Short Communication

A Pilot Study Using Remote Digital Necropsy Images to Diagnose Gross Lesions in Swedish Cattle

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Abstract | Remote digital necropsy (RDN) in cattle is a systematic method of post mortem diagnostic remotely, with the aim of increasing knowledge about deaths. The method is based on a standardized, systematic approach to opening and photo documenting dead cattle on farm. Images are sent to a bovine practitioner, experienced in interpreting gross lesions, for analysis. In this pilot study, education and training sessions on the RDN method were administered to veterinarians. After the training sessions, the participants performed 15 RDNs. Subsequently, interviews were conducted with 10 participants to capture their experiences and views on using the RDN method. In many of the necropsied animals, the RDN diagnosis matched well with the on-site veterinarian's observations. The participants expressed a great interest in developing and obtaining more skills in performing on-farm necropsies. This pilot study identified several challenges with the RDN and these need to be considered before implementing this service for Swedish cattle farms. The pilot study also showed that the RDN method could be a good complement to the regular post-mortem examinations and that it is possible to use the RDN in Sweden to determine a gross diagnosis of the cause of death of cattle, with subsequent increased disease surveillance.

Keywords | Cause of death, Digital pathology, Necropsy, Off-site evaluation, On-farm death, Post-mortem examination

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INTRODUCTION

Post-mortem examination is an important and often necessary tool for diagnosing disease problems in a herd. Post-mortem examinations also play an important role in disease surveillance and have the potential of early detection of infectious diseases. In Sweden, the cause of death for cattle dying on farm often remains unknown as only a small number (<1%) of adult cattle dying on farm undergo post-mortem examination (Swedish Veterinary Agency, 2022). This means that the reported cause of death is often based on the farmers own assessment, which can be misleading or even incorrect (McConnel *et al*., 2009; Thomsen *et al*., 2012; Alvåsen *et al*., 2014). The limited numbers of post-mortem examinations of Swedish cattle might be due to logistical barriers, e.g., transport of the cadaver to a post-mortem site within a reasonable time. In Sweden, the cost of a post-mortem examination at a

necropsy facility is heavily subsidised and the service is free of charge for farms that are customers of the veterinary advice organisation Gård and Djurhälsan. The cost for transport and destruction of cadavers is covered by the farmer, regardless of whether the carcass is subjected to post-mortem examination or not. Remote digital necropsy (RDN) is a systematic method of diagnosing dead cattle remotely, with the aim of increasing knowledge about cattle deaths. The method was developed by Feedlot Health Management Services (FHMS) in Canada to provide a rapid and reliable syndrome-level diagnosis of cause of death when used in combination with signalment, treatment history and knowledge of the production system whenever possible (Agnew *et al*., 2015; Wildman *et al*., 2000). The method has also been tested in New Zealand with good results (Bryan *et al*., 2015). In short, the method involves a simplified on-farm necropsy by trained technical staff, where the carcass and relevant organs are photographed in a standardised manner. The images are uploaded to a database managed by FHMS where a bovine veterinary practitioner experienced in interpreting gross lesions makes a syndromic diagnosis. The aim of this project was to pilot test the RDN method and to explore its potential to determine gross lesions in dead cattle under Swedish production conditions.

MATERIALS AND METHODS

RDN method

The RDN method, developed and offered by FHMS in Canada, is based on opening and photo documenting dead cattle in a systematic way. Before opening an animal, a pre-necropsy assessment is needed. If an epizootic disease is suspected, the national authorities should be contacted. It is recommended to perform the RDN in an isolated and cleanable area of the farm to avoid exposing live animals to potential infectious agents. The first step of the RDN is to cut off an ear tag, to be included in all images. Photographs are taken with a digital camera with high resolution and under good lighting conditions. The animal should be placed so it is lying on its left side. The animal is then opened from the jaw (*Mandibular symphysis*) to the pelvis, a hands-width above the midline along neck, ribs and *linea alba*. Several organs are removed and photographed *ex situ* to document possible findings. Depending on the age and sex category of the animal, different numbers of photographs are requested: for neonatal calves 12 pictures, for calves and young animals (2-24 months) 10 pictures; for older beef cattle 12 pictures; and for older dairy cows 20 pictures (Supplementary Figure 1). For an experienced person, the whole procedure of opening the animal and taking the images takes about 15 minutes. The images are then uploaded to the FHMS software PM Photos along with any signalment, treatment history and comments on the production system. The images and information are analysed by a bovine veterinary practitioner experienced in interpreting gross lesions. If necessary, there is communication between the bovine veterinary practitioner analysing the images and the person submitting the images. A diagnosis based on the gross lesions is sent back to the person who submitted the images within 24 hours.

Training of RDN veterinarians

In October 2017, R. Kent Fenton from FHMS gave two training sessions on the RDN method in two different geographical locations. Course participants were two groups of Swedish veterinarians, the corresponding personnel for in-field carcass examination in Sweden. The participants were recruited by advertising the course in a closed veterinary group for large animals on Facebook, through emails to district veterinarians and targeted emails and phone calls to people at e.g., necropsy sites and field veterinarians from the northern districts of Sweden. The course lasted two full days.

Data collection and analysis

Course participants were encouraged to use the RDN method in their own daily business and in addition provide their observations of the carcass. A total of 15 RDNs were carried out between October 2017 and January 2018 (Table 1). The course participants emailed the RDN images and any additional information to K Alvåsen, who uploaded the material to "PM Photos" for analysis by RK Fenton. Tissue specimens from three animals were sent to the Swedish Veterinary Agency for histological examination of tissues with gross changes or PCR analysis when specific diseases where suspected. Interviews with 10 of the course participants were held in the end of January 2018. These interviews were performed face-to-face or by phone, to capture experiences and views on using the RDN in the Swedish setting.

This study did not require official or institutional ethical approval as the carcasses were handled in accordance with national legislation and were destructed after the RDN was performed.

RESULTS AND DISCUSSION

For several of the necropsied animals, the RDN diagnosis matched well with the on-site veterinarian's comments and the gross diagnosis given the animal could not have been reached without opening the carcass (Table 1). Out of the nine animals for which information from the on-site veterinarian was available (case number 1-4, 8-10, 12 and 15 in Table 1), the RDN diagnosis corresponded well in seven cases. Another six cases had only brief or no comments on the possible cause of death provided by the

Table 1: Comments from the veterinarian performing the field necropsy and the RDN diagnosis made by an experienced bovine veterinary practitioner based on submitted digital images and any relevant information of the assessed animal.

Case number	Animal	Comments from the on-site veterinarian	RDN diagnosis based on images
1	Young bull	Suspected poisoning	Miscellaneous (systemic disease)
2	Newborn calf	Weak, pneumonia	Pleuritis
3	Cow	Something with abomasum?	Abomasitis
4	Young bull	Valvular endocarditis	Pleuritis
5	Cow	Necrosis of the thigh muscles	Diffuse interstitial pneumonia
6	Cow	Anorexia	Metritis
7	Calf	Diarrhoea	No visible lesions
8	Cow	Suspected mycoplasmosis	Chronic pneumonia, *Mycoplasma*
9	Young bull	Enlarged liver	Neoplasia, liver
10	Calf	Negative section	No visible lesions
11	Young bull	Reticulum magnet	Diffuse interstitial pneumonia
12	Heifer	Brain abscess	No visible lesions
13	Young bull	Not provided	No visible lesions
14	Cow	Not provided	Stomach disorder
15	Cow	Negative section	No visible lesions

on-site veterinarian and thus could not be compared to the RDN diagnosis. However, a RDN diagnosis was made for four of these animals (case number 5, 6, 11 and 14 in Table 1), while no visible lesions were found for two animals (case number 7 and 13 in Table 1).

