + additional events	45 min.	4–5 Weekend events/year (3 h)
OU TO GO	Orthopaedics and Trauma Surgery	03/2020	48 early morning events and 48 late night events	45 min.	No
PAED TO GO	Pediatrics	10/2020	24 late night events + additional events	50 min.	Weekend Events
AINS TO GO	Anesthesiology, Intensive Care Medicine, Emergency and Pain Medicine	03/2020	11 events	3 hrs.	No
NCH TO GO	Neurosurgery	09/2020	21 late-night events + additional events	45 min.	Weekend Events

Distribution of currently active medical specialties with past online CME live events on MEDIZIN TO GO at the time the survey was conducted. Other specialties only offering live events after the survey was conducted are not listed.

**Online live lectures consisting of a 45-min lecture, with a subsequent live discussion round. Weekend events consisted of multiple lectures related to a selected main topic with live discussion. GYN TO GO, NOW TO GO, OU TO GO, PAED TO GO, and NCH TO GO offer this type of CME. AINS TO GO events are similar to formerly described weekend events. CME certification by the corresponding German medical board requires 45-min events for one CME accreditation point.*

media and other means of interpersonal communication. Data evaluation was started on January 17, 2021.

General Educational and Demographic Data

Responders were asked to provide information regarding their age, gender, country of origin, and the medical profession. Type of practice (e.g., hospital and private practice) and level of education/experience were inquired in physicians. Sources of CME, number of face-to-face events per year, concerns regarding online education, having attended online sessions, and at what frequency per year were surveyed to better assess the role of online CME. Furthermore, the importance of non-profit sponsoring free and free of charge education, the importance of active participation in discussions, anonymity, video functions, duration of each session, and further technical issues were inquired.

Participants were also requested to describe the ideal form of education and corresponding characteristics within the margins of multiple-choice and numeric scale answers. Additional free-text answers and comments were allowed to better display the improvement suggestions of responders beyond the rigid margins of questions with distinct answer options.

Online Continuing Medical Education and COVID-19

Besides general educational and demographic data, the questionnaire was intended to capture the impact of the pandemic on the educational behavior of responders. The number of face-to-face and online educational sessions per year was inquired before and since the pandemic to better understand the demand for online lectures. This is related to online medical education *per se* and to this specific platform. Moreover, concerns about using online services before and since the pandemic.

Platform Specific Questions

A part of the survey was designed to allow members of the platform with previous experience with its online services to provide anonymous feedback and evaluate technical and content-related issues. Corresponding data were excluded from analysis, as these do not add relevant value to this study.

Data Analysis

Anonymized data analysis was performed utilizing SPSS 25.0 for Mac (IBM Corp. Released 2017. IBM SPSS Statistics for Mac, Version 25.0. Armonk, NY: IBM Corp.). Prior to data analysis, free text passages were thoroughly reviewed for typing and form errors with possible impact on software analysis and were properly aligned. Numerical scale answers (0–100 and 0–10) were used to identify four groups of responders depending on the individual perception of the issues investigated in this survey and listed above. As such, groups were classified as minor (<25 or <2.5), low intermediate (25 to <50 or 2.5 to <5), high intermediate (50 to <75 or 5 to <7.5), and major (75–100 or 7.5–10) for any aspect investigated.

Univariate analysis was performed to identify possible significant differences, when applicable. The Fisher exact test and the chi-square test were used to analyze categorical variables, and the Student t-test to analyze continuous variables. A power analysis was not required, due to the descriptive character of the survey without pursuing a specific hypothesis.

Ethical Approval and Data Protection

The study design was conducted in accordance with the declaration of Helsinki. Ethical review and approval were not required for this study in accordance with the local legislation and institutional requirements. The survey included a preliminary introduction regarding the nature of the study and an opt-out option asking to formally agree with the participation in this survey. Data protection/privacy policy was clearly provided by the survey platform, it applies to all data recorded using this survey (https://www.surveymonkey.com/mp/legal/privacy-policy/). The study adhered to the 2016 version of the General Data Protection Regulation (GDPR) applicable in Europe since 2018 (https://gdpr-info.eu/). Data with potential personal data protection risk were planned to be deleted from all files and platforms after the final data analysis.

The translated full-version questionnaire, such as multiple choice and free text options, is shown in **Supplementary Data**.

RESULTS

Participating Healthcare Professionals

Two thousand nine hundred and sixty-one questionnaires were returned, 2,949 were properly completed and included in the final analysis. Responders from the three main German-speaking countries (Germany, Switzerland, and Austria), the Netherlands, other European countries, and from outside Europe contributed to the partially global outreach of this project, which was mainly aimed to reach German-speaking healthcare professionals (Survey in the German language). A completion rate of 99.6% (2,949/2,961) was realized, as almost every initiated survey was adequately completed. As some questions were only intended for specific user groups, being not filled out by other groups was not acknowledged as an incompletion. The estimated completion rate calculated by the software was 62%. A response rate could not be accurately calculated based on the method of distribution utilized for this survey also including social media. In light of formerly performed worldwide surveys among healthcare professionals, the response rate for this survey was slightly higher at 14% (2,961/21,007 newsletter subscribers) (20, 21).

Most contributions originated from Germany, followed by Austria, Switzerland, and the Netherlands (86.88, 3.39, 1.63, and 0.20%). Responders from other European countries and countries outside Europe accounted for 4.24 and 3.66% of answered surveys. The median age was 40 years (range 17–80). Total 71.4% of responders were female healthcare personnel (27.8% male and 0.1% diverse). Physicians accounted for 78.3% (57.5% hospital doctors, 17.3% private practice employees, 17.2% private practice owners, and 8.0% other employments) of responses followed by midwives (7.3%) and paramedics (5.7%). On closer analysis, participating physicians were mainly board-certified specialists (in total 69% of responding doctors; 55.7% hospital specialists, 13.3% specialists in private practice). Total 3.2% were department heads, 17.2% attending specialists/consultants, and 31% residents/trainees. **Figure 1** demonstrates the distribution of healthcare professions.

Continuing Medical Education and COVID-19

A relevant part of the survey was intended to highlight the impact of the pandemic on CME, online CME in particular. When asked about the number of yearly visited face-to-face CME events, a shift toward online CME was clearly visible (**Figure 2**). When only 38.9% of responders stated visiting <5 face-to-face events per year before, 90.8% reported doing so since the pandemic, and 46% reported using online CME before compared to 91% since COVID-19. On a closer analysis, 87.3% reported using online CME more frequently since the pandemic compared to 1.6% less frequently and 11.1% unchanged. Overall, 87.8% of participants used MEDIZIN TO GO for online CME since COVID-19 (60.5% before). Analyzing the number of visited online CME events, 35.3% visited 5–10 or >10 before, opposed to 75.1% since the outbreak (43.6 vs. 68.1% for MEDIZIN TO GO). Major concerns regarding online CME before and since the pandemic were also inquired. More than half the participants stated no concerns either before or since the pandemic (50.1 and 60%). Major concerns identified by participants were time and technical issues (19.5 and 28.3% vs. 18.0 and 16.1%). Therefore, technical issues seemed to be less of a problem since the outbreak (**Figure 3**).

The majority of participants stated having no concerns regarding online CME before and since the pandemic. Major concerns identified by the survey were technical and time issues. Technical issues seem to have declined since the pandemic.

General Perception of Respondents of (Online) Continuing Medical Education

Participants identified online and face-to-face lectures as the main source of continuing education. However, journals, websites, books, and colleagues were also chosen as corresponding educational references (**Figure 4**). Free-text answers also named apps, guidelines, departmental journal clubs, and podcasts were considered as additional means of education. Participants were in favor of frequent online lectures at regular intervals (77.8%) and combined face-to-face and online educational formats also known as blended learning (55.9%). In addition, lectures followed by discussion rounds (48.3%) or combined lectures with expert discussions (43.5%) were identified as more suitable for online lectures than sole expert discussions (8.2%). Responding professionals found a duration of 1–2 h ideal (57.5%) compared to <1 h or 2–3 h (40.1 and 2.4%). Evening sessions were generally preferred by 73.1% of answers (15.6% morning and 11.3% weekend) and most attended online CME by oneself (83.6%; 4.8% in a group, 11.6% both).

To further assess how ideal online CME should be composed, the survey offered numeric scale questions (0 as not important−10 as most important) to evaluate the importance of specific composition and content-related parameters. Free of charge and sponsoring free (i.e., not related or sponsored by the Industry) online CME was of high intermediate importance for users (average points on 0–10 scale: 7.4 ± 2.5/10 and 7.4 ± 2.9/10). Being independent of national medical societies was less an issue (4.3 ± 3.1/10). Having a possibility for live discussions after lectures were also of high intermediate (5.1 ± 2.9/10) interest. Interestingly, it was reported to be even less important to be able to discuss anonymously (4.6 ± 3.2/10). The lecturer being visible by webcam was also only of low intermediate relevance (4.9 ± 3.3/10; **Figure 5**). Participants were inquired to rate the relevance of online CME content-related specifications. Basic clinical knowledge in form of a structured curriculum and content being evidence based was of high intermediate value (7.1 ± 2.5/10 and 6.8 ± 2.5/10). Special and advanced

