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Can drones be a solution for defibrillation and blood transfusions? A review on the impact of new technologies in emergency healthcare

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Life-threatening arrhythmias, shock and airway compromise represent the most crucial situations to treat in the daily routine of acute medicine. Rapid access to automated external defibrillators (AEDs) and other necessary equipment increases survival rates significantly. The unmanned aerial vehicles (UAV) appear to revolutionize prehospital medicine enabling advanced health care delivery to those in austere environments and difficult regions for both defibrillators and blood products (BP). Although there are still many factors to consider, drone networks show potential to greatly reduce lifesaving equipment travel times for those with cardiac arrest (CA). More research should be performed to fill the gaps in routine practice of operating drones in different clinical scenarios, and geographical variations. As far as delivery of BP via drones, key benefits are minimized risk to human life, cost, speed of delivery and ability to cover areas beyond those of conventional planes. Challenges can be airspace management of BP, decisions on appropriate level of care to deliver during transit and user acceptability. Appropriate integration of drones to ambulances and emergency medical services facilitates efforts to improve healthcare, particularly in difficult and underserved regions. In brief, indications of drone use should be individualized to deliver vital equipment and care to the victim in emergency need, while the effectivity of UAVs must be evaluated case by case basis. This article aims to review the current status of above-mentioned technology and pluses and minuses of UAVs used worldwide, along with future projections.

KEYWORDS

drone, unmanned aerial vehicles, defibrillation, blood products, transfusion, cardiac arrest, out-of-hospital cardiac arrest

Introduction

Time is probably the most critical resource in the whole concept of healthcare. Cardiac emergencies such as life-threatening arrhythmias, shock and airway compromise represent the most crucial situations in this context. Around 80,000 patients with out-of-hospital cardiac arrests (OHCA) are treated by English ambulance services every year (1). Likewise, around 350,000 patients suffer from OHCA in the US annually, with only 10% surviving from this event, despite innovations in emergency medical care (2). This survival rate is two-fold when a bystander defibrillates the patients and initiates cardiopulmonary resuscitation (CPR) before ambulances arrive (3).

Expedient initiation of 'high-quality CPR' composed of effective compression and defibrillation via automated external defibrillators (AEDs) is the life-saving intervention in patients with OHCA. Among these, early defibrillation is the most critical factor for survival. Emergent intervention using AED within three to 5 min following arrest situation can result in survival rates exceeding 50% (4). For every minute that passes following OHCA, the victim's survival probability is reduced by 7% to 10%, due to the inadequate blood flow to the brain (5). Lagging in access to high quality healthcare resources represents the worst scenario to decrease chances of survival in most emergency conditions. This timing issue is still the most vital constraint in managing OHCA.

The unmanned aerial vehicles (UAV) -also known as drones- appear to revolutionize prehospital medicine enabling advanced health care delivery to those in austere environments and difficult regions for both defibrillators and blood products (BP). Although primarily launched for the military, UAVs are nowadays used in a myriad of situations (6). UAVs have already been used to deliver aid packs to people affected by major disasters, since the 2010 earthquakes in Haiti, the 2012 hurricanes in the US, Canada, and Nepal (7).

Unmanned aerial systems which are composed of an operational network of UAVs encompasses successful integration of drones which appears to be a promising innovation in life-saving operations in many fields of medicine, including defibrillation and delivery of BP. Adopting this system has been reported to improve response times for some OHCA by avoiding ground barriers to care (8). Rapid access to AEDs increases survival rates significantly. Moreover, it can enable the system to provide AED and BP coverage for all residents in the target area.

Blood is also among the most vital but restricted resources of healthcare needs. All kinds of trauma cause the greatest share of transfusion needs, followed by anemia of different etiologies. Rapid delivery of various BPs can allow initiation of replacement of blood volume and some critical components of blood which can restore hemostasis.

Almost all countries have published data on key characteristics of OHCA. For example, young age at presentation, failure to achieve layperson CPR, and lagging emergency medical services (EMS) access time are the main properties in Riyadh, Saudi Arabia (9). This issue of long EMS response time is a factor to be curbed by faster interventions by UAVs, both for basic life support and replacement of BP. This review is designed to itemize practical questions and answers encountered in the routine practice and launched to enlighten global healthcare providers and the public using the most recent literature data.

Use of drones in EMS and transfer of blood products: why should drones be used for defibrillation?

Location of AEDs were criticized to be dispersed unrelated to needs of the population residing in the region. For example, in England the devices were reported to be disproportionately placed in more affluent areas, with a lower residential population density (10).