In a case of suspected *Mycoplasma bovis* infection (case number 8 in Table 1) the pathogen was later confirmed by Polymerase chain reaction analysis. Histological examination was performed by a veterinary pathologist (K Olofsson) on a young animal (case number 9 in Table 1) with enlarged liver, but as the specimen was putrefied it could not be clearly determined whether the change was of neoplastic or of inflammatory nature, but the former diagnosis was favoured. Histology was also performed on a new-born calf with suspected pneumonia (case number 2 in Table 1). In that case the histological sections showed atelectasis (non-ventilating lung tissue). Grossly signs of pleuritis were seen, whereas histologically the atelectasis predominated with only minor foci of aerated tissue. One young bull (case number 1 in Table 1) was found dead on pasture and the farmer suspected cowbane flower *(Cicuta virosa)* poisoning. This was, however, not confirmed by RDN but changes in multiple organs indicated that a systemic disease process was involved. Hence, the gross diagnosis "Miscellanous" was used, supplemented with notes, and not the gross diagnosis "No visible lesions". Another discrepancy was seen in a heifer (case 12 in Table 1) where the on-site examinator detected a brain abscess and this was not discovered from the images as the RDN protocol do not cover any brain images, hence the pathologist viewing the case remotely could not diagnose the lesion. In one animal (case 4 in Table 1) the lesions seen grossly in the heart valve by the examinator was not visible in the submitted photographs for RDN evaluation, resulting in a different diagnosis.

During the interviews, the participants expressed a great interest in developing and obtaining more skills in performing on-farm necropsies. They also reported that many farmers were interested in knowing the cause of death and were positive to allow their cattle for necropsy. During the project, RDN was offered to the farmers without any fee. Furthermore, there were a few challenges reported by the participating veterinarians. They stated that parts of the RDN, mainly opening the animal and photographing according to the manual, involved extra work. On an adult animal, this took on average 30 minutes, but only about 20 minutes if they had help from an assistant. The procedure was slightly faster on a young animal. Some veterinarians highlighted that they preferred to have a clean assistant helping them with taking the photos, to avoid changing gloves when switching between taking photos and handling the carcass and organs. As field veterinarians usually are working on their own, they tried to involve the farmer, which was not always possible. This additional time needed for performing the RDN was a major barrier in their busy schedules. In addition, several course participants mentioned that the necropsy images should be supplemented with sampling for histology and bacteriology, to increase the benefit of the necropsy.

Making a gross diagnosis based on a RDN will not provide as thorough an understanding of cause of death as a regular post-mortem examination, but it will add information that would otherwise have gone missing if the animal was sent

directly to destruction. According to Swedish regulations, dead cattle must be transported to a destruction site. From an ethical standpoint, we perceive a trade-off between the potential increased risk of disease spread at the site of RDN and the increased possibility of early detection of hazardous infectious diseases, which is beneficial for the biosecurity on a regional scale. However, as the animal subjected to RDN lived on the farm where the RDN is performed, the increase in biohazard of opening an animal after its death is most likely of little importance.

Information from the RDN could be of importance in preventing further deaths in a herd, especially if it prompts the implementation of higher biosecurity measures, and could therefore be used to stop the spread of infectious agents (Nietfeld, 2010). Furthermore, with an on-farm examination, animals carrying severe disease can be handled in a better way, which may also improve the biosafety, e.g., if the transporter avoids going to other farms after picking up high risk animals. On the other hand, it can be difficult for the company collecting carcasses to pick up opened carcasses without risking infected body parts and fluids to be dispersed. In addition, there is an extra charge to be paid by the farmer in situations where the carcass is decomposed or parts have become detached. To enable transport of opened carcasses without incurring excessive costs or risking a deterioration in disease control, calves and intestines from large animals, could be placed in a plastic bag and sealed with strapping tape. Alternatively, the organs and smaller parts could be placed in a tractor bucket which then could be tipped into the container on the collection lorry. Hence, several issues with the RDN method encountered during the project could be solved by collaborative efforts between governmental agencies, field veterinarians and farmers.