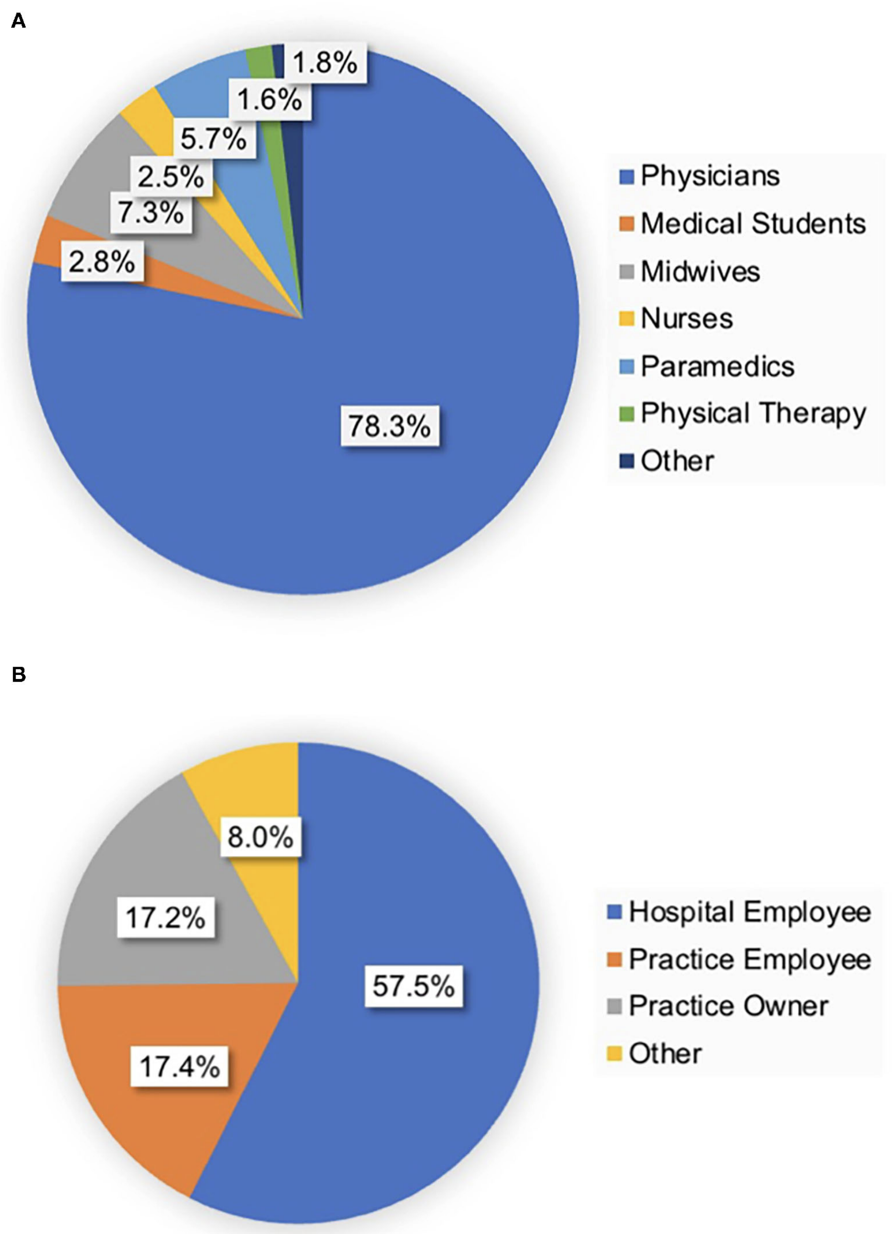


FIGURE 1 | Healthcare professions of participants and occupation of physicians. **(A)** The majority of responders were physicians (78.3%) followed by midwives and paramedics. **(B)** Most physicians were hospital employees.

content seemed more important than basic content (7.8 ± 1.9/10). Online CME being some kind of an expert discussion round/meet the experts was of lower interest but remained high intermediate (5.7 ± 2.5/10). Attending online CME in form of online conferences or congresses was of comparable high intermediate interest (5.7 ± 3.0/10). Participants were satisfied with MEDIZIN TO GO as a CME platform at an average of 88% (average percentage on 0–100% scale: 0 not satisfied at all-—100% fully satisfied).

The certification process to acquire CME points (in Germany obligatory for specialist physicians; 250 points per 5 years) was reported to be utilized in 74% of responses (note that 78.3% of participants were physicians).

Overall, the majority of participants would recommend online CME (9.2 ± 1.4/10). To further capture the respondents' expectation of future CME (i.e., after the pandemic), two specific questions on this topic were inquired. Total 87% of participants would prefer the availability of online CME to be similar to

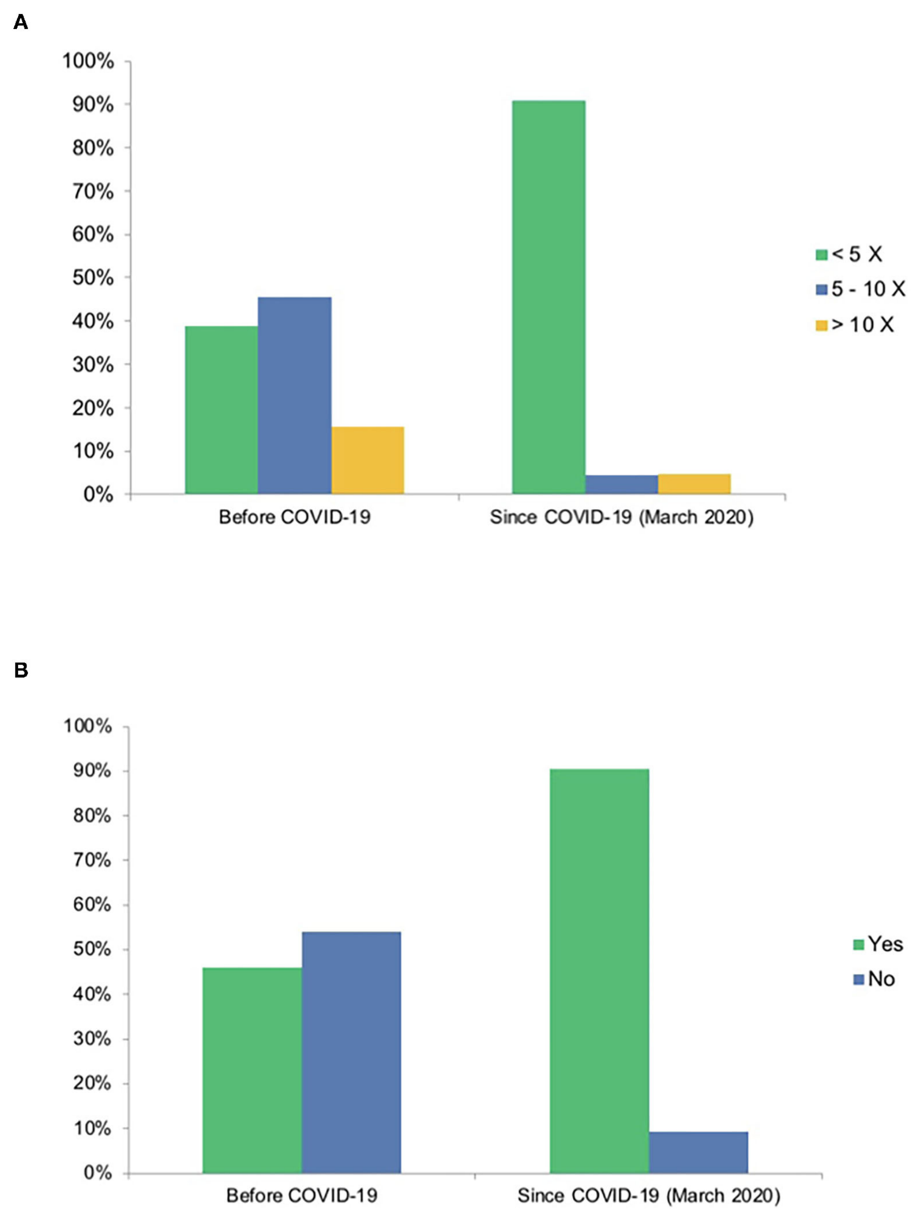


FIGURE 2 | Reported shift in medical education due to COVID-19. **(A)** Number of attended face-to-face events (percentage). **(B)** Attendance of online events (percentage). **(A)** A shift away from face-to-face events for continuing medical education was expectedly detected since the outbreak. **(B)** Also, a shift toward online events can be documented.

COVID times, while only 13% stated that it should be less available after the pandemic. When asked what respondents would rather attend for CME, 30% picked only online, 14% only face-to-face, and 56% a combination of both face-to-face and online CME formats.

DISCUSSION

The COVID-19 pandemic has forced medical societies and educational institutions to develop and implement new strategies to minimize close inter-personal contacts. This has substantially supported digital online education. This survey addressed the perception of participants of past and present CME; online CME, in particular, inquired expectations of future CME and offered a somewhat realistic presentation of the impact of the pandemic on CME.

Pros and Contras of Online (Continuing Medical) Education in General

The obvious advantages of online education are being easy to access without requiring physical attendance. Lecturers are therefore able to contribute and present their content globally. Thus, making lectures available for attendees who otherwise would only be able to take part having to travel far distances. One major advantage during the pandemic was and still is limiting the risk of being infected.

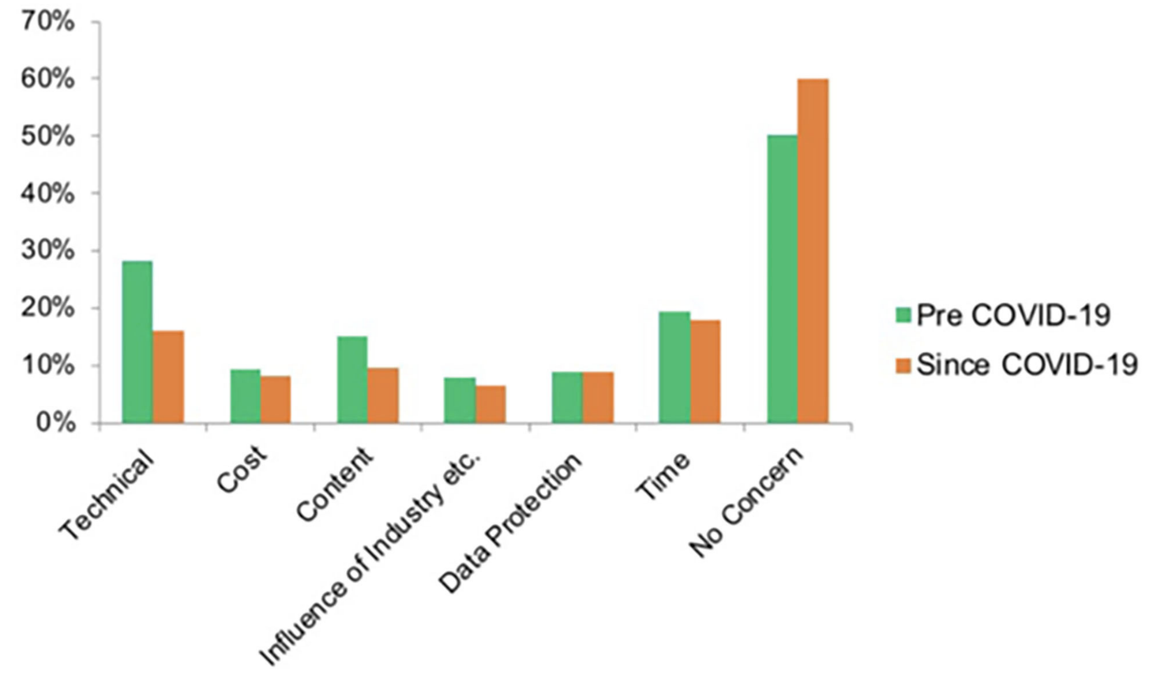


FIGURE 3 | Concerns of responders regarding online CME.

