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Exploring the potential for on-animal sensors to detect adverse welfare events: A case study of detecting ewe behaviour prior to vaginal prolapse

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Abstract

*Parturition is a critical period for the ewe and lamb, and the incidence of dystocia has known impacts on lamb and ewe welfare and productivity. Current methods of dystocia monitoring are mostly conducted through visual observation. Novel approaches for monitoring have also been suggested, including the application of on-animal sensor technologies for remote surveillance of parturition success. This short communication explores how the use of sensor-based parturition detection models can be applied for detection of adverse and successful parturition events, respectively, in pasture-based sheep (*Ovis aries*). Specifically, the alert profile of a single ewe that experienced vaginal prolapse is reported and compared with the alert profiles of 13 ewes that experienced typical birth events. Although the ewe that experienced vaginal prolapse exhibited some common precursor alerts similar to ewes that progressed through a typical birth event, the overall alert profile was markedly different for the prolapsed animal, with an increased number of alerts occurring from five days prior to the prolapse event. As successful parturition has significant welfare and productivity outcomes, application and validation of these research findings in a commercial system could greatly improve current methods of welfare monitoring at lambing.*

Keywords: *accelerometers, animal welfare, GNSS loggers, machine learning, on-animal sensors, sheep*

Introduction

Parturition is a critical period for the ewe and lamb, with implications for welfare and productivity (Alexander 1980, 1988). It is during this high-risk period that ewes may experience dystocia (abnormal or difficult birth), which is a known cause of lamb mortality (Hinch & Brien 2014; Refshauge *et al* 2016). Dystocia can also impact on the ewe, with adverse consequences such as pregnancy toxaemia and physical trauma, including vaginal or uterine prolapse (Scott 2015).

Current techniques for dystocia monitoring in commercial systems are limited to periodic visual assessment, usually from a distance (Welch & Kilgour 1970). However, large flock sizes, limited labour and extensive terrain may make inspection challenging (Waterhouse 1996). In addition, as human presence can increase the risk of mismothering (Alexander 1980), many sheep producers may minimise the time spent closely observing their animals to reduce interference. Sheep (*Ovis aries*) are also characteristically stoic, tending to hide signs of pain and discomfort (Doyle 2017). Thus, the ability of the producer to successfully identify adverse parturition events such as dystocia may be limited using visual observation alone.

A potential solution to this issue is to deploy on-animal sensor systems for remote surveillance of animals (Waterhouse 2019). While the application of sensors for parturition detection has been reported for sheep (Fogarty *et al* 2021; Gurule *et al* 2021), there are few, if any, publications exploring how sensors might be used to detect adverse parturition events such as dystocia, and how this may be differentiated from successful parturition. Furthermore, there has been no consideration of how these might be integrated into a sensor-based system for commercial application.

This short communication reports a case study of a single ewe that experienced an adverse parturition event (vaginal prolapse) and explores how behavioural data from on-animal sensors might be integrated with routine visual inspections to optimise intervention and improve livestock welfare and production outcomes. Although a formal comparison of the behavioural differences between adverse and typical parturition events would be ideal, data were only available for a single prolapsed ewe, and thus the results are presented as a proof of concept. The early-warning symptoms of vaginal prolapse are consistent with the early signs of labour (Scott 2015). Therefore, we applied a previously developed parturition detection model (Fogarty *et al* 2021) to explore if the ewe that experienced vaginal prolapse exhibited common precursor parturition behaviours to ewes that progressed through a typical birth

Table 1 The timeline of alerts reported for parturition for the case study ewe experiencing prolapse (Ewe 1) and 13 other ewes experiencing typical birthing events (Ewes 2–14).

ID	Type of birth	Day around lambing						Notes
		–5	–4	–3	–2	–1	0	
1	Prolapse	X	X	–	X	X	X	Alerts on five days: Prolapse identified and animal euthanased on Day 0
2	Typical	–	–	–	–	X	X	False positive on the day prior to lambing: Subsequent correct detection on Day 0
3	Typical	–	–	–	–	X	X	False positive on the day prior to lambing: Subsequent correct detection on Day 0
4	Typical	–	–	–	–	X	X	False positive on the day prior to lambing: Subsequent correct detection on Day 0
5	Typical	–	–	–	–	–	X	Correct detection of day of lambing
6	Typical	–	–	–	–	–	X	Correct detection of day of lambing
7	Typical	–	–	–	–	–	X	Correct detection of day of lambing
8	Typical	–	–	–	–	–	X	Correct detection of day of lambing
9	Typical	–	–	–	–	–	X	Correct detection of day of lambing
10	Typical	–	–	–	–	–	X	Correct detection of day of lambing
11	Typical	–	–	–	–	–	X	Correct detection of day of lambing
12	Typical	–	–	–	–	–	X	Correct detection of day of lambing
13	Typical	–	–	–	–	–	X	Correct detection of day of lambing
14	Typical	–	–	–	–	–	–	Detection failure: no alerts provided

For Ewe 1, Day 0 refers to the day when prolapse was identified.
For Ewes 2–14, Day 0 refers to the day of recorded lambing.
Alerts are noted as 'X'; Lack of alerts are noted as '–.'

event. We hypothesised that ewes experiencing prolapse will exhibit heightened parturition behaviours, such as restlessness, and that these will appear as outlier data compared to ewes progressing through a typical birth event.

