Assessment of the temperature cut-off point by a commercial intravaginal device to predict parturition in Piedmontese beef cows

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Assessment of the temperature cut-off point by a commercial intravaginal device to predict parturition in Piedmontese beef cows

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Abstract:

Dystocic parturitions have an adverse impact on animal productivity and therefore the profitability of the farm. In this regard, accurate prediction of calving is essential since it allows for efficient and prompt assistance of the dam and the calf. Numerous approaches to predict parturition have been studied, among these, measurement of intravaginal temperature (IVT) is the most effective method at the field level. Thus, objectives of this experiment were, 1) to find an IVT cut-off to predict calving within 24 h, and 2) to clarify the use of IVT as an automated method of calving detection in housed beef cows. A commercial intravaginal electronic device (Medria Vel'Phone®) with a sensor that measures the IVT every 12 h was used. Piedmontese cows (n = 211; 27 primiparous and 184 multiparous) were included in this study. One-way analysis of variance was used to assess the temperature differences at 0, 12, 24, 36, 48 and 60 h before parturition. Receiving operator characteristic curves were built to determine the temperature cut-off which predicts calving within 24 h with the highest summation of sensitivity (Se) and specificity (Sp). Binomial logistic regression models were computed to identify factors that may affect the IVT before calving. Mean gestation length was 291.5 ± 13.7 d (primiparous, 292 ± 14.1 d; multiparous, 289±9.2 d). A decrease ($P < 0.001$) in the average IVT was found from 60 h before calving until the expulsion of the IVT device. A significant ($P < 0.05$) reduction in the IVT was noticeable from 24 h before until parturition. The IVT drop to predict parturition 24 h before calving was 0.21°C (area under the curve [AUC] = 0.72; Se = 66%, Sp = 76%). Furthermore, the IVT cut-off value to predict parturition within 24 h was 38.2°C (AUC = 0.89; Se = 86%, Sp = 91%). None of the evaluated fixed effects (parity, dystocia, season or length of gestation) affected ($P > 0.05$) the IVT variation from 60 h before and up to calving. To conclude, the IVT average seems to be a better parameter than the drop in temperature to predict parturition within 24 h. In this regard, a cut-off of 38.2°C showed a high Se and Sp for predicting calving. This study demonstrates the usefulness of a commercially available device to predict calving to improve management in stabled beef farms.

Keyword: Intravaginal temperature, dystocia, prediction of parturition, partum assistance, cows.

1- Introduction

Parturition is a complex physiological event characterized by distinct physical and hormonal changes, observable up to 72 h before parturition. Both dystocia and stillbirth have a significant impact on animal productivity and the profitability of the farm; often requiring a skilled assistant and immediate intervention at the moment of delivery [1]. Moreover, dystocia has an adverse effect on future reproductive performance and cattle welfare with increased incidences of retained placenta (RP), uterine infections, and involuntary culling [2]. Patterson et al. [3] described dystocia as the primary cause of calf mortality in the first 96 h of life. Human assistance at parturition is reported to occur only between 11 and 51% of parturitions in beef and dairy cattle [4, 5, 6, 7]. When prompt and efficient assistance was achieved, a significant decrease in calf mortality, (RP), and postpartum infections were reported [8]. Therefore, accurate calving prediction is a determining factor to support animal welfare and herd profitability [9] and accurate calving management is crucial to reduce the adverse effects of dystocia for both the cow and the calf [12]. However, the broad variability in gestation length and the unclear identification of the beginning of parturition affect the possibility of prompt calving assistance [10, 11].

Numerous methods to predict parturition have been presented in literature over the years. Some authors propose methods based on the measurement of external clinical signs of the preparatory stage of parturition such as pelvic relaxation, vaginal secretion and udder hyperplasia [13]. Other authors focused on measurement of the hormonal concentration of progesterone [14, 12] or estrone sulfate/17β estradiol in blood [15]. Ultrasound monitoring [16] and electrolyte concentrations in mammary gland secretions [11] have also been used as complementary methods to predict parturition. With advancements in image recognition technology, the use of continuous video-recording has also been investigated to monitor the onset of parturition [17]. The use of automated mechanical and electronic equipment is being implemented in all aspects of bovine livestock production including feeding, rumination, estrus detection and calving prediction [18,19, 20]. Many new devices to predict parturition are now available on the market: accelerometers to detect tail raising and behavioral changes; abdominal belts to measure uterine contractions; intravaginal thermometers to evaluate temperature changes; and devices fixed in the vagina or at the vulvar lips to detect calf expulsion [9].

Cattle show a decrease in body temperature (Tb) before calving [21- 26]. The Tb in beef cattle decreases from 48 to 8 h before calving and is not affected by the environmental temperature [27]. Lammoglia et al. [27] suggested that the decrease in maternal Tb (eg. vaginal temperature) before parturition is the consequence of the increased placental blood flow in the immediate precalving period. This increased blood flow causes a raise in the foetal temperature, which may mitigate heat loss by the neonatal calf in its new life ex utero. Interestingly, there is significant diurnal variation in the rectal and vaginal temperature of up to 0.5 °C, which is lower in the morning (0.2-0.3°C) and higher in the late afternoon (0.4-0.5°C), showing the importance of at least two repeated measurements per day [25, 28]. Recently, the use of repeated Tb measurements (either rectal or intravaginal) has become one of the most used tools of telemetry in livestock production due to its easy assessment at the field level [28]. Variations in Tb has been used to predict the time of calving with different results [30, 31, 25]. Furthermore, there are no publications about the possibility of using a particular temperature cut-off to predict parturition.