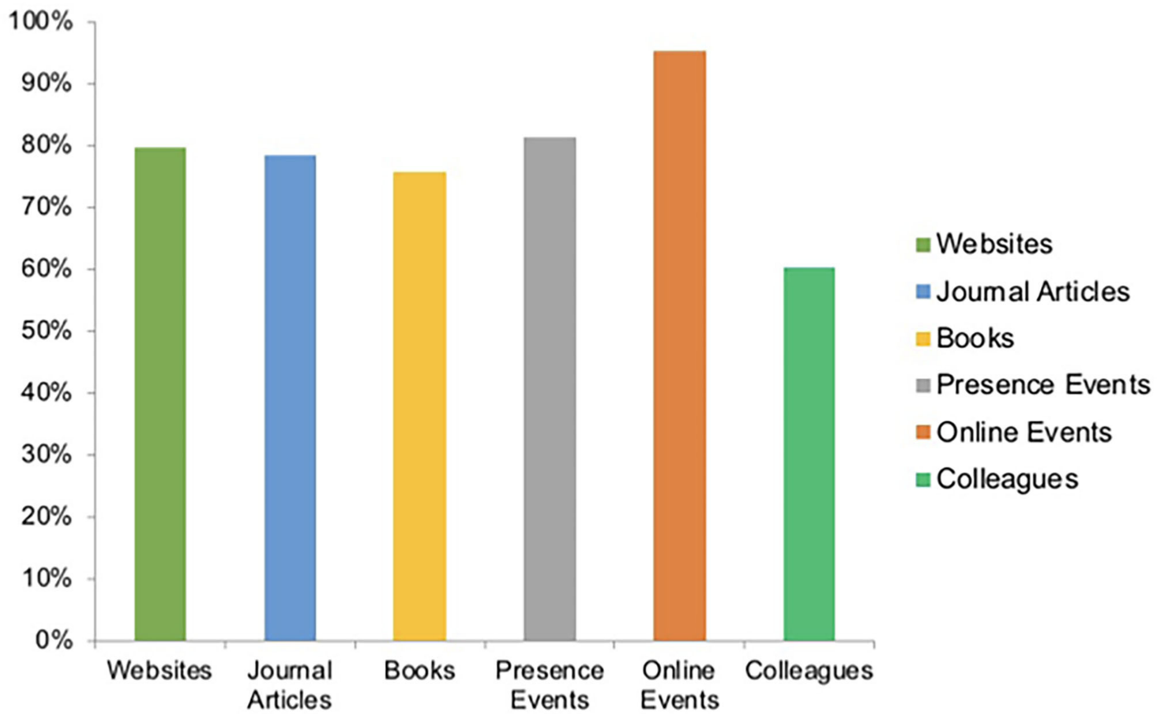


FIGURE 4 | Sources of continuing medical education (percentage). Most responses identified online and face-to-face events as the main source of continuing medical education. Percentages were calculated for a question with multiple answer options.

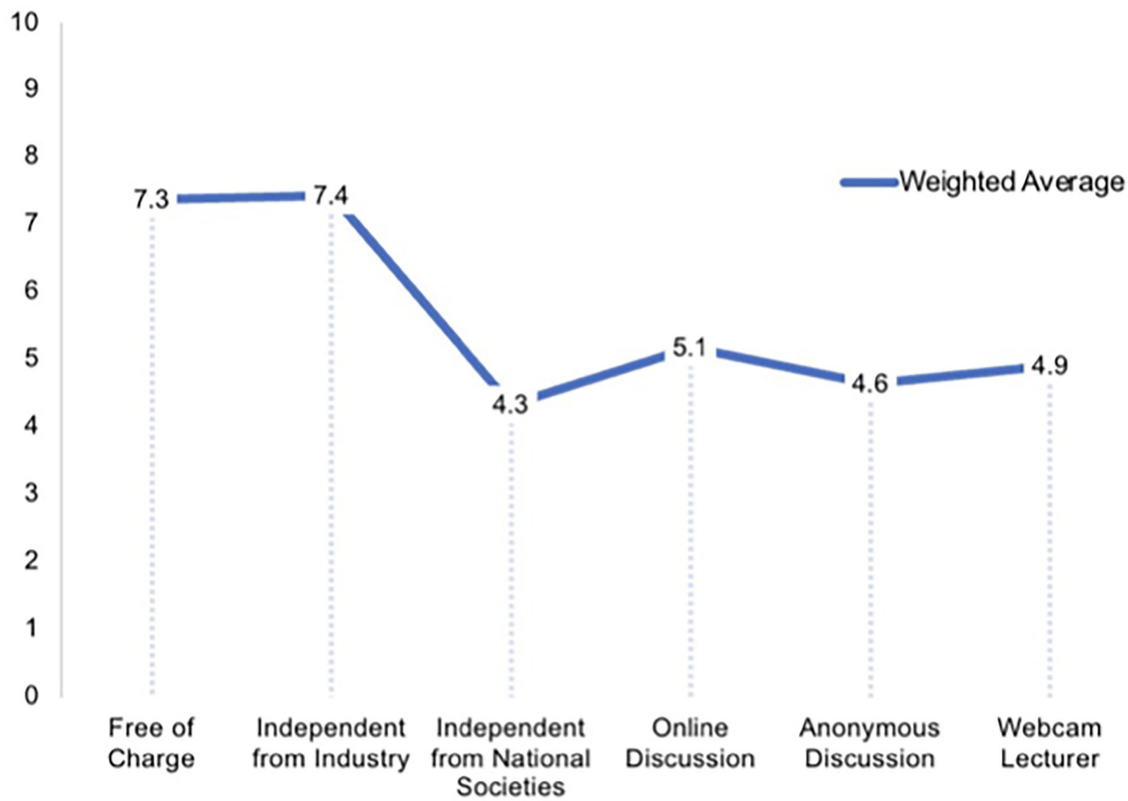


FIGURE 5 | Expectations of participants of continuing medical education. Participants strongly prefer continuing medical education to be free of charge and independent from industrial influence. Other content-related issues were less relevant.

The disadvantages of online courses on the other hand are the lack of direct personal interaction. In cases of large groups, face-to-face interaction during lectures is an important feedback tool for both lecturer and trainee. Without, valuable communication is unfortunately lost. In addition, online education carries the risk of diminishing discussions with peers. There is a substantial psychological impact of isolation. Online platforms cannot provide direct interaction with a patient and are highly dependent on technical requirements. The issue of licensing and credits in online education is yet to be uniformly defined. The lack of hands-on activities in sole online educational events is a relevant problem and makes a combination of traditional face-to-face learning with online formats (Blended learning) a necessity. However, several digital surgical skill-training resources are on their way from development to everyday tools, such as virtual reality trainers, simulation models, video games, surgical videos, and smartphone applications (22).

Results of The Multinational Survey

General and Demographic Data

The relevance of this topic was clearly highlighted by the number of participants and the high completion rate. With a total of 2,949 completed surveys included in the final analysis, this study represents the largest pool of responders (In the German language) related to this matter until this day. The age of participants (median 40 years) adequately represented the targeted group. The range (17–80 years) also demonstrated that very young (to be) and elderly (retired) healthcare professionals could be reached by this survey and relate to online CME. Given that physicians require CME certification on a regular basis (in Germany 250 CME points per 5 years), the main group of responders was physicians (78%). Notably, midwives and paramedics each contributed to more than 5% of participations (7.3 and 5.7%), also demonstrating the profession-independent relevance of CME. Female healthcare professionals provided over 70% of responses. This might be explained by the fact that gynecology and obstetrics (GYN TO GO) had been established over 10 years ago and attracts almost 2,000 attendees per live online lecture today. The high percentage of board-certified physicians can be related to CME certification being obligatory for specialists (voluntary for trainees/residents) at least in Germany but might also underline the quality and clinical relevance of the offered online CME lectures.

COVID-19 and Online CME

A major part of the composition of the survey was intended to detect the impact of COVID-19 on CME in general and the view of the participants of and attitude toward online CME in particular. The expected shift away from face-to-face toward online CME could be distinctly observed and is mainly a result of social distancing, political measures and infection risk minimization. This was detected in general and specifically for MEDIZIN TO GO as a platform. A relevant subjective concern of both participants and lecturers regarding online CME was of technical nature. On the one hand, this should raise interest in improving technical knowledge in both groups. On the other hand, the results of our study showed that before the pandemic technical concerns had been evaluated much higher than during the pandemic (**Figure 3**). This might mirror users having realized that technical boundaries are not as present as they expected them to be. In addition, this might represent the fast technical advancement probably resulting in easier access and user-friendly applications.

Formats Like MEDIZIN TO GO and The Future of CME

Finding a suitable solution to keep medical education up and running during the pandemic is one challenge. However, an even greater one is how to setup education after the pandemic. Will continuing medical education return to old habits? It might be possible to develop and adopt novel educational systems reasonable during the pandemic but also in the long run afterward, especially as it is realistic that pandemics might repeatedly occur in the future and that recipients of CME might have settled with current possibilities or even prefer the change (2). The current wave of digitalization shall push medical education into a real digital transformation (11, 14, 15, 23). The current crisis should be recognized as an opportunity for medical education to permanently adopt and implement digitalization using modern online formats and maybe combined (Blended learning) events after the pandemic. Of course, online courses cannot and should not generally replace face-to-face in-classroom teaching. Both formats can perfectly complement each other for better results. Participants clearly highlighted the importance of evidence-based content, free of charge education, having the possibility for live discussion, and that they would preferably attend events reoccurring on a regular basis rather than sole sporadic lectures and also combined face-to-face and online events rather than one single format (56% of responses). The demand for online CME events was obviously demonstrated by the survey, also with regard to The Future of CME. Total 87% of participants expect the availability of online CME to remain as high after COVID-19. Online courses as offered by MEDIZIN TO GO are held live, free of charge, non-profit, and are independent of industrial influence (**Table 1**). Due to the simple and easy access, standard technical requirements, and open number of participants, such platforms offer a virtual lecture hall for live lectures utilizing well-known lecturers and reaching attendees independent from physical, regional, and financial boundaries. In addition, discussion can be joined anonymously, allowing reluctant attendees to actively participate. The live character with room for live discussions is a substantial advantage compared to widespread-recorded online educational material and is one step closer to real human interaction but finally cannot replace it.

Limitations

The results of this survey are limited by the number of participants, their medical profession, level of education, and intentionally by the subjective statements of single individuals. While the majority of questions were designed as multiple choice, the free text could be submitted in various subsections of the survey hence the total amount of information provided might be hardly comparable. Although the study design focused on the potential for the data collected to be representative, answers are subject to bias. Since more than two thousand German-speaking healthcare professionals and medical students participated, this survey is subject to individual variations among participants, their personal circumstances, working and educational routine and individual aversion to uncertainty might have heavily influenced their answers. However, it has to be considered that in pragmatic qualitative studies with an inductive approach (exploring the characteristics of a problem, not of the subjects), representativeness is not the priority (24). This was precisely the intention of this survey: simply to document the perceptions of CME pre- and during COVID-19 among users of a single online platform (MEDIZIN TO GO) and to help improve CME for upcoming generations and for post-COVID-19.