Materials and methods

A complete description of the materials and methods is available in Fogarty *et al* (2021). In that work, a simulated online parturition detection model was developed using machine learning techniques. This short communication applies that model in the context of identifying typical and adverse parturition events.

Location and use of animals

All research procedures and use of animals were approved by the Massey University Animal Ethics Committee (approval number MUAEC 17/59). The study was conducted at a commercial mixed enterprise farm in North Canterbury, New Zealand (42°56'47"S, 173°11'43"E) from 30 September (Study Day 1) to 13 October 2017 (Study Day 14). Mixed-age ewes (n = 40; Merino and Merino-cross) were selected from the larger commercial flock based on estimated lambing date (confirmed by ultrasound as per normal farm practice). Ewes were kept in a 3.09-ha paddock with *ad libitum* access to pasture and water.

Of the 40 ewes, 26 were excluded from the current study due to sensor failure (n = 5), failure to lamb during study period (n = 13), or previous use in model development (n = 8). The remaining 14 ewes are the focus of this study with one of these being the subject of the adverse event and 13 acting as examples of typical parturition. The case study ewe was identified as prolapsed between 0700–0730h on Day 14. Once identified, the farm manager was alerted and the animal humanely euthanased at 0900h. This was conducted according to normal farm practice. The lamb was not able to be recovered.

Instrumentation and observation

Ewes were fitted with GNSS loggers (Mobile Action, Taiwan) attached to neck collars and accelerometers (Axivity AX3, Axivity Ltd, Newcastle, UK) attached to ear tags. The GNSS loggers were programmed to collect location data at 3-min intervals. Accelerometers were programmed at 12.5 Hz and fixed with an orientation of the x-, y- and z-axis along the up-down, side-to-side, and forward-backward axes, respectively.

Visual observations were carried out on each day of the trial from 0730–1230h and 1330–1730h (± 30 min) for the purpose of recording parturition-related activities. The day of parturition was recorded as the day where the lamb was first identi-

Figure 1

Conceptual flowchart detailing commercial application of predictive type models for improved surveillance of ewes during parturition and identification of at-risk ewes.

fied. The hour of birth is unknown for animals in this study, as the event occurred during periods where the observer was not present (eg overnight or during observation breaks).

Data management and analysis

A full description of the data management and analysis is reported in Fogarty *et al* (2021). Briefly, selected features from GNSS and accelerometer data were integrated and analysed using a Support Vector Machine (SVM) to classify each animal as expressing either lambing or non-lambing behaviour on an hourly basis. SVM is an example of a supervised machine learning algorithm that aims to separate observations into binary classes (Nathan *et al* 2012). The features used to develop the SVM from the GNSS data were mean distance to peers (MDP; expressed in metres), MDP for each ewe compared to the mean MDP of the flock (expressed as a percentage), and distance to closest peer (expressed in metres). The selected feature from the accelerometer data was the number of posture changes per hour (expressed as a count). Once each feature had been calculated for each hour and each ewe, the SVM model (Fogarty *et al* 2021) classified each hour into a lambing or non-lambing class. Model development and evaluation is presented in Fogarty *et al* (2021), where the SVM was reported to detect 90.9% of lambing events within ± 3 h.

The SVM was applied to the 13 ewes that progressed through typical parturition and a single ewe that experienced an adverse parturition experience (vaginal prolapse). This ewe was the only animal to experience an adverse parturition event during the trial period.

Results and discussion

Comparison of parturition alerts for the case study ewe compared to typical animals

The results of the parturition detection model application are presented in Table 1. As shown, the algorithm correctly alerted to the day of lambing for 12 of the 13 ewes that experienced a typical birth process. The remaining animal (Ewe 14) did not report any lambing alerts. Three ewes that experienced a typical birth process also reported a false positive on the day prior to recorded lambing (Ewes 2, 3 and 4), followed by the subsequent accurate alert on the day of lambing. Given that only the day of parturition is known for these animals, it is possible that these false positive alerts on the day prior were indicative of overnight lambing events. However, this cannot be confirmed.