Drone networks are a promising potential to greatly decrease travel times of life-saving equipment for victims of OHCA (11). Ryan et al. (8) reported that at least 95% of the population could be covered by the ideal placements of drones within a given area.

Which other materials can be transported to improve EMS?

Other than AEDs, drones can improve the time interval to intervention through the rapid delivery of naloxone, resuscitative drugs, antiepileptics, and various BP (12).

How fast can drones operate?

Fischer et al. designed a field test trial with manikins as victims of OHCA in a difficult geography in Europe. Mean delivery times of the drones was 5.2 min. The paramedics applied the first shock after a mean of 12:1 ± 2:0 min (13). Mission times from alert to AED release were reported to be between 3:48 min and 11:20 min (14). In Rwanda, hospitals ordered blood and medicines via simple messages and received the BP using drones in 30 min (15).

Emergency response times can be curbed with the use of aerial cameras on UAVs for rapid evaluation of the scene. UAVs can improve ambulance response and provide faster arrival on scene for patient assessment and interventions (16). Studies employing OHCA simulations revealed that only 15 s to 39.7 s were spent to bring the AED to the victim after access to UAV, which indicates that bystander-drone interactions did not represent the critical maneuver in intervention using UAVs (17–19). Drones with a cruise speed of 70 km/h got to the simulated victims (median flight distance: 3.2 km) earlier than ground EMS in all patients with OHCA, which led to a median decrease in response time of 16 min and 39 s (20).

Is there a distance issue?

Flight distances ranged from ∼1–7 kms (14). In a simulation study, Baumgarten et al. (17) explored UAV-AED delivery combined with smartphone-based community first responders. Dispatch missions were flown autonomously but piloting was necessary for landing. Distances (km) and mean time periods from alert to defibrillation (min:sec ± standard deviation-SD) were 0.4 (6:0 ± 0:5), 2.29 (6:5 ± 0:2), 4.0 (8:5 ± 0:2), 7.43 (14:5 ± 1:05), and 9.8 (15:5 ± 1:2), respectively. All caregivers were able to retrieve the AED within seconds after UAV landing and all operations were interpreted as safe (17).

AEDs were delivered by drone to 12 real-life suspected OHCAs in Sweden, covering a distance of 5.3 km on average (21). Most of the flights (11/12) successfully dropped the AED by parachute within 9 meters of their target. Of these, 64% delivered the AED before ambulance arrival (mean time reduction: 1:52 min) (21).

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What is the utilization profile of the UAVs in the world?

Most American states take advantage of UAVs in EMS operations, especially in suburban areas (8). Likewise, most middle-income countries from Poland to Middle Eastern region have launched their systems integrated into EMS.

Differences between day- and night-time use

Operational and safety data indicate no major differences between day- and night-time use (14).

Differences between geographical characteristics for use of drones?

Geographical Information Systems (GIS) mapping is getting more widespread in routine practice in EMS utilizing UAV. Main issue to tackle is to identify "ideal" location placement plan for an estimate of total population covered by the system (8).

UAS have long been used for remote sensing and aerial imagery collection. Pulver et al. (11) found that using existing EMS stations to initiate UAVs resulted in 80.1% of OHCA cases being reached in 1 min (11). Using existing EMS and new targets led to more than 90% of the cases being achieved which also reduce total costs substantially.

Is UAS useful for delivering blood products?

Drones have long been utilized to transfer BP to any military locations in Afghanistan and defibrillators to those who are in emergency need in the USA and Sweden (22). There have been important advances in regard to expedite emergency delivery of BP to recipients in need of these products. In 2019, a private firm (Zipline) delivered more than one-fifth of Rwanda's blood supply in the rural areas (23).

In a pilot study, Amukele et al. (24) prepared and sent 6 red blood cell (RBC) and 6 apheresis platelet (PLT) units using sterile techniques. The units were placed in a cooler, attached to the UAV, and flown for up to 26.5 min with temperature records. There was no untoward effect of UAV on RBC, PLT, or temperature in BPs. The authors postulated that UAS transportation are a feasible alternative for the delivery of BPs. UAVs were used to transfer BP and drugs to certain institutions and remote areas in Rwandan cities (15). The devices navigated via the Global Positioning System (GPS). Hospitals ordered BP and medications with text messages and received the equipment in 30 min.

Peltier et al. investigated the post-delivery viability and hemostatic function of whole blood units (WBU), which were sampled for a preflight control and loaded onto a fixed-wing drone (25). Post-flight and preflight samples were studied for coagulation functions. They concluded that the use of UAVs for WBU delivery results in substantial benefits for EMS. As far as delivery of BP via drones, key benefits are minimized risk to human life, cost, speed of delivery and ability to cover areas beyond those of conventional planes. Challenges can be airspace management of BP, decisions on the necessary procedures to perform during transit and user acceptability.