CONCLUSION

Continuing medical education is a major part of healthcare and medical education. Digitalization was accelerated by the COVID-19 pandemic. Fortunately, digital and online CME platforms already existed and bridged the gap until some kind of universal adaptation settled and adequate online CME became abundant. Users have specific requirements, value human interaction, and are in favor of combined face-to-face and online CME events (Blended learning) defining the way for and The Future of CME development.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

TS and SR devised the project, the main conceptual ideas, the proof outline, supervised and finalized the manuscript, and performed an independent literature search. SR carried out data acquisition, worked out almost all of the technical details, performed the statistical calculations, and drafted the manuscript assisted by TS. TG, BR, JW, MP, and KJ contributed to the survey draft, carried out additional data assessment, and assisted with manuscript completion and the submitted figures. All authors contributed to the article and approved the submitted version.

FUNDING

The SurveyMonkey license was privately funded by SR.

ACKNOWLEDGMENTS

We would like to thank all participants responding to this survey and helping us at MEDIZIN TO GO contribute to improving online continuing medical education. Furthermore, we would like to thank all lecturers for sharing their expertise on an honorary basis. Also, all donors, who helped and continue to help keeping MEDIZIN TO GO going.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmed.2021.773806/full#supplementary-material

REFERENCES

1. O'Doherty D, Dromey M, Lougheed J, Hannigan A, Last J, McGrath D. Barriers and solutions to online learning in medical education – an integrative review. *BMC Med Educ.* (2018) 18:130. doi: 10.1186/s12909-018-1240-0
2. Althwanay A, Ahsan F, Oliveri F, Goud HK, Mehkari Z, Mohammed L et al. Medical education, pre- and post-pandemic era: a review article. *Cureus.* (2020) 12:e10775. doi: 10.7759/cureus.10775
3. Sandars J, Patel R. The challenge of online learning for medical education during the COVID-19 pandemic. *Int J Medical Educ.* (2020) 11:169–70. doi: 10.5116/ijme.5f20.55f2
4. Schneider SL, Council ML. Distance learning in the era of COVID-19. *Arch Dermatol Res.* (2020) 313:389–90. doi: 10.1007/s00403-020-02088-9
5. Shah S, Diwan S, Kohan L, Rosenblum D, Gharibo C, Soin A, et al. The technological impact of COVID-19 on the future of education and health care delivery. *Pain Phys.* (2020) 23:S367–80. doi: 10.36076/ppj.2020/23/S367
6. Singhi EK, Dupuis MM, Ross JA, Rieber AG, Bhadkamkar NA. Medical hematology/oncology fellows' perceptions of online medical education during the COVID-19 pandemic. *J Cancer Educ.* (2020) 35:1034–40. doi: 10.1007/s13187-020-01863-6
7. Torda A. How COVID-19 has pushed us into a medical education revolution. *Intern Med J.* (2020) 50:1150–3. doi: 10.1111/imj.14882
8. Teele SA, Sindelar A, Brown D, Kane DA, Thatte N, Williams RJ, et al. Online education in a hurry: delivering pediatric graduate medical education during COVID-19. *Prog Pediatr Cardiol.* (2020) 60:101320. doi: 10.1016/j.ppedcard.2020.101320
9. Zoia C, Raffa G, Somma T, Pepa GMD, Rocca GL, Zoli M, et al. COVID-19 and neurosurgical training and education: an Italian perspective. *Acta Neurochir.* (2020) 162:1–6. doi: 10.1007/s00701-020-04460-0
10. Stoehr F, Müller L, Brady A, Trilla A, Mähringer-Kunz A, Hahn F, et al. How COVID-19 kick-started online learning in medical education—The DigiMed study. *PLoS ONE.* (2021) 16:e0257394. doi: 10.1371/journal.pone.0257394
11. Martin A, Lang E, Ramsauer B, Gröning T, Bedin GL, Frank J. Continuing medical and student education in dermatology during the coronavirus pandemic – a major challenge. *Jddg J Der Deutschen Dermatologischen Gesellschaft.* (2020) 18:835–40. doi: 10.1111/ddg.14190
12. Ferrel MN, Ryan JJ, N FM, J RJ. The impact of COVID-19 on medical education. *Cureus J Med Sci.* (2020) 12:e7492. doi: 10.7759/cureus.7492
13. Edigin E, Eseaton PO, Shaka H, Ojemolon PE, Asemota IR, Akuna E. Impact of COVID-19 pandemic on medical postgraduate training in the United States. *Med Educ Online.* (2020) 25:1774318. doi: 10.1080/10872981.2020.1774318
14. Loda T, Löffler T, Erschens R, Zipfel S, Herrmann-Werner A. Medical education in times of COVID-19: German students' expectations – a cross-sectional study. *PloS ONE.* (2020) 15:e0241660. doi: 10.1371/journal.pone.0241660
15. Offergeld C, Ketterer M, Neudert M, Hassepaß F, Weerda N, Richter B, et al. "Ab morgen bitte online": Vergleich digitaler Rahmenbedingungen der curricularen Lehre an nationalen Universitäts-HNO-Kliniken in Zeiten von COVID-19. *HNO.* (2021) 69:213–20. doi: 10.1007/s00106-020-00939-5
16. Ridwan S, Ganau M, Zoia C, Broekman M, Grote A, Clusmann H. Unequal impact of COVID-19 on private and academic neurosurgical workforce: results of an international survey. *Front Surg.* (2021) 8:749399. doi: 10.3389/fsurg.2021.749399
17. Lenzner, T., Neuert, C., and Otto, W. (2016). *Cognitive Pretesting. GESIS Survey Guidelines.* Mannheim: GESIS-Leibniz Institute for the Social Sciences.
18. Hassan ZA, Schattner P, Mazza D. Doing a pilot study: why is it essential? *Malays Fam Phys.* (2006) 1:70–3.
19. Yusoff MSB. ABC of response process validation and face validity index calculation. *Educ Medicine J.* (2019) 11:55–61. doi: 10.21315/eimj2019.11.3.6
20. Gnanakumar S, Bourqiun BE-E, Robertson FC, Solla DJF, Karekezi C, Vaughan K, et al. The WFNS young neurosurgeons survey (part i): demographics, resources and education. *World Neurosurg X.* (2020) 8:100083. doi: 10.1016/j.wnsx.2020.100083
21. Robertson FC, Gnanakumar S, Karekezi C, Vaughan K, Garcia RM, Bourquin BAEE, et al. The World Federation of Neurosurgical Societies young neurosurgeons survey (part ii): barriers to professional development and service delivery in neurosurgery. *World Neurosurg X.* (2020) 8:100084. doi: 10.1016/j.wnsx.2020.100084
22. Hoopes S, Pham T, Lindo FM, Antosh DD. Home surgical skill training resources for obstetrics and gynecology trainees during a pandemic. *Obstetr Gynecol.* (2020) 136:56–64. doi: 10.1097/AOG.0000000000003931
23. Megaloikonomos PD, Thaler M, Igoumenou VG, Bonanzinga T, Ostojic M, Couto AF, et al. Impact of the COVID-19 pandemic on orthopaedic and trauma surgery training in Europe. *Int Orthop.* (2020) 44:1611–19. doi: 10.1007/s00264-020-04742-3
24. Saunders MNK, Townsend K. Reporting and justifying the number of interview participants in organization and workplace research. *Br J Manage.* (2016) 27:836–52. doi: 10.1111/1467-8551.12182

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers | Frontiers in Surgery

ORIGINAL RESEARCH
published: 04 April 2022
doi: 10.3389/fsurg.2022.749092

Check for updates

The Effectiveness of Simulation in Education 4.0: Application in a Transesophageal Echocardiography Training Program in Malaysia

Sakinah AwangHarun[1], Noorjahan Haneem Md Hashim[2] and Suhaini Kadiman[3]*

[1] IJN College, National Heart Institute, Kuala Lumpur, Malaysia, [2] Department of Anesthesiology, Faculty of Medicine, Universiti Malaya, Kuala Lumpur, Malaysia, [3] Department of Anesthesiology and Intensive Care, National Heart Institute, Kuala Lumpur, Malaysia

Introduction: A Malaysian Higher Education Provider has applied technology as part of its pedagogical approach, in alignment with Education 4. 0. The use of simulation, which aligns with the principles of Education 4.0, employs digital technologies and supports learning by bridging the classroom and the clinical areas. We reported the effectiveness of learning in our program that utilizes multimodal pedagogy, including interactive lectures, pre-recorded video lectures, simulation, and hands-on supervised clinical sessions, using the program's cumulative assessment data.

Methodology: This program evaluation was based on Kirkpatrick's framework. End-points for learning (Kirkpatrick level 2) were analyzed based on improved overall post-test theoretical and clinical assessment performance. Quantitative data analysis of theoretical pre-test, theoretical post-test, clinical assessment, and post-test scores was performed to compare cohorts.

Results: The performance of 19 trainees, over six cohorts from 2012 to 2019, were analyzed. All our trainees had equal opportunities to learn using the multimodal pedagogy, including a simulator. The analysis of pre- and post-theoretical test scores showed a significant improvement in the mean scores (pre-test 48.7% (± *SD* 9), post-test 64.1% (± SD11.5); $p \leq 0.001$). Overall, 19 out of 21 trainees completed the clinical assessment and case presentation satisfactorily

Conclusion: The Kirkpatrick framework served as a useful framework to perform the evaluation of the TEE program. The significant improvement in post-test scores, when compared with pre-test scores, suggested that the program is effective with regard to learning. As part of a multimodal pedagogy, simulation has proven to be an added value to our training program, and this was reflected by the improvement in the clinical assessment scores when compared to the pre-test scores. This result aligned with the concept of technology-enhanced learning in Education 4.0, where simulation in TEE training is applicable in the Malaysian context.