The RDN method could also be valuable, even without a gross diagnosis, since ruling out different diagnoses is also of great importance. The RDN could serve as a good complement to the regular post-mortem examinations especially in remote areas with long distances to the necropsy site. A Brazilian study by Lemos *et al.* (2023) showed that smartphone messaging applications could be useful tools to expand the performance of veterinary diagnostic laboratories and improve their diagnostic efficiency. Technology, supporting transfer of images and video material, can also be useful for veterinarians in the field when they need support in their assessment. Using video or similar technology would provide an extra, interactive, dimension to the RDN method and allow the off-site pathologist to get a sense of e.g. the shape and consistency of the organs.

Usually, a field veterinarian can identify the main pathological lesion and targeted organs, hence in these cases images could be more focused on specific organs. One could perhaps argue that veterinarians are overqualified to implement the RDN. There is, however, a great potential for other professionals to conduct the examination. This has recently been evaluated for veterinary meat inspections at slaughter where on site non-veterinary technicians equipped with cameras enabled off-site examination via live-streamed video (Almqvist *et al.*, 2021). An idea suggested during interviews was that the drivers collecting dead livestock could be trained to perform RDN. These drivers are currently offering a service of euthanising animals.

As this was a pilot study on a limited scale, there are of course limitations in both reliability and generalizability. The small sample size resulted in a limited selection of disease cases and the included herds were not representative for all geographical regions of Sweden. One specific limitation was that the photos did not cover the entire carcass. This was visible in case number 5 and 12, where the skeletal muscles and brain abscess were not documented, respectively. Another constraint with the method was highlighted in case number 4 where the lesion was not visible due to a blurry picture. This underlines the need for good quality imaging and submission of valuable additional information by the in-field examinator. Due to the limited sample size and the absence of a gold standard, a validation of the RDN method was not possible within the frame of this study. The evaluated cases have outlined the difficulties in the method as well as it highlighted a plausible diagnostic value under certain conditions. As the method was originally set up for Canadian production systems there is a need of modification before implementing the method to other production systems and circumstances. The present pilot study serves as a foundation for a more thorough validation study where the carcasses are subject to both RDN and a post mortem. Moreover, the RDN method could be further developed and applied to other animal species such as pig, reindeer, goat and sheep as well as to wild animals examined by hunters.

CONCLUSIONS AND RECOMMENDATIONS

The RDN method presents a valuable alternative to immediate destruction of deceased animals, offering insights that could aid in preventing further deaths within herds and improving biosecurity measures. While RDN does not provide the same depth of understanding as post-mortem examinations, its potential for early detection of infectious diseases and complementary role in ruling out diagnoses make it a promising tool, especially in remote areas. The use of new technology can enhance the diagnostic efficiency of RDN, expanding its utility

beyond conventional methods. Despite limitations in the pilot study, including sample size and representativeness, the groundwork has been laid for further validation and adaptation of the RDN method for broader application. The RDN has potential to be a cost-effective method to increase the post-mortem information in Swedish cattle and contribute to a more geographical encompassing national disease surveillance.

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NOVELTY STATEMENT

The RDN method offers an alternative to traditional post-mortem examinations, with its capacity to increase knowledge of on-farm deaths. This study is the first to highlight the possibilities and challenges of using the RDN method in Swedish cattle production systems.

AUTHOR'S CONTRIBUTION

KA, KF, UR and KO designed the pilot study and applied for funding. KA, UR, KO and KF participated in the RDN training sessions. KF performed the RDN diagnoses, KO was responsible for the histological examinations and KA conducted the interviews. KA, NF, LMT and KO drafted the manuscript and interpreted the results with help from UR and KF. All authors have read and approved the final version of the manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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