“Double muscling” is a heritable condition present in the Piedmontese cattle, that results in muscular hypertrophy and hyperplasia [32]. The condition contributes to a low-fat and tender meat that has made the breed well known and spread all over the world, as confirmed by the National Association of Piedmontese Cattle Breeders (A.N.A.B.O.R.A.P.I.). Unfortunately, Piedmontese cows and in general double-muscle breeds are more susceptible to difficulties at parturition [33, 1]. Due to the increased trauma associated with parturition in double muscle beef cattle, there is an increased need for accurate detection of the onset of parturition in order to provide assistance during labor. Thus, the primary objective of this experiment was to establish an intravaginal temperature (IVT) cut-off to predict calving in Piedmontese cows. Moreover, we aimed to clarify the utility of using an IVT as an automated method of calving detection in livestock farming to assist parturition in the case of dystocia.

2- Materials and Methods

A total of 248 (219 multiparous and 29 primiparous) healthy pregnant Piedmontese cows from four small-to-medium size herds (30 to 200 cows) located in the Piedmont region of Italy were enrolled in the present study from November 2013 to April 2015. All cows were submitted to AI after heat detection and checked for pregnancy at 32-35 days post-AI by a skilled veterinarian via ultrasound examination. All animals were housed in free stall barns throughout the entire year. Adequate *ad libitum* feed was provided (hay, bent grass, and corn flour and soya) enriched with vitamins (A and E) and mineral supplementation (Ca, P and Mg). All herds were officially free of IBR, tuberculosis, brucellosis and enzootic bovine leucosis, and vaccinated against BVD and pneumonia.

The intravaginal electronic device (Medria Vel’Phone®, Châteaubourg, France) is an on-farm tool designed to predict (and alarm) calving by the IVT variation and expulsion of the device just before parturition. The device consists of a rigid tube with a plastic mandrel in which a temperature detector (TDetector) is inserted, covered with a plastic shell with ridges (Figure 1a). The tool is produced in two different sizes: large (for cows) and small (for heifers) (Figure 1b). Briefly, after cleansing the device and the perineal area of the cow with a povidone-iodine solution (Betadine®), the tubular support was gently inserted in the vulva and the TDetector was deposited deep into the vagina (Figure 2). As indicated by the manufacturer, the TDetector should be introduced 7 d before expected parturition, considered to be between 278 to 283 days in pregnancy depending on breed, age, weight of the calf, milk yield, and season of parturition [34,35]. Once the TDetector is in the cranial vagina, its thermometric sensor generates a radio wave signal which is transmitted to a receiver (Figure 3) that analyzes the data and sends a text message via Global System for Mobile (GSM) communication technology to the herd staff mobile phone; providing an alert of the prediction (IVT variation) or the imminent beginning of calving (device expulsion, EXP). Vel’phone monitors the IVT every 12 h (8:00 and 20:00), starting from the day of the device insertion until delivery. A brief description of the Vel’Phone function process is described in Figure 4.

Although the literature has discordant definitions of dystocia [33, 36] for this study we categorized parturitions into three groups:

- *eutocic:* the autonomous and spontaneous calving. There is not an active intervention from the staff members.

Dystocic parturitions were separated into two categories:

- *assisted:* calving in need of assistance with a weak or a strong traction from the farmer, or requires intervention from a veterinarian.
- *caesarean:* parturition that requires a caesarean section.

Statistical analysis

The day of TDetector insertion, IVT for each day (2 times per day), and date and temperature at EXP were exported from the Medria Vel'phone® to a Microsoft Excel (Microsoft Corporation, Redmond, WA) spreadsheet file. All data were statistically analyzed via R version 3.3.0 (R Core Team, Vienna, Austria). Descriptive statistics (mean, median, quartiles and standard deviation) were calculated using the summary functions of R software (*stats* package). Verification of the assumption of normality was evaluated using Shapiro-Wilk's test and F-Folded or Levene’s variance uniformity for all continuous data (*stats* package). The statistical significance level was set at $P < 0.05$.

A scatter plot with a smooth curve fitted by Loess (*princurve* package) of all IVT measurements for each cow by day was created based on measurements recorded from 60 h before parturition until EXP. One-way ANOVA (*car* package) was used to assess temperature differences at 0, 12, 24, 36, 48 and 60 h before parturition (parturition = EXP). Next, the optimal IVT cut-off point to predict calving (within 24 h), with the greatest summation of sensitivity (Se) and specificity (Sp) and its respective positive predictive value (PPV) and negative predictive value (NPV), was calculated. For this, two receiver operator characteristics (ROC) curves (*pROC* package) and the area under the curve (*cvAUC* package) