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Remote antemortem inspection at slaughter in Sweden

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Domesticated and farmed animals that are slaughtered commercially for human consumption undergo antemortem inspections (AMIs) by official veterinarians to comply with the legislation of the European Union. Small-capacity abattoirs and game-handling establishments are often located in remote areas and have high resource demand for onsite control. This study aimed to study the feasibility of remote AMIs performed by veterinarian raters with limited prior experience in AMI and to evaluate the user experiences assessed by raters having lifelong experience with digital devices in their daily lives. The present study was performed over 4 d (18 sessions) at a large-capacity abattoir slaughtering pigs and another 4 d (four sessions) at a small-capacity abattoir slaughtering cattle and sheep. The interrater variability between two raters (one technical support person conducting onsite AMI and one remote rater conducting remote AMI over a live video feed) was assessed, and the raters scored their user experiences for each session. A total of 4,032 pigs, 39 cattle, and 10 sheep were inspected over the 22 sessions. We observed high levels of overall agreement (99.4%), Cohen's kappa (0.920; 95% confidence interval (CI): 0.888–0.953), and prevalence- and bias-adjusted kappa (0.989; 95% CI: 0.983–0.993) between the onsite and remote AMIs for the large-capacity abattoir. These results were also supported by the McNemar test ($\chi^2 = 0.375$; df = 1; $p = 0.54$). The sample size at the small-capacity abattoir was low (N = 49), and marginal rating frequencies were different, for which the Fisher's exact test showed statistical differences ($p < 0.001$) between the onsite and remote AMI results. The average user experience scores for all categories were rated as satisfactory or better. Consequently, remote AMI is a feasible and flexible option for official meat inspections in slaughter, provided the inspectors are trained and aligned in their assessments of AMI findings.

KEYWORDS

animal health, animal welfare, control flexibility, digitalized control, domestic animals, food safety, meat inspection, modernized meat control

1 Introduction

Effective official control at abattoirs and game-handling establishments (GHEs) support safe food production practices through focus on food safety, animal health, and animal welfare. Official control measures in commercial food chain supply are highly regulated (EU, 2017) and require considerable resources. In this sense, new and modernized control methods need to be developed to enhance sustainability. Small-scale food production provides opportunities when living in rural areas. Small-capacity slaughterhouses are expected to provide sustainable solutions in accordance with Sweden's National Food Strategy (Government Offices of Sweden, 2017) and are significant for improving Sweden's resilience through a higher degree of self-sufficiency (SOU, 2015; SOU, 2022; SOU, 2024).

Small-capacity slaughterhouses and GHEs handling less than 1,000 livestock units (LUs) annually represented 81% of the approved establishments but accounted for only approximately 2% of the total red meat produced in Sweden in 2024 (pers. comm. AH Kautto; SCB, 2025). The cost of meat inspection (MI) at these smaller establishments is higher than that required for larger establishments when measured in terms of SEK per kilogram of produced meat (Almqvist et al., 2021; Kautto and Comin, 2023). However, small-capacity slaughterhouses could work in harmony with farmers to improve animal welfare by decreasing the transportation distance between the farm and abattoir as well as reducing the need to house animals overnight (Hultgren et al., 2016). In addition, this allows reducing the transport time to the end-consumer, thereby increasing accessibility to locally produced food (Kautto and Comin, 2023).

Official control of slaughter and game-handling in Sweden is in accordance with the regulations of the European Union (EU, 2017; EU, 2019a; EU, 2019b) and is complemented by national control instructions (Swedish Food Agency, 2024) in approved abattoirs and GHEs. All domesticated animals and farmed game require inspection by an official veterinarian (OV) employed by a competent authority (CA), which in our case is the Swedish Food Agency (SFA), before slaughter to ensure food safety, animal health, and animal welfare (SFS, 2018; SFS, 2019).

MI requires the presence of official onsite staff, which entails costs for the food business operator (FBO). Additionally, staffing these statutory inspection areas that are often located far from the office of the CA can be challenging, especially when considering the logistics of several different hurdles.

Thus, the aim of the present study was to determine the feasibility of remote antemortem inspections (AMIs) performed by veterinarian raters with limited prior experience in official antemortem control, along with evaluation of the impacts of various conditions on the user experiences of the raters having lifelong experience with digital devices in their daily lives, studies, and work.

2 Materials and methods

2.1 Study sites

A comparative study was conducted at two separate abattoirs during the autumn of 2024. The first was a large-capacity abattoir for pigs that processed more than 2,000 animals daily and was selected to achieve a sufficient sample size. The second was a small-capacity abattoir for cattle and sheep that processed approximately 15–30 animals daily and was selected to mimic the conditions under which the proposed method is intended to be used in the future.

At the large-capacity abattoir, the pigs were transported in from several primary producers via approved animal transport. The small-capacity abattoir was owned by a primary producer slaughtering their own animals as well as animals from other primary producers nearby; this establishment was visited at least once and mostly twice per day by control staff from the official control office situated approximately 100 kilometers away.

2.2 AMIs

The AMIs were performed by two veterinarian students about to complete their studies at the Swedish University of Agricultural Sciences. The use of digital devices has been a natural part of their daily lives since an early age. Prior to starting the study, the students attended a seminar on official MI organized by the SFA as well as a 2-day training session at a large-capacity abattoir separately from the establishments involved in the study. During each session, one student conducted an onsite AMI as a technical support person (TSP) while the other student conducted a remote AMI as a remote official veterinarian (R-OV).

The AMIs were conducted in the lairage pens in both abattoirs through a two-way remote video connection. Onsite by the lairage pen, the TSP carried a smartphone mounted on the back of their hand and connected to a wireless headset. This smartphone was used to relay video and verbal information about the animals to the R-OV, who could in turn give verbal commands to the TSP. During each session, the animals were assessed for welfare, health, and cleanliness according to the guidelines of the Swedish Board of Agriculture (SBA, 2024) and internal instructions of the SFA. All possible findings (anatomical, physical, and infectious abnormalities) covering all animal species in slaughter and game handling are listed in these documents. The ID marking and food chain information (FCI) of the animals were also assessed for possible non-compliances.

The TSP performed the AMI according to the routine instructions for the OV; they also filmed the animals from accessible angles during unloading and in the pens to mimic the procedures of the OV. Then, the TSP showed the animals again, varied the video angles, moved closer to the animals, or answered any questions from the R-OV. To avoid influencing each other's findings, all communications during the sessions were strictly as per the instructions for aiming the camera so that the R-OV could conduct their inspection. In the event of any issues with the internet connection, the TSP and R-OV were advised to wait few minutes before continuing the AMI.

A crossover design was used to increase vigilance and reduce the impact of the students' user experiences on the measured data. The assessments were conducted in continuous sessions at time points aligned with the abattoir's flow of incoming animals. The roles of the TSP and R-OV were alternated between sessions so that each student spent the same amount of time in both roles. However, for some cases at the larger abattoir, the duration of a session was extended to facilitate inspection of a transport during arrival to the lairage pens.

Each student was assigned to a numbered role of either TSP or R-OV; for instance, student number one was designated as TSP 1 or R-OV 1, and student number two was identified as TSP 2 or R-OV 2.

2.3 Technical devices

The communication device used by each student was a Samsung Galaxy S9+ smartphone (Samsung Inc., Seoul, South Korea) running Android version 8.0.0 (Alphabet Inc., Mountain View, California, United States) and connected over wireless local area network (WLAN) to a local area network (LAN). The receiving terminal was a Lenovo ThinkPad X1 Carbon PC running Windows 10 (Microsoft Corp., Redmond, Washington, United States). At the larger abattoir, the receiving terminal was connected via ethernet to the same LAN as the smartphone. At the small-capacity abattoir, the receiving terminal was connected over WLAN to one LAN, and the smartphone was connected via WLAN to another LAN. The software used for video transmission was Microsoft Teams (2024 version).

During each session, the illuminance was measured at the place of the AMI using a Light Meter MT-906 (Clas Ohlson AB, Insjön, Sweden).

2.4 Sampling

Finishing pigs, sows, and a single boar were observed at the large-capacity abattoir between 8 and 11 October 2024. The animals were observed during offloading from the transport vehicles into the pens or when moving around in the pens, while the TSP stood just outside or above the pen.

At the small-capacity abattoir, the cattle and sheep were inspected between 14 and 17 October 2024. The AMIs were conducted with small groups of animals, with the TSP inspecting and filming from outside the lairage pens. The group sizes varied among the individual pens from groups of five cattle or up to ten sheep in one pen.

2.5 Data collection

After each inspection session, any non-compliances with the guidelines of the SBA and SFA used in routine MI were registered, along with the total number of animals inspected during the session. Both the TSP and R-OV registered their findings separately.

The finding categories for the pigs were as follows: non-defined tail injury, inflamed tail injuries, healed tail injuries with <50% of the total tail length remaining, abdominal hernias >30 cm in length, severe lameness (grade 4–5), and sickness with systemic symptoms (animal is rejected for slaughter in this case).

For the cattle and sheep, the categories were as follows: lack of FCI, excessive manure contamination (posing a threat to hygiene during the slaughtering process), long hooves, and severe lameness (grade 4–5).

Additionally, data from the postmortem inspections (PMIs) conducted by the SFA were collected at the small-capacity abattoir to facilitate cross-referencing for any non-compliances overlooked during project AMIs.

In addition to the above findings, both the TSP and R-OV (the role in session) scored their user experiences for the following set of categories:

- experienced internet quality,
- lighting at the place of AMI,
- facilities at the place of AMI, and
- experienced ability to communicate and quality of the streamed video and audio.

These categories were graded on a scale as follows: 1 = good, 2 = less good, 3 = satisfactory, 4 = less satisfactory, 5 = not satisfactory, and 6 = non-existent.

2.6 Statistical analysis

The AMI results of the TSP and R-OV were compared with each other along with any total condemnations at the small-capacity abattoir. Descriptive statistics like the overall agreement, Cohen's kappa (Cohen, 1960), prevalence- and bias-adjusted kappa (PABAK) (Byrt et al., 1993), and McNemar's chi-squared test (McNemar, 1947) were used to present and analyze the data. Cohen's kappa and PABAK were not calculated for the results from the small-capacity abattoir because of the low sample sizes and differences in true marginal rating frequencies (Bujang and Baharum, 2017).

For results based on low numbers of observations (<5 per cell) at the small-capacity abattoir, we used the Fisher's exact test for count data (Fisher, 1970). The user experience scores were determined as the mean values per category and per role for the large-capacity abattoir. The software used to analyze the data was R® (R Core Team version 4.4.3) along with the packages epiR (Cohen's kappa and PABAK) (Stevenson et al., 2023) and "stats" (McNemar's chi-squared and Fisher's exact tests).

3 Results

3.1 Samples

Each data point was from a single animal. A total of 4,032 pigs were observed at the large-capacity abattoir, while 49 cattle and sheep were observed at the small-capacity abattoir. The number of animals in each category and abattoir examined by each pair of students is presented in Table 1.

The TSP 1 and R-OV 2 examined a total of 2,286 animals, whereas TSP 2 and R-OV 1 examined 1,795 animals. Furthermore, a total of 18 sessions were conducted over 4 d at the large-capacity abattoir, while four sessions were conducted over 4 d at the small-capacity abattoir.

3.2 Findings

The non-compliances registered at the large-capacity abattoir by each role (TSP 1, R-OV 2, TSP 2, and R-OV 1) are presented in Table 2. Most of these non-compliances were related to tail injuries, while the other categories of non-compliances were scarce. During the first nine sessions where non-specific tail injuries was the only category examined, we noted non-compliance in 2,044 pigs of the total 4,032, which included 34 of the 62 sows. The only finding of a sick animal that was rejected for slaughter (shown in Table 2) was a sow in a lairage pen that had previously been inspected during unloading with no observed remarks.

The non-compliances registered during the four sessions at the small-capacity abattoir are presented in Table 3. The total number of

TABLE 1 Numbers of different animals assessed at the small-capacity and large-capacity abattoirs by each pair of technical support person (TSP) and remote official veterinarian (R-OV) combination with settings TSP 1 + R-OV 2 and TSP 2 + R-OV 1.

Animal group	Small-capacity abattoir	Large-capacity abattoir	TSP 1 + R-OV 2	TSP 2 + R-OV 1
Finishing pigs	0	3,969	2,221	1,748
Sows	0	62	30	32
Boars	0	1	0	1
Cattle	39	0	35	4
Sheep	10	0	0	10
Total	49	4,032	2,286	1,795

TABLE 2 Non-compliances registered at the large-capacity abattoir by the technical support persons 1 and 2 (TSP 1 and TSP 2) as well as remote official veterinarians 1 and 2 (R-OV 1 and R-OV 2).

Non-compliance	TSP 1	R-OV 2	TSP 2	R-OV 1
Non-defined tail injury	45	37	47	42
Inflamed tail injury	7	11	15	18
Healed tail injury with <50% of total length missing	16	20	16	12
Abdominal hernia >30 cm	1	1	1	2
Severe lameness (grade 4–5)	2	1	2	2
Sickness with systemic impact (animals are rejected for slaughter)	0	1	0	0

TABLE 3 Non-compliances registered at the small-capacity abattoir by the technical support persons 1 and 2 (TSP 1 and TSP 2) as well as remote official veterinarians 1 and 2 (R-OV 1 and R-OV 2).

Non-compliance	TSP 1	R-OV 2	TSP 2	R-OV 1
Lack of FCI	0	0	0	0
Excessive manure contamination	1	1	0	0
Long hooves	4	3	0	0
Severe lameness (grades 4–5)	2	2	0	0

TABLE 4 Summary of non-compliances documented by the remote official veterinarian (R-OV +) and technical support person (TSP +) as well as absence of non-compliances according to the remote official veterinarian (R-OV −) and technical support person (TSP −) at the large-capacity abattoir.

	R-OV +	R-OV −	Sum
TSP +	138	13	151
TSP −	10	3,871	3,881
Sum	148	3,884	4,032

TABLE 5 Summary of non-compliances documented by the remote official veterinarian (R-OV +) and technical support person (TSP +) as well as absence of non-compliances according to remote official veterinarian (R-OV −) and technical support person (TSP −) at the small-capacity abattoir.

	R-OV +	R-OV −	Sum
TSP +	6	1	7
TSP −	0	42	42
Sum	6	43	49

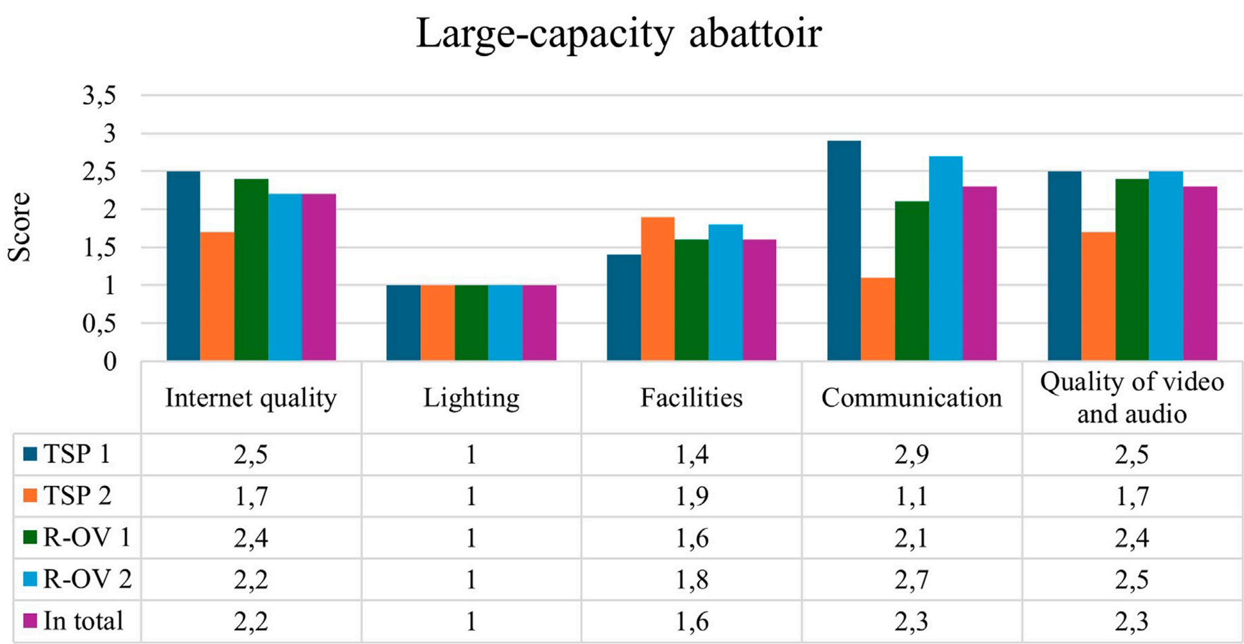
animals observed at this abattoir was significantly lower than that at the large-capacity abattoir, as noted in Table 1.

In three of the four total sessions at this abattoir, the pair TSP 1 and R-OV 2 conducted the AMIs, whereas TSP 2 and R-OV 1 only performed AMI during one session.

There was one report on animal welfare that was sent to the county administrative board (CAB) from the large abattoir and none from the small-capacity abattoir for non-compliance, as filed by the onsite OV during data collection. Additionally, comparing the results of the PMI on the animals to the AMI project, there were no registered PMI findings that should have been apparent during the AMIs.

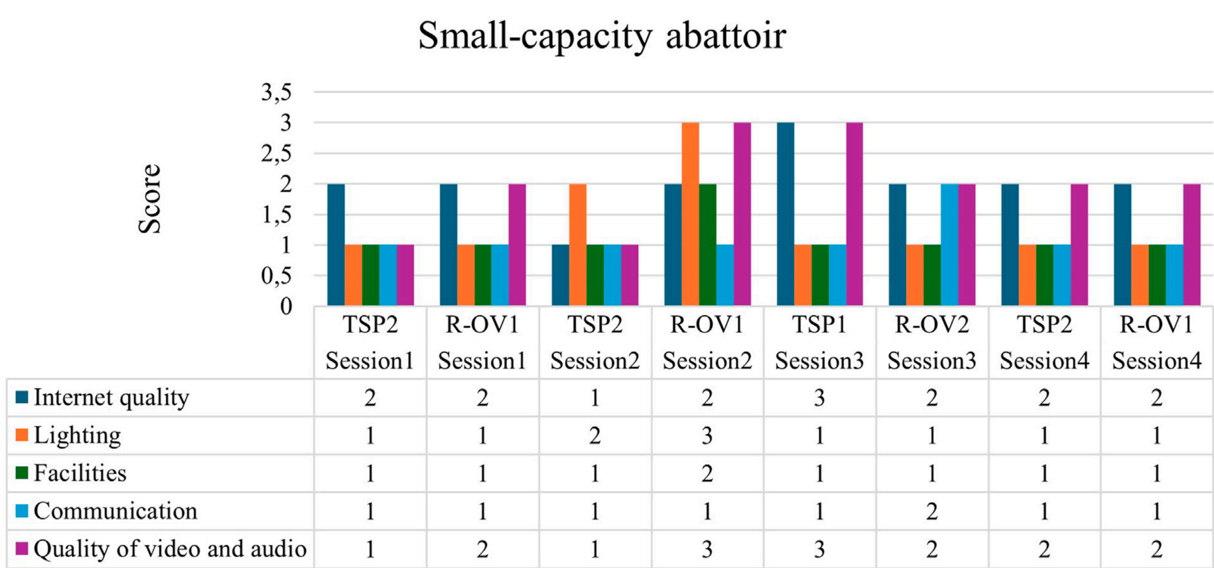
Overall, the agreement between the R-OV and TSP at the large-capacity abattoir was 99.4%, Cohen's kappa was 0.92 (95% confidence interval (CI): 0.89–0.95), and PABAK was 0.989 (95% CI: 0.982–0.993); the McNemar's chi-squared test with continuity correction produced results of $\chi^2 = 0.174$, $p = 0.677$, and df = 1, which shows that there was no statistical significance (Table 4).

Fisher's exact test showed a statistical difference between the raters ($p = 0.000013$, 95% CI: 16.9–∞), as shown in Table 5.



	Internet quality	Lighting	Facilities	Communication	Quality of video and audio
TSP 1	2,5	1	1,4	2,9	2,5
TSP 2	1,7	1	1,9	1,1	1,7
R-OV 1	2,4	1	1,6	2,1	2,4
R-OV 2	2,2	1	1,8	2,7	2,5
In total	2,2	1	1,6	2,3	2,3

FIGURE 1
Arithmetic means of the user-rated conditions at the large-capacity abattoir as well as by category and role, where 1 = good, 2 = less good, 3 = satisfactory, 4 = less satisfactory, 5 = not satisfactory, and 6 = non-existent. TSP 1 and TSP 2 = technical support persons 1 and 2; R-OV 1 and R-OV 2 = remote official veterinarians 1 and 2.



	TSP2 Session1	R-OV1 Session1	TSP2 Session2	R-OV1 Session2	TSP1 Session3	R-OV2 Session3	TSP2 Session4	R-OV1 Session4
Internet quality	2	2	1	2	3	2	2	2
Lighting	1	1	2	3	1	1	1	1
Facilities	1	1	1	2	1	1	1	1
Communication	1	1	1	1	1	2	1	1
Quality of video and audio	1	2	1	3	3	2	2	2

FIGURE 2
Users' ratings of the conditions at the small-capacity abattoir by category and role for each of the four sessions, where 1 = good, 2 = less good, 3 = satisfactory, 4 = less satisfactory, 5 = not satisfactory, and 6 = non-existent. TSP 1 and TSP 2 = technical support persons 1 and 2; R-OV 1 and R-OV 2 = remote official veterinarians 1 and 2.

3.3 User experiences

The users' experiences were measured for all 18 sessions at the large-capacity abattoir and four sessions at the small-capacity abattoir. The average of each user's scoring of their experiences during the sessions at the large-capacity abattoir is illustrated by category in Figure 1. The results for the four sessions at the small-capacity abattoir are visually presented in Figure 2.

Additionally, during these sessions, the illuminance at the place of AMI was measured using a luxmeter. At the large-capacity abattoir, the average illuminance was 229 lux, with the lowest measurement being 85 lux and highest being 360 lux for the

15 sessions included. At the small-capacity abattoir, the average illuminances were 350, 450, and 600 lux during the three sessions in which measurements were obtained.

The median experience score for lighting and facilities was 1 (good); for internet quality, communication, and quality of video and audio, the median experience score was 2 (less good).

4 Discussion

The primary responsibilities for food safety, animal welfare, and animal health are vested with the FBO, while the MI is an official control procedure that must be performed by official control personnel. The official controls should be risk based and consider all identified risks, such as the FBO's past records and more (EU, 2017). All domesticated and farmed animals intended for slaughter for human consumption must be subjected to AMIs within 24 h of arrival at the slaughterhouse and also less than 24 h before slaughter (EU, 2019b). Although the regulation (EU) 2019/624 (EU, 2019a) describes some limited circumstances in which AMIs may be performed by personnel other than OVs, the OV must be available to conduct the AMI in person in the majority of the cases. The OV is always responsible for the AMI even if they are supported by the official auxiliary (OA).

These regulations have been enforced since January 2006, when there was less focus on climate change, less reliable food value chains, no experience of a pandemic, or the current turmoil with war, hybrid warfare, and political unrest in Europe. Remote AMIs could increase the resiliency of European food production as well as decrease the environmental impacts and economic costs associated with official controls in the meat value chain (Almqvist, 2021). The present study suggests that remote AMIs can be implemented without compromising food safety or animal health and welfare.

The advantages of remote approaches in clinical animal medicine have been documented as the most preferred choices for customers experiencing hurdles with being located remotely (Oxley and Saunders, 2015). During the COVID-19 pandemic, the use of remote human medical consultations increased even as the user experiences and Internet or mobile net access were the biggest hurdles for good service (Gareev et al., 2021). Official controls and other official activities were exceptionally possible through the available means of distance communication (EU, 2020); this possibility ended on the first day of September 2021 and was never allowed to be used for MI.

4.1 Performance of remote AMI

The present study shows a high level of overall agreement (99.4%) between the findings of the onsite inspector and results of remote MI at the large-capacity abattoir; this is also reflected in the Cohen's kappa of 0.920, meaning almost perfect interrater reliability (McHugh, 2012). Additionally, an almost perfect PABAK value was observed (0.989), suggesting that remote AMIs according to our proposed model may be feasible alternatives to onsite AMIs. The McNemar's chi-squared test with continuity correction also supports that the proposed methods, remote AMI, and onsite AMI are equally reliable for performing AMIs.

At the small-capacity abattoir, the small sample size and scarcity of the non-compliances recorded together with large differences in the marginal rating frequences limited our ability to compare the onsite results with the remote assessments. Here, non-compliances were found with respect to long hooves, lameness, and manure contamination. Assessments of these non-compliances were noted by the inspectors as being subjective. In fact, interrater variability is present in all MI efforts while some non-compliances are more consistently assessed than others (Almqvist et al., 2021; Comin et al., 2023; Kautto and Comin, 2023; Kautto et al., 2023). Variability in professional assessments is both in terms of bias (i.e., average error in judgment) and noise (i.e., variability of error in judgment), and the level of objectivity is connected to the grade of noise (Kahneman et al., 2021).

The majority of animals arriving for slaughter are healthy, as expected according to the regulations (EU, 2004). However, there is a level of tolerance for certain non-compliances, e.g., tail injuries or length of hooves. Animals with fresh wounds that are still bleeding are deemed unfit for transport to the abattoir. However, an animal with an inflamed tail that has healed and is not bleeding is considered fit for transportation with a group of other animals.

There are very few documented non-compliances in the official MIs performed by the onsite veterinarians in both the large-capacity and small-capacity abattoirs, meaning that there are insufficient data for comparison between the project results and officially documented results.

4.2 User experience of remote AMI

User experience is defined as "the experience of someone using a product, system, or service, for example whether they find it enjoyable and easy to use" (Cambridge University Press and Assessment, 2024). In the present study, the raters scored their user experiences for a set of categories. The average score for each category was never less than satisfactory (3.00). There was one session at the large-capacity abattoir for which the internet, video, and audio qualities were scored as unsatisfactory (5.00).

Internet quality was the third most commonly mentioned technological challenge in the qualitative survey concerning the remote MI conducted by Hunka et al. (2024). Furthermore, in a survey by Daniel et al. (2024), connectivity was considered most important by 18.46% of the respondents. In our study, the internet quality score fluctuated more at the large-capacity abattoir than the small-capacity abattoir. In general, the TSP tended to be more satisfied with the internet quality than the R-OV; this trend was observed at both abattoirs and could be attributed to the TSP being focused on observing the animals rather than the video feed, since they also functioned as an onsite inspector. Although the scores at one point were unsatisfactory according to the R-OV, they did not report fewer observations of non-compliances than the TSP during that session; the R-OV for this session (R-OV 1) also did not feel that the conditions hampered them from performing the AMI.

Internet quality has a direct impact on the perceived quality of the video and audio during remote AMI. In our study, there is a clear correlation between the two, and a perceived poor internet quality can be observed in the rater giving poor scores to their perception of the quality of video and audio. The common issues with video and audio feed included dropped frames, stuttering, pixelation, and audio compression. This resulted in the R-OV having less time to make their assessment of each animal, especially at the large-capacity abattoir where many observations were made at the point of unloading. However, this issue is not reflected in the overall agreement between the TSP and R-OV in sessions where the R-OV was less content with the quality of the internet, video, or audio. This could be explained by the manner in which the TSP and R-OV chose to manage instances with poor video or audio quality. In some cases, mild disruptions dissipated without intervention; in other cases, the position of inspection was simply adjusted slightly until an acceptable level of quality was regained, meaning that the dissatisfaction scores should be interpreted as a session in which multiple adjustments had to be made rather than a session in which the quality of the video and audio was continuously unsatisfactory. This was possible due to the working interpersonal communication.

Communication, specifically regarding the assistance of the abattoir staff, has been noted by the OVs as an issue that might affect remote AMI (Hunka et al., 2024). Communication may also be affected by the internet and audio qualities. However, there was no predetermined definition of communication for the raters during data collection, which could have led to a possible disconnect between the two raters when scoring this category. One interpretation of good communication is having no technical disturbances during the session, i.e., audio corruption, stuttering, or noise, whereas an alternative interpretation is how well the TSP was able to respond to verbal cues from the R-OV or *vice versa*, i.e., good interpersonal communication. During this project, environmental noise was never a hurdle for communication at the place of inspection. It is important to note that the quantitative study by Daniel et al. (2024) showed the lower importance of oral communication between the R-OV and TSP during remote MI.

In the study by Hunka et al. (2024), inadequate facilities were noted as a potential limitation of remote AMI, where the majority of the interviewed OVs described having to rely on their own "creative solutions" to adapt to existing conditions at abattoirs, i.e., having to jump walls or fences. Another concern mentioned was the inadequate space and coverage of pens, which could obstruct the performance of remote AMI. In our study, similar to communication, there was no clear predetermined definition of facilities for the two raters. Nevertheless, the scores for this category were good (1.00), indicating that no key issues were perceived by the raters during this project. However, there were a few sessions where observations were not possible during unloading, meaning that the TSP was walking above or between the lairage pens during the remote AMI; the scores for these sessions were satisfactory (3.00) or less than satisfactory (4.00). Additionally, there were instances where the TSP had to change their location during AMI to avoid adversely affecting the willingness of the animals to be herded into the lairage pens. Still, both raters perceived that they were able to conduct the AMIs despite these conditions.

Good lighting has been highlighted as an important factor in remote AMI (Kautto et al., 2023). Furthermore, in the survey by Hunka et al. (2024), the interviewed OVs mentioned poor lighting conditions as one of the main technical issues in conducting remote AMI. Contrary to these concerns, neither the lighting nor illuminance was perceived as obstructive by the raters during the entirety of our project's data collection efforts. Both the perceived quality of lighting as well as measured illuminance at the spot of AMI were recorded. The scores for this category were by far the most unanimous. In 20 of 21 sessions, including all sessions at the large-capacity abattoir, both raters scored their perceived lighting conditions as good (1.00). In one session at the small-capacity abattoir, the lighting was scored as less good (2.00, TSP) and satisfactory (3.00, R-OV); this was the only session in which there was a perceived issue with backlighting. However, this was not perceived as an obstruction to conducting AMI.

Overall, during the entirety of this project, the conditions were perceived to be adequate as well as non-obstructive. At these abattoirs, given the equipment used in this study, the raters considered their user experiences to be suitable for performing remote AMI.

There are inherent challenges in remote MI with regard to the internet or mobile net quality (Kautto et al., 2023). Implementation of remote MI therefore presumes that there are possibilities for the OVs to be able to travel to the inspection premises whenever needed.

4.3 Working environment, emissions, and food waste

The possible benefits associated with the working environment for implementing remote AMI in remote locations compared to the current practices with an onsite OV were explored by Hunka et al. (2024). Remote AMIs could enable more centralized official control with fewer OVs at a given office. The opportunity to obtain second opinions for assessments could mitigate interrater variability by calibration of the OVs, including training of new OVs who have only started performing MIs. Improvements to the working environment are closely linked with improved consistency and effectiveness of official control through better "decision hygiene." The reduced travel time for the OVs could be considered as an improvement to the working environment too; reducing the travel time for the OVs would further increase the effectiveness of official control, resulting in more efficient use of resources and possible reductions to the official control costs for the SFA. Additionally, using remote AMI means that an OV can be easily supported by another OV with only a short waiting time (Hunka et al., 2024). This is of great significance, especially in remote locations, where the replacement of control personnel could cause consequential delays in production since the slaughter cannot commence without AMIs completed with satisfactory results. This could help the present situation, where the perceived irreplaceability of OVs can result in reluctance to appropriately call in sick. Remote AMIs could further help reduce travel-based emissions (Kautto et al., 2023).