Keywords: simulation as pedagogical tool, simulation in TEE, Kirkpatrick's framework for program evaluation, education 4.0, technology-enhanced learning

Edited by:
Dinker R. Pai,
Sri Balaji Vidyapeeth University, India

Reviewed by:
Dorota Nowosielecka,
John Paul II Hospital, Poland
Joanna Ooi,
Universiti Kebangsaan Malaysia Medical Center (UKMMC), Malaysia

****Correspondence:***
Sakinah AwangHarun
sakinahawang@ijn.com.my

Specialty section:
This article was submitted to Thoracic Surgery, a section of the journal Frontiers in Surgery

Received: *29 July 2021*
Accepted: *21 February 2022*
Published: *04 April 2022*

Citation:
AwangHarun S, Md Hashim NH and Kadiman S (2022) The Effectiveness of Simulation in Education 4.0: Application in a Transesophageal Echocardiography Training Program in Malaysia. Front. Surg. 9:749092. doi: 10.3389/fsurg.2022.749092

INTRODUCTION

Education 4.0 is the revolution that focuses on smart technology, including advanced medical devices, artificial intelligence, and robotics, that has given impact to current perioperative cardiothoracic surgical care. Transesophageal echocardiography (TEE) is a high technology device utilized in cardiothoracic surgery to inform the diagnosis and clinical management of patients with diverse pathologies (1). In performing peri-operative TEE, training is necessary to ensure minimal competencies are achieved to provide better clinical outcomes for patients. Due to limited patient access and high-risk patient groups, the use of simulation in TEE training assists the development of the practitioners' competence while maintaining patient safety (2).

Technological advancement transforms teaching and learning strategies in advanced or specialty training (3, 4). In our center, we have applied the principles of education 4.0 in introducing technology and simulation when developing a curriculum for Perioperative Transesophageal Echocardiography.

The use of simulation, which aligns with the principles of Education 4.0, employs digital technologies and supports learning by bridging the classroom and the clinical areas (2, 5). The features of Education 4.0, including personalized learning, learning tools customized to the learner's choice, project-based learning, hands-on and experiential learning, formative and workplace-based assessment, learners' feedback in shaping the curriculum, and independent learning while the teacher facilitates, are all applicable to our TEE program. This is because learners are provided with multiple learning tools to be adaptive to the mentioned features, such as lectures, simulation-based learning tasks, hands-on experience on real patients in the clinical workplace, and trainee evaluation of the program that advises improvement measures. Simulation offers an opportunity for deliberate practice in preparation for hands-on learning in the clinical setting. Knowledge and skills (cognitive and psychomotor) were developed by repetitive and focused training in an alternative safe environment without compromising trainee safety and patient care in the busy and high-risk clinical setting.

The purpose of this study was to measure the effectiveness of a postgraduate TEE training program in Malaysia using the Kirkpatrick Evaluation Model (6). In this study, TEE simulation was used by novice TEE users to learn cognitive and psychomotor skills. We report the effectiveness of learning in our program that utilizes multimodal pedagogy, including interactive lectures, pre-recorded video lectures, simulation, and hands-on supervised clinical sessions, using the program's cumulative assessment data. The Kirkpatrick model was chosen due to its practicality in program evaluation since the information analyzed can be used to improve learners' reaction, learning, behavioral changes, and impact on the institution (6).

RESEARCH OBJECTIVE

This study aimed to measure the effectiveness of the TEE training curriculum, which included simulation-assisted learning, in a postgraduate TEE training program in Malaysia using the Kirkpatrick evaluation model.

Research Question

This study mainly asked, what is the effectiveness of the TEE training curriculum, which includes simulation-assisted learning, in a postgraduate TEE training program in Malaysia using the Kirkpatrick education model?

Study Rationale

The rationale of this study was to improve the effectiveness of the program based on Kirkpatrick's evaluation model (Kirkpatrick level 2: learning).

METHODOLOGY

Program Description

This program focused on the basic understanding of TEE and its peri-operative applications in cardiothoracic surgical care. This includes the basic understandings of applied ultrasound principles, knobology, clinical indications for TEE, the value of TEE in various clinical situations, understanding standard TEE images, and interpretation of various clinical conditions using TEE over a duration of 7 months to 2 years.

The training was divided into two parts. The first part comprised sessions that include the theoretical knowledge, cognitive and psychomotor skills to acquire and perform semi-quantitative analysis of 20 tomographic views in (i) a simulator and on (ii) 25 patients in Institut Jantung Negara (IJN). Upon achieving satisfactory knowledge and skills in a structured assessment, trainees then proceed to the second part of the program. The second part required trainees to perform and document TEE examination reports on 150 patients at their own institution, over a period of 6 to 18 months.

Trainees' knowledge and skills were assessed at four different points throughout the program, strategies summarized in **Figure 1**. Despite each cohort having the chance of being asked different questions at each assessment session, the domains to be examined and examination methods remained constant for each cohort. Program assessors are internationally certified TEE practitioners and trainers who actively perform perioperative TEE.

Theoretical knowledge and cognitive skills were assessed at the beginning of the program, as a multiple-choice questions pre-test, and at the end of part 1 *via* multiple-choice questions post-test and incorporated in the clinical assessment. The 100 post-test MCQs may differ amongst the cohorts, as the question bank consists of 1500 vetted questions that are blueprinted to the course outcomes. The psychomotor skills were assessed at the end of part 1. At the end of the program, trainees' knowledge, cognitive and psychomotor skills were assessed based on the submitted logbook and a case presentation session. In the case presentation session, trainees were expected to present four cases from their logbooks based on a pre-determined criterion (adult valvular surgery,

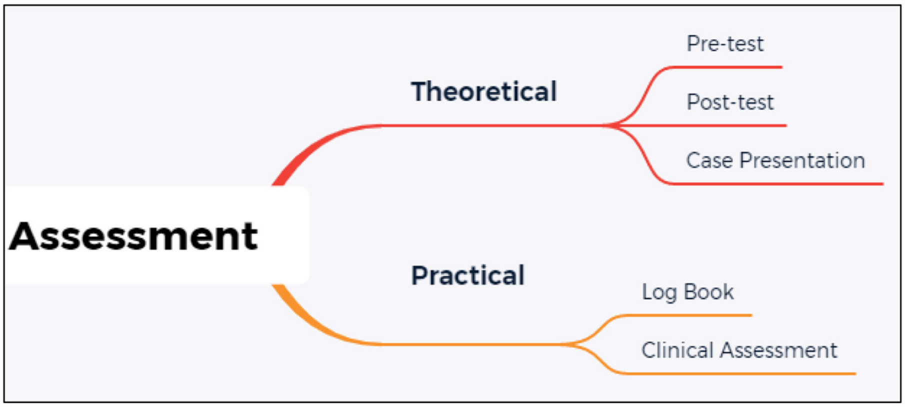


FIGURE 1 | Assessment strategies.

coronary arterial bypass surgery, combined surgery, and pediatric surgery) supported by its prerecorded relevant echocardiography video loops. The loops were recorded to demonstrate the trainees' understanding of the pathology and their cognitive and psychomotor skills to obtain the relevant views. The question-and-answer session during the presentation assesses the trainees' theoretical understanding.

The pieces of evidence collected from these assessments support that the trainees have achieved the learning outcomes of the program and will be used to measure the effectiveness of the program based on Kirkpatrick Level 2. The description of the program, which includes teaching and learning activities, strategies, and assessment, is summarized in **Table 1**.

The program was evaluated before each intake in accordance with institutional and licensing regulations. Improvements were made according to the trainee, trainer, and other stakeholders' feedback. The simulation was integrated into the curriculum for the second cohort in 2012, based on the feedback from Cohort 1, for improvement of cognitive and psychomotor skills. Changes that were made by applying simulation principles, that include feedback, deliberate practice, and independent learning, were the major contributing factors to learning. A checklist of the 20 tomographic images to be acquired was provided to the trainees, to facilitate image recognition, as shown in **Figure 2**. The second change made was to improvise the checklist to guide the image acquisition of the 20 tomographic views in 2013 for the third cohort. Contents of the checklist include the thematic image of the tomographic views with the appropriate probe position and angulation, as shown in **Figure 3**. The third change introduced was to include the element of time in the learning outcome of all 20 views, wherein acquisition was made within 20 mins for all 20 basic views for the fourth cohort in 2016, as shown in **Figure 4**. The time limit chosen was based on recorded time to image acquisition of the previous batches both on the simulator and patients. The fourth change was to provide personalized on-demand coaching to acquire optimal image within 2 min for the same cohort while trainees learn on the TEE simulator.

Study Sample

The study sample included anesthesiologists, cardiothoracic anesthesiologists, cardiologists, and intensivists who enrolled in the Perioperative Transesophageal Echocardiography program at Institut Jantung Negara from 2012 to 2019. Sampling was universal, as all participant's performances were included in the analysis.

The rationale for universal sampling is perioperative TEE is a niche area focusing on the perioperative care of cardiac patients, and the pool for potential participants is small, to begin with. In addition, the limited number of learners enrolled in the program was also limited by our aim to maintain an optimal trainer: trainee ratio and procedure: trainee ratio to ensure each learner receives an equal learning opportunity.

The heterogeneity and possible differences between trainees on joining the program are expected of professionals and adult learners. However, all enrolled trainees fulfilled the minimum program entry requirement of being licensed physicians enrolled or completed their specialty training program. Their baseline knowledge and cognitive skills reflecting prior learning are assessed using the theoretical pre-test upon entry. Their psychomotor skills were not assessed.

Outcome Measures

The outcomes studied were based on the Kirkpatrick program evaluation framework, learning (Kirkpatrick level 2) (6). Overall learning was defined as improved theoretical post-test results and clinical assessment performance for all trainees. Cohort learning, to compare the learning effects of pedagogical interventions, was defined as improved theoretical post-test results, clinical assessment, and case presentation scores between cohorts.

Data Analysis

Retrospective data were analyzed using IBM SPSS version 27 (IBM Corp, Armonk, NY, USA). Paired sample *t*-tests were used

TABLE 1 | Summary of teaching and learning activities and strategies and assessment.