Military health care missions offer a unique milieu and opportunities for critical medical interventions, such as delivery of BP or advanced airway equipment (26). These critical steps were reported to be associated with lower mortality in combat care. However, technical limitations such as fragility of components, short shelf life, and limited carrying capacity impair availability of these procedures (27, 28).

What are the current challenges to tackle?

Regulation, safety, flying conditions, privacy, consent and confidentiality, details surrounding the development, operation, and maintenance are among the challenges to enlarge the field of medical drones in EMS (16). Technological restraints include stability of flight, weight, flight range, the incorporation of machine learning, sensing of barriers and other aircraft, and landing procedures.

Discussion of literature data

Recent years witnessed emergence of *de novo* strategies for defibrillation easily accessible for public, including volunteer bystander and responder programs and AED-delivery by drones (29). Although many factors should be considered to improve quality of care in EMS, drone networks have the potential to minimize lifesaving equipment travel times for those with OHCA (11).

Drones donned with video surveillance may be useful in identification of drowning patients, which will allow lifeguards to rescue them and perform defibrillation and other resuscitative interventions much faster (6). Only a small percentage of people living in rural communities are able to get timely access high quality healthcare (30). Some researchers employed simulation-based programs to train laypersons on the operation of AEDs delivered by drones in rural and difficult regions (31).

A UAV was launched with a simulation scenario to train healthcare workers in AED operation and direct lay people in safe use with basic life support protocols (32). A literature review showed that different training methods yielded similar outcomes. The authors postulated that a comprehensive training program related to UAVs should include cognitive, affective, and psychomotor aspects, addressing different skills and knowledge areas (32).

In a simulation study to test the effectiveness of UAVs' delivery of AEDs to OHCA cases, Claesson et al. (33) used GIS models in urban and rural areas. They reported a prediction that UAVs would arrive faster than EMS in around one-third of urban OHCA cases (mean time saved: 1.5 min) and in 93% of rural OHCA cases (mean time saved: 19 min) (33).

These innovative approaches will allow healthcare providers to transport AEDs rapidly to the location of the patient in need of these interventions. These devices are utilized effectively for diagnosis, treatment, perioperative assessment, and the support for those on the scene, so it places their use on national and international agendas (34). Ongoing technological advancement of UAVs has already helped patients with OHCA, as the devices have shown superb potential to deliver AEDs expediently (35). Finally, the effectivity of UAVs must be individualized to deliver vital equipment and care to the victim in emergency need.

Some important analyses should be performed to design the future of the operations of UAVs. Planning of service cooperation, dividing the region into parts, risk evaluation, and legal framework for the operations is needed to incorporate the UAVs in the healthcare system and EMS (36). Many industrialized countries have strict legislations for UAVs, whereas different regulations apply to various classes of the drones, mainly related to their weights. The operators need to issue appropriate licensure before flying a vehicle, if it is above certain limits of weights. A flight plan has to be prepared for the heavy drones, while certain flight height/place restrictions also exist (UAVs cannot fly close to airports, crowded places, etc.) (37).

Balasingam et al. (38) reminded that the efficacy of UAVs depends on the individual to rescue the patient. A sufficient discussion on the ethical, legal, environmental, and clinical issues should be completed prior to widespread use of drones in medicine (6). Current Federal Aviation Administration (FAA) guidelines on drones are very strict. In brief, legal regulations can boost or hamper the developments related to UAVs throughout the world.

Potential drawbacks of UAVs in practice

Future challenges of drones and UAVs include user-dependent performance of AEDs and other resources transported to the point of care, inability to transport specialized personnel to the site together with the devices, probable technical complications of transport, standardization problems and difficulties regarding the follow-up of the procedures. In addition, variations in weather conditions and technical capabilities of the devices can also pose different risks and drawbacks (39).

Conclusion

UAVs can enable the system to provide AED and BP coverage for all residents in the target area. The utilization and efficacy of UAVs should be gauged both for the individual in emergency need and also for the rescuer or practitioner who will deliver help to the ill or injured. Appropriate integration of drones to EMS facilitates efforts to improve healthcare, particularly in austere and underserved regions. Legal regulations should be used to establish a framework for the developments related to UAVs in countries, without overlooking the specific needs of the regions throughout the world.

Author contributions

CA: Conceptualization, Data curation, Resources, Validation, Visualization, Writing – review & editing. NS: Data curation, Formal analysis, Resources, Supervision, Validation, Visualization, Writing – original draft. OK: Investigation, Methodology, Validation, Writing – original draft, Writing – review & editing.

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