It has been shown that the on-farm mortality rates of dairy cattle have increased since the 1990s (Compton et al., 2017). Although the reason behind this increase is not fully understood, remote AMIs could be useful tool for judging the suitability of slaughtering these animals for human consumption. Currently, domestic and farmed animals in commercial slaughter can only be approved for human consumption if the animals have undergone AMIs by OVs prior to emergency slaughter (EU, 2004). However, animal welfare is the number one priority, and it can be logistically difficult to ensure that the AMIs are completed, resulting in potential food wastes and economic losses for the primary producer. Additionally, slaughter of domestic animals at the holding of provenance, farmed game at the place of origin, and emergency slaughter could be equally facilitated using remote AMIs under certain well-defined conditions, ensuring positive economic ramifications for primary producers and authorities.

4.4 Limitations and improvements

One of the main limitations of this study was the small sample size from the small-capacity abattoir. Additionally, all animals observed at the smaller abattoir were reared by the same primary producer with high standards of animal health and welfare, which resulted in very few registered non-compliances. The numbers and fractions of non-compliances were very small, which could further skew the overall agreement toward near-perfect (100%) and contribute to high values for both Cohen's kappa and PABAK, along with narrow CIs. Furthermore, certain non-compliances are seasonal in nature, which could further contribute to the low number of registered non-compliances.

Another limitation of this study is that both raters had limited experiences in the role of OV, which could have skewed the gathered data. This further implies that it may not be reasonable for one of the raters, namely, the TSP conducting the AMI in person, to always be performing at the gold standard of AMI, so there would be no such standard to compare against the results of the R-OV's AMI. Moreover, there were no detailed comparative data from the SFA OV's AMIs. This was attributable to the sparse number of registered non-compliances, which could lead to inability to evaluate the impacts of poor conditions on the performance of remote AMI.

Future studies would then have to include a secondary video feed from a fixed camera mounted at a different viewing angle than the TSP's body-mounted camera, as suggested by Hunka et al. (2024), which could assist the R-OV in assessing the animals from many angles as well as compensate somewhat for the inability to follow an animal with one's gaze.

The use of 4K video streams instead of 2K could theoretically provide more detailed images with higher quality for the R-OVs. However, 4K video necessitates four times the bandwidth, and achieving smooth transmission would mean that the image would likely need to be compressed to such an extent where the color accuracy and overall quality would be diminished. Furthermore, without the use of 4K monitors at the receiving end, this quality increase would be less significant. Since remote inspections are carried out in real time, if higher quality is desired, the R-OV can always ask the TSP for a closer view rather than relying on higher resolution for magnification. As such, 4K video does not have enough benefits at this time to outweigh the potential downsides.

To The use of other spectral wavelengths like the infrared band in fixed camera images could support remote AMIs in the case of inflammation, e.g., bruise detection (Roy et al., 2019), when calibrated to measure the difference between normal body temperature and local or general elevated temperature on an animal.

Lastly, further studies and follow-ups of possible implemented remote AMIs would allow data collection throughout the year with greater sample sizes from multiple raters at several abattoirs of varying low capacities. This approach with a larger sample size could even enable analysis through modeling, e.g., by latent class analysis (Hui and Walter, 1980). If remote AMIs could be used in emergency slaughter of animals at the holding of provenance, a predictive model could be developed by including data related to the actual primary FBO. This risk-based procedure could meet the legal demands of efficiency and accuracy of the official control performed by the CA in all kinds of slaughter and game handling.

To support further developments at both the EU and national level, a professional cost–benefit analysis could be performed on the economic and environmental indicators of the implementation and performance of remote MIs.

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

Ethical approval was not required for the study involving animals in accordance with the local legislation and institutional requirements. The animals involved in this study were a part of a normal slaughter flow and observed by official veterinarians during routine antemortem inspections. The animals were not harmed during the study.

Author contributions

EH: data curation, formal analysis, investigation, visualization, writing – original draft, writing – review and editing. IM: methodology, project administration, resources, writing – review and editing. VA: methodology, writing – review and editing. SB: methodology, validation, writing – review and editing. IV: methodology, supervision, validation, writing – review and editing. RÖ: data curation, writing – review and editing. AK: conceptualization, formal analysis, funding acquisition, methodology, project administration, resources, software, supervision, visualization, writing – original draft, writing – review and editing.

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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.

Generative AI statement

The author(s) declare that no Generative AI was used in the creation of this manuscript.

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