Domains	Details	Learning activities	Study duration (h)	Assessment strategies
Cognitive	Part 1			
	Learning outcomes			
	1. Theoretical knowledge	Lectures (didactic and interactive)	40	100 SBA (MCQ)
	2. Cognitive skills: diagnostic skills	Lectures (interactive); Simulation		
Psychomotor	Learning outcomes			
	3. Technical skills: 3.1. Probe & equipment handling 3.2. Image acquisition 3.3. Image interpretation 3.4. Image storage &retrieval 3.5. Reporting and documentation	Simulation Clinical placement with patient under supervision, to apply the theory, cognitive and psychomotor skills, into appropriate clinical decision making	14	Self-assessment Clinical assessment
Cognitive,	Learning outcomes		42	
psychomotor and affective	4. Non-technical skills: 4.1. Teamwork 4.2. Communication 4.3. Situational awareness 4.4. Recognizing limitations	Clinical placement with real patients under supervision, to apply the cognitive and psychomotor skills in clinical environment		Clinical assessment
Cognitive	Part 2			
	Learning outcomes			
	1. Cognitive skills: diagnostic skills			
Psychomotor	Learning outcomes			
	2. Technical skills: 2.1. Probe & equipment handling 2.2. Image acquisition 2.3. Image interpretation 2.4. Image storage &retrieval 2.5. Reporting and documentation	Clinical placement with real patient in respective institution to apply theory, cognitive and psychomotor skills, into clinical decision making in the real clinical environment.	809	Log book; Case presentation
Cognitive,	Learning outcomes			
psychomotor and affective	3. Non-technical skills: 3.1. Teamwork 3.2. Communication 3.3. Situational awareness 3.4. Recognizing limitations			

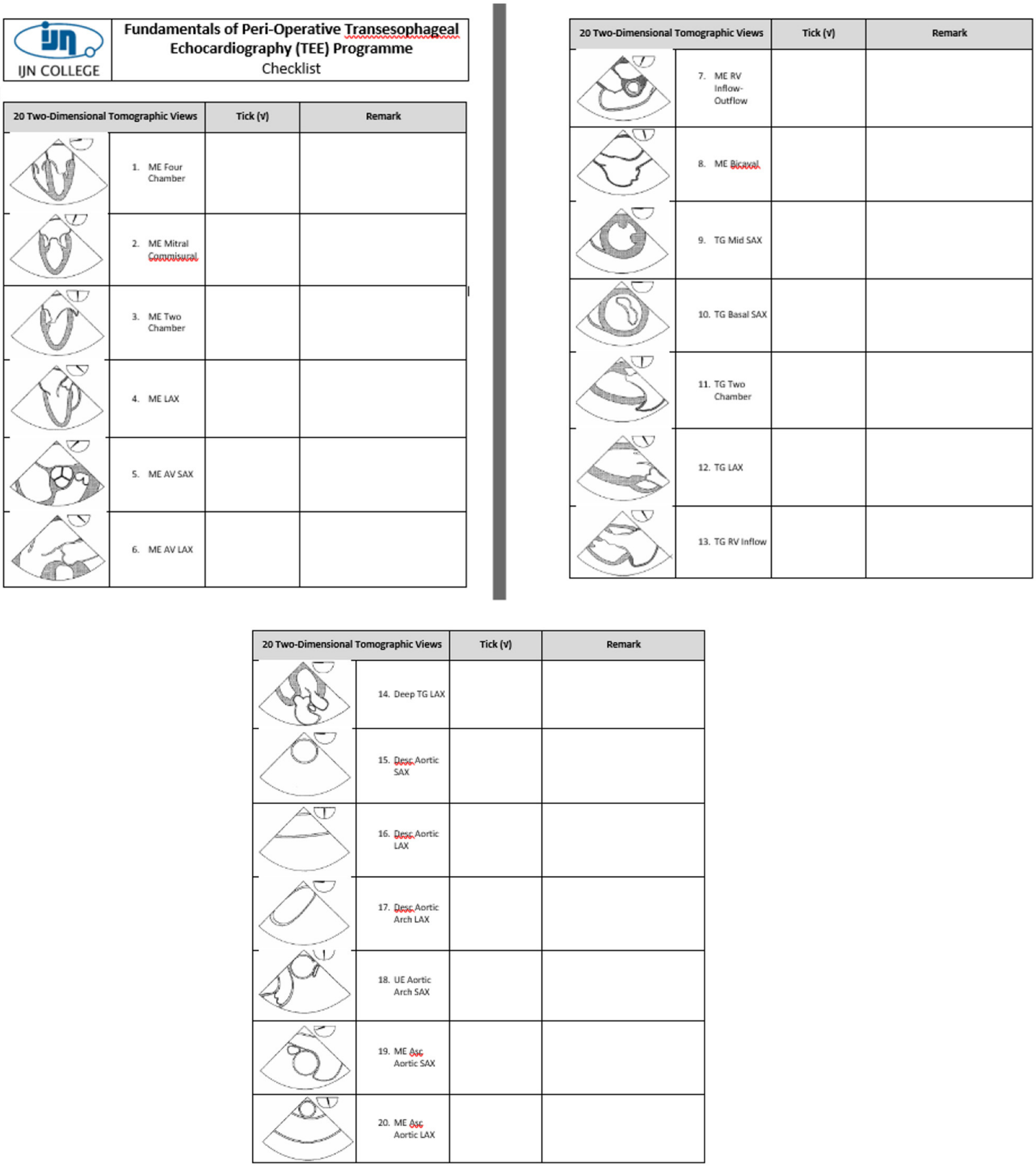
SBA, Single best answer; MCQ, Multiple Choice Questions.

to compare means where data was normally distributed, for all cohorts. When comparing means between cohorts, no statistical analysis was performed due to the small sample size.

RESULTS

The performance of 19 trainees, over six cohorts from Cohort 2/2012 to 8/2019 were analyzed. Trainees from Cohort 1 were excluded from the analysis as they were the pilot group for the program and had different pedagogy and assessment time points. All trainees analyzed had equal opportunities learning using the multimodal pedagogy, including a simulator. The summary of trainee scores for all assessment components is shown in **Table 2**.

The performances of 19 trainees were analyzed for the theory assessment component. The analysis of pre- and post- theoretical test scores showed a significant improvement in the mean scores (pre-test 48.7 % (± *SD* 9), post-test 64.1% (± *SD* 11.5); $p \leq 0.001$), shown in **Figure 5**.



IJN COLLEGE

Fundamentals of Peri-Operative Transesophageal Echocardiography (TEE) Programme

Checklist

20 Two-Dimensional Tomographic Views		Tick (√)	Remark
	1. ME Four Chamber		
	2. ME Mitral Commisural		
	3. ME Two Chamber		
	4. ME LAX		
	5. ME AV SAX		
	6. ME AV LAX		

20 Two-Dimensional Tomographic Views		Tick (√)	Remark
	7. ME RV Inflow-Outflow		
	8. ME Bicaval		
	9. TG Mid SAX		
	10. TG Basal SAX		
	11. TG Two Chamber		
	12. TG LAX		
	13. TG RV Inflow		

20 Two-Dimensional Tomographic Views		Tick (√)	Remark
	14. Deep TG LAX		
	15. Desc Aortic SAX		
	16. Desc Aortic LAX		
	17. Desc Aortic Arch LAX		
	18. UE Aortic Arch SAX		
	19. ME Asc Aortic SAX		
	20. ME Asc Aortic LAX		

FIGURE 2 | A checklist to guide the image acquisition of the 20 tomographic views in Cohort 2/2012.

Overall, 19 out of 21 trainees completed the clinical assessment. The means for each change in program delivery improvements were 66% (introduction of checklist with probe position and angulation) and 67.2% (time as part of learning outcome and personalized on-demand coaching) respectively compared to the original program delivery method of 59.5%.

DISCUSSION

Curriculum integration in simulation-based healthcare education allows education providers to perform a goal-directed evaluation of student learning and supports sustained use of its technology (3). When the technology became available, its use was piloted in our program and was formally integrated into the curriculum based on learner feedback for the second cohort. There was an improvement in the mean clinical performance scores (59 and 67.8%) in the cohorts pre- and post-integration of simulation. This is supported by Vega (7). where the effectiveness of simulation training is enhanced by verbal cues, training sequences (evidenced by the use of checklist), visual cueing from the checklist, and feedback from high fidelity simulator.

The use of simulation in education has been implemented in other TEE training programs. Simulation technology has been available for many decades and has been shown to improve learning and patient outcomes in many fields (8). TEE simulation has been used to train cognitive, psychomotor, and affective domains that increase performance. The simulation is also capable of reducing incidences of human error and increasing the standards and quality of patient care. This supports the findings in our program, where trainees were able to demonstrate the 20 tomographic image acquisition within 20 min by practicing with simulation, aided by a holistic checklist and personalized coaching and feedback.

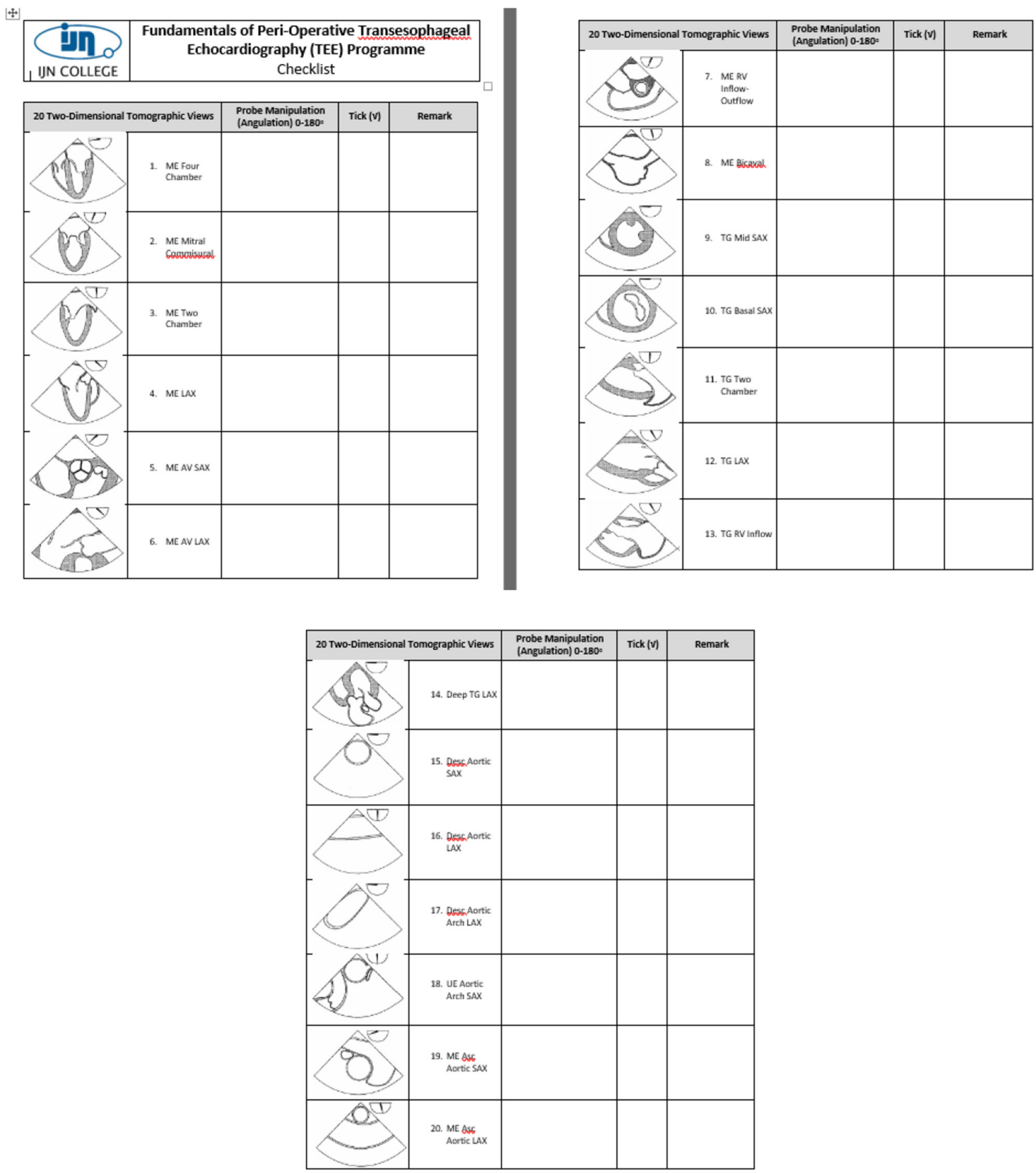
The significant improvement of the theoretical post-test, when compared to the pre-test, shows that learning occurred during the program. Though the best method would be to include a comparison of pre- and post-simulation clinical performance, this was neither feasible nor safe in our setting. Nazerian et al. agreed to evaluate the ability of emergency physicians (EPs) to obtain and maintain skills in performing TEE to aid resuscitation after a course with clinical training in the cardiac surgical theater (1). Therefore, training on a simulator improves competency and reduces errors and harm to patients. Training using the simulation for TEE experience may improve proficiency, learning speed, increase trainees' comfort, and increase performance while performing the procedure in clinical practice after completion of the study. In this study, the program allocated 14 h for TEE simulation training for trainees to practice before placement in the clinical environment. The TEE simulator created a dynamic environment in which trainees can improve their abilities in critical thinking, decision making, and clinical judgment. Within the structure of simulation, trainees focus on psychomotor components to master the TEE probe manipulation skills to obtain images by using TEE technology. A variety of TEE simulator models has been incorporated into our curriculum to enhance the efficiency of teaching and evaluate proficiency in TEE.