The case study ewe (Ewe 1) demonstrated a markedly different alert profile compared to the other sheep. This individual reported an alert on both Days –5 and –4 and then again on Days –2, –1 and 0. The alerts on Days –2 and –1 were consistent with the other sheep that experienced typical parturition (particularly Ewes 2–4), and are likely to reflect typical pre-partum behaviours (Scott 2015; Fogarty *et al* 2020a,b, 2021). In contrast, the alerts generated on Days –5 and –4 are less obviously related to the observed prolapse event. Although false positive alerts have been reported from seven days prior to birth using this same model (Fogarty *et al* 2021), it is feasible that these behaviours were indicative of impending prolapse. It is possible that the ewe began experiencing difficulties up to 4 or 5 days prior to actual prolapse, however this cannot be confirmed. Future research is required to determine if this pattern of behaviour is consistent.

Application for improved animal management

The results of the current study indicate the ability to detect parturition-related behaviour in pasture-based sheep, and the capacity to extend this application for an indication of prolapse. However, while the alert to parturition and prolapse is an important proof of concept, it is of little value if it cannot be integrated into a viable management system.

To explore this further, a conceptual flowchart was developed (Figure 1) to demonstrate how the individual alerts could be interpreted to enhance the likelihood of observing and/or intervening in an adverse event. As depicted in Figure 1, once an alert is triggered, the producer would inspect the flock within a reasonable timeframe (eg within 24 h), visually confirming the presence or absence of new lambs and thus designating the alert as 'true positive' or 'false positive.' If a parturition event was confirmed (ie true positive), application of the model for this ewe would cease, and no further action would be required. Conversely, if the alert was a false positive, this information would be integrated into the system for further analysis. If an alert was generated for two days but the producer was unable to identify a lamb for the ewe in question, this would escalate the ewe to a potential-risk status, and subsequently continued observation in the paddock is recommended. Once a third alert was generated without the presence of a lamb, the ewe's risk status would be escalated further to encourage separation for closer inspection. This rationale is based on previous work (Fogarty *et al* 2020a,b) where most lambing-related behaviour change was reported to commence either the day of lambing or the day prior. Therefore, it is reasonable to assume that repeated alerts without the presence of the lamb may indicate the ewe is expressing parturition behaviour but unable to expel the lamb, thereby warranting closer inspection.

In the instance of the case study ewe, the ewe would have been identified for closer inspection after Day –4 (Escalation One) and then again after Day –2 (Escalation Two). If this process was applied and if the escalation status was genuine, it is feasible that the ewe could have been targeted for separation and close monitoring, potentially allowing intervention and/or prevention of prolapse progression. At the very least, the escalation after Day –2 would have enabled rapid detection of the prolapse condition and reduced the animal's suffering. It is also worth noting that the case study animal received early treatment in this study due to the presence of the observer. Under normal commercial conditions where observation is less frequent, it is possible that the ewe would not have been identified for a longer period and therefore suffered for a longer period of time.

Animal welfare implications

Successful parturition has a significant and lasting impact on animal welfare and productivity outcomes in sheep production systems (Brien & Hinch 2010). Identification of animals either before or during a disease state could greatly improve survival, allowing producers to address areas of concern before they become an issue. This would not only improve on-farm welfare, but also result in increased productivity and profits for the farmer (Trotter 2013; Trotter *et al* 2018). Similarly, when animals are detected as being in an untreatable disease state, or when injured or distressed, the length of time spent suffering could be reduced through earlier detection. As public concern for animal welfare continues to rise (Dawkins 2017), it is also possible that a push for autonomous welfare assessment will come from outside the industry, increasing the current requirements for transparency and adequate documentation (Smith *et al* 2015). There is already a shift in business behaviour, for example, targeted marketing of 'certified ethical' wool (ZQ Natural Fibre 2019), promoting animal welfare and traceability as major company values.

As with any novel monitoring system, some critical issues remain which require consideration. For example, using the proposed method, the model of response requires additional investment in time to undertake closer individual inspections and, where necessary, invoke management actions. Furthermore, knowledge of negative welfare status changes the duty of care of producers, effectively increasing their responsibility to act on an alert once they become aware of any issues (Waterhouse 2019; Manning *et al* 2021). Considering this, further research into how sensor-based welfare systems can be practically applied across livestock production systems is required, including ways that satisfy all parties involved.

Although the use of a single animal may be regarded as a limitation of this study, it is feasible that the outcomes of this research could be further applied to other adverse welfare events including abortion, neonate death or predation. Furthermore, as the parturition detection model applied in this study only uses measures of social behaviour and posture change to detect parturition events, it is possible that a model that incorporates more features would also be valuable. For example, this could include measurements of temporal changes in behaviour for individual animals to help identify differences in individual idiosyncrasies (Fogarty *et al* 2021). Inclusion of data from other sensor systems (eg weather data) could also be valuable to identify other risk factors that may compromise welfare (Hinch & Brien 2014). This warrants further investigation using a larger sample number.

Declaration of interest

None.

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