Incorporating simulation, either as a pedagogical or assessment tool, was also documented by two programs that train physicians in focused cardiac ultrasound for the emergency setting. The first program focused on training residents in French cardiology, anesthesiology, and emergency medicine setting (9). The investigators described a three-stage training program, which included didactic lectures in an e-learning platform, free access to a TTE simulator with on-demand experts for one day, followed by placement in the echocardiography laboratory where the trainees perform focused TTE in 10 consecutive patients. The third stage was self-training in image analysis in an online platform. All trainees underwent a pre-test evaluation using TEE simulators, using the same criteria as the post-test evaluation and end of stage 2 assessment. Trainees' cognitive (ability to interpret images) and practical skills were assessed using simulators at the end of the first stage and with real patients during the second stage. The time to image acquisition was recorded. TEE examinations were recorded and assessed by two blinded assessors. Image quality, visualization of structures, image stability, and interpretability of the TEE examinations were the criteria being scored. The final evaluation was an interpretation of 20 video clips of the TEE examination. The results of this study showed significant improvement in practical and interpretive skills of trainees at the end of echocardiography laboratory placement. The main difference with our program is their pre-test assessment strategy using simulation, where baseline image acquisition skills were recorded and compared to after training, and the images were recorded and scored by 2 different assessors. This allows tracking of trainees' performance, and the program would be able to identify trainees' learning curves and areas for improvement.

In another study in North America, Beraud et al. (10) also designed and implemented a focused TTE curriculum, for critical care medicine fellows. The training consisted of weekly lectures and 15-h of one-on-one bedside ultrasound scanning instructions in the ICU by a cardiologist instructor. Trainees then performed, recorded, and reported TEE examinations, which were assessed by the cardiologist instructor. Feedback was provided regarding image quality and interpretation. At the end of 1 year, trainees were assessed using the recording of their last three examinations and using a simulator. The results show significant improvement in the scanning and diagnostic abilities of the fellows. This shows that simulation, when combined with real patient experience can be an effective tool for learning echocardiography.

The significant improvement of the theoretical post-test and practical clinical shows that learning occurred during the program. Though the best method would be to compare pre- and post-clinical performance, this was neither feasible nor safe in our setting. Therefore, theoretical components, especially related to diagnosis were incorporated in the clinical performance assessment.

The advancement of technology has been changing significantly, especially in cardiovascular and thoracic services as well as in the education industry. These technological advancements, along with changing expectations regarding training hours, patient safety, and limited patient encounters, have supported the paradigm of incorporating technology in providing education (3). Integrating simulation as a pedagogical tool is the best approach to link theoretical knowledge, workplace-based learning, and clinical practice (4). The TEE simulator as an advanced technology plays an important role in helping trainees become active learners. Learning and



IJN COLLEGE

Fundamentals of Peri-Operative Transesophageal Echocardiography (TEE) Programme
Checklist

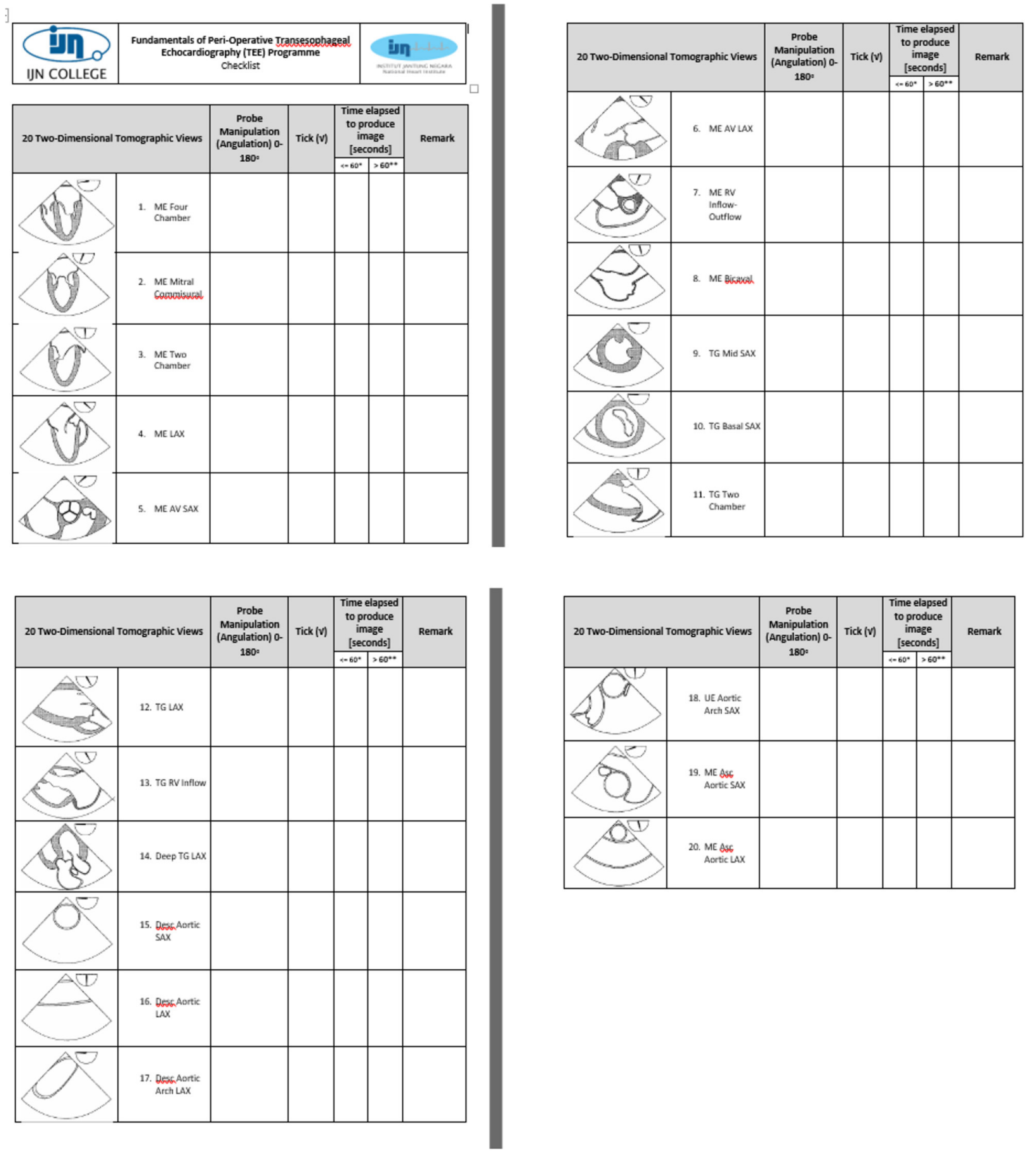
20 Two-Dimensional Tomographic Views		Probe Manipulation (Angulation) 0-180°	Tick (√)	Remark
	1. ME Four Chamber			
	2. ME Mitral Commisural			
	3. ME Two Chamber			
	4. ME LAX			
	5. ME AV SAX			
	6. ME AV LAX			

20 Two-Dimensional Tomographic Views		Probe Manipulation (Angulation) 0-180°	Tick (√)	Remark
	7. ME RV Inflow-Outflow			
	8. ME Bicaval			
	9. TG Mid SAX			
	10. TG Basal SAX			
	11. TG Two Chamber			
	12. TG LAX			
	13. TG RV Inflow			

20 Two-Dimensional Tomographic Views		Probe Manipulation (Angulation) 0-180°	Tick (√)	Remark
	14. Deep TG LAX			
	15. Desc Aortic SAX			
	16. Desc Aortic LAX			
	17. Desc Aortic Arch LAX			
	18. UE Aortic Arch SAX			
	19. ME Asc Aortic SAX			
	20. ME Asc Aortic LAX			

FIGURE 3 | Contents of the checklist include the thematic image of the tomographic views with the appropriate probe position and angulation.

mastery are evidenced in our program with the improvement in theoretical post-tests, compared to pre-test, ability to acquire, interpret and report images in real patients in the authentic clinical setting (11). The TEE simulator technology has created new and diverse methods for conducting these processes, supported the trainees in multiple ways. Technology integration is the use of technology tools in general content areas in education to allow trainees to apply TEE simulator



IJN COLLEGE

Fundamentals of Peri-Operative Transesophageal Echocardiography (TEE) Programme
Checklist

INSTITUT JANTUNG NEGARA National Heart Institute

20 Two-Dimensional Tomographic Views	Probe Manipulation (Angulation) 0-180°	Tick (√)	Time elapsed to produce image [seconds]		Remark
			<= 60*	> 60**	
1. ME Four Chamber					
2. ME Mitral Commisural					
3. ME Two Chamber					
4. ME LAX					
5. ME AV SAX					
6. ME AV LAX					
7. ME RV Inflow-Outflow					
8. ME Bicaval					
9. TG Mid SAX					
10. TG Basal SAX					
11. TG Two Chamber					
12. TG LAX					
13. TG RV Inflow					
14. Deep TG LAX					
15. Desc Aortic SAX					
16. Desc Aortic LAX					
17. Desc Aortic Arch LAX					
18. UE Aortic Arch SAX					
19. ME Asc Aortic SAX					
20. ME Asc Aortic LAX					

FIGURE 4 | The element of time in the learning outcome of all 20 views: acquisition within 20 min for the fourth cohort in 2016.

and technology skills to learning and problem solving, critical thinking, decision making, and clinical judgment (12).

Kirkpatrick's framework for program evaluation was chosen, as it provided a clear taxonomy for decision-making (13). We chose it for its simplicity and helped us focus on the learners: their reactions, learning, behavioral change, and system-level impact. We chose to focus on learning at this point as we wanted to learn the immediate effects of our educational interventions.

TABLE 2 | Summary of assessment scores of all the trainees, with changes in pedagogy.

Cohort	Year	Changes	Number of trainees	Mean theory scores (%, ±SD)		Changes in scores (post-test-pre-test)	Mean clinical assessment scores (%, ±SD)	Mean logbook scores (%)	Mean case presentation score (%, ±SD)
				Pre-test	**Post-test**				
1	2012	-	2	-	74.5	-	59.5 (12.73)	100	80 90.00)
2	2012	Simulation and checklist	3	45.3	55.3	+10	68.7 (11.02)	100	64.5 (3.54)
3	2014	Checklist with probe position and angulation	2	49.5	57.5	+8	66.0 (22.62)	100	69
4	2016	Time + coaching	2	62.0	68.5	+6.5	75.5 (7,78)	100	78
5	2016	-	2	48.0	60.5	+12.5	65.5 (0.71)	100	63.5 (0.71)
6	2017	-	3	50.0	66.3	+16.3	61.0 (6.56)	100	75.5 (4.77)
7	2018	-	4	44.5	69.25	+24.75	70.0 (14.14)	100	83 (15.56)
8	2019	-	3	47.3	76.0	+28.7	Not applicable	100	Not applicable

	Pre-test	Post-test	p-value
Theory (mean score ±sd)	48.7 (8.96)	64.1 (11.46)	<0.001

FIGURE 5 | Chart showing improvement in post-tests mean scores across cohorts.

Our study has a few limitations. Our sample size was very limited. As mentioned previously, this was due to the limited pool of learners as this is a very niche learning area, as well as due to our aim to ensure that opportunities for learning were constant and equal for all learners.

We were also not able to provide direct supervision of the first 50 TEE performance and interpretation, as recommended by the 2013 consensus statement of the American Society of Echocardiography and the Society of Cardiovascular Anesthesiologists basic TEE training requirement (14) due to the limited number of patients in our center and our learners are only allowed to be in our institution for one month.

The significant improvement measured in the theoretical post-test and clinical assessment shows that learning occurred during the program. Though the best method would be to compare pre- and post-simulation clinical performance, this was neither feasible nor safe in our setting. Therefore, theoretical components, especially related to diagnosis were incorporated in the clinical performance assessment.

Another limitation was we were not able to cross-check self-directed learning TEE findings in part 2, as trainees were in their own institutions, and it was not feasible to record all TEE examination findings due to potential patient confidentiality issues and unavailability of assigned trainers in the respective centers. When crosscheck was available, it was due to chance, rather than, designed in the curriculum.

Despite these limitations along with the results only showing statistical significance in the theory components, the experiences reported by the trainees that were paired with their performance had provided meaningful feedback for program improvement to support learning.

FUTURE RECOMMENDATIONS

Performance of TEE requires the psychomotor ability to obtain interpretable echocardiography images and simulation is an effective tool for learning psychomotor skills by novices. The COVID-19 pandemic opens other opportunities for the application of technology into online and distant learning. This can be facilitated with a learning management system and a virtual learning environment. Integrating a learning management system that supports word processing documents, audio and video streaming into our program would facilitate multiple teaching, learning, and assessment activities: access to lectures, remote case presentations, remote preceptors and facilitators, and theoretical and virtual live cases for assessments. Though the advantages of online learning have been highlighted in numerous studies, items to be integrated into the LMS must be carefully selected. Items that can be selected are videos, online discussions, and case presentation items. Novel items that can be included are remote clinical teaching and assessment. The LMS can also be used to track trainee performance on the simulators. This would facilitate trainers and trainees to decide trainee readiness for practice in real patients.

CONCLUSION

Integrating a TEE simulator as a pedagogical tool for our postgraduate TEE training program has proven to be effective in supporting learning theoretical knowledge and clinical competency in perioperative cardiac surgical TEE amongst our trainees.

The TEE Simulator was helpful in providing a bridge from theory to the clinical environment by supporting trainees' cognitive and psychomotor skills.

The Kirkpatrick framework served as a useful framework to evaluate the effectiveness of this training program. The significant improvement in post-test scores, when compared with pre-test scores, suggested that the program is effective with regards to learning. Simulation, as part of a multimodal pedagogy, has added value to our training program, and this was reflected by improvement in the clinical assessment scores when compared to the pre-test scores. This result aligned with the concept of technology-enhanced learning in Education 4.0, where simulation in TEE training is applicable in the Malaysian context.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

SA: program design and developer and implementation, contributed to design, conception of the study (Introduction, Methodology, Results, Discussion, and Future Recommendation), the acquisition of data, analysis, interpretation, and wrote the paper. NM: analysis and interpretation, wrote the paper (Introduction, Methodology, Results, and Conclusion), and performed first and second proofreading. SK: contributed to program design and implementation, first, and second proofreading. All authors contributed to the article and approved the submitted version.

REFERENCES

1. Nazerian P, De Stefano G, Albano G, Gaspari V, Bevilacqua S, Campagnolo V, et al. Transesophageal echocardiography (TEE) in cardiac arrest: results of a hands-on training for a simplified TEE protocol. *Ultrasound J.* (2020) 12:41. doi: 10.1186/s13089-020-00189-0
2. Mahdy ZA, Maaya M, Atan IK, Abd Samat AH, Isa MH, Saiboon IM. Simulation in healthcare in the realm of education 4.0. Sains Malaysiana. (2020) 49:1987–93. doi: 10.17576/jsm-2020-4908-21
3. Motola I, Devine LA, Chung HS, Sullivan JE, Issenberg SB. Simulation in healthcare education: a best evidence practical guide. *AMEE Guide No 82 Med Teach.* (2013) 35:e1511–30. doi: 10.3109/0142159X.2013.818632
4. Chernikova O, Heitzmann N, Stadler M, Holzberger D, Seidel T, Fischer F. Simulation-based learning in higher education: a meta-analysis. *Rev Educ Res.* (2020) 90:499–541 doi: 10.3102/0034654320933544
5. Fisk P. *Education 4.0 … the Future of Learning Will be Dramatically Different, in School and Throughout Life*. (2017). Available online at: https://www.peterfisk.com/2017/01/future-education-young-everyone-taught-together/ (accessed February 12, 2022).
6. Kirkpatrick JD, Kirkpatrick WK. *Kirkpatrick's Four Levels of Training Evaluation*. Alexandria, VA: ATD Press. (2016). Available online at: https://d22bbllmj4tvv8.cloudfront.net/9b/64/10662ab3a4e3b469cdede8eb0d3b/111614-kirkpatricks-four-levels-of-training-evaluation-sample-chapter.pdf (accessed February 12, 2022).
7. Vega NG. *Factors Affecting Simulator-Training Effectiveness [Doctoral dissertation]*. Finland: University of Jyväskylä. (2002). Available from: https://www.researchgate.net/publication/34731287 (accessed February 12, 2022).
8. Arntfield R, Pace J, McLeod S, Granton J, Hegazy A, Lingard L. Focus transesophageal echocardiography for emergency physicians-description and results from simulation training of a structured four-view examination. *Crit Ultrasound J.* (2015) 7. doi: 10.1186/s13089-015-0027-3
9. Bernard A, Chemaly P, Dion F, Laribi S, Remerand F, Angoulvant D, et al. Evaluation of the efficacy of a self-training programme in focus cardiac ultrasound with simulator. *Arch Cardiovasc Dis.* (2019) 112:576–84. doi: 10.1016/j.acvd.2019.06.001
10. Beraud AS, Rizk NW, Pearl RG, Liang DH, Patterson AJ. Focused transthoracic echocardiography during critical care medicine training: curriculum implementation and evaluation of proficiency. *Crit Care Med.* (2013) 41:e179–81. doi: 10.1097/CCM.0b013e31828e9240
11. Hilton CE. The importance of pretesting questionnaires: a field research example of cognitive pretesting the exercise referral quality of life scale (ER-QLS). *Int J Soc Res Methodol.* (2015) 20:21–34. doi: 10.1080/13645579.2015.1091640

12. Khan K, Pattison T, Sherwood M. Simulation in medical education. *Med Teach.* (2010) 33:1–3. doi: 10.3109/0142159X.2010.519412
13. Haji F, Morin MP, Parker K. Rethinking programme evaluation in health professions education: beyond 'did it work'? *Med Educ.* (2013) 47:342–51. doi: 10.1111/medu.12091
14. Reeves ST, Finley AC, Skubas NJ, Swaminathan M, Whitley WS, Glas KE, et al. Basic perioperative transesophageal echocardiography examination: a consensus statement of the American Society of Echocardiography and the Society of Cardiovascular Anesthesiologists. *J Am Soc Echocardiogr.* (2013) 26:443–56. doi: 10.1016/j.echo.2013.02.015

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Advantages of publishing in Frontiers

OPEN ACCESS
Articles are free to read for greatest visibility and readership

FAST PUBLICATION
Around 90 days from submission to decision

HIGH QUALITY PEER-REVIEW
Rigorous, collaborative, and constructive peer-review

TRANSPARENT PEER-REVIEW
Editors and reviewers acknowledged by name on published articles

Frontiers
Avenue du Tribunal-Fédéral 34
1005 Lausanne | Switzerland

Visit us: www.frontiersin.org
Contact us: frontiersin.org/about/contact

REPRODUCIBILITY OF RESEARCH
Support open data and methods to enhance research reproducibility

DIGITAL PUBLISHING
Articles designed for optimal readership across devices

FOLLOW US
@frontiersin

IMPACT METRICS
Advanced article metrics track visibility across digital media

EXTENSIVE PROMOTION
Marketing and promotion of impactful research

LOOP RESEARCH NETWORK
Our network increases your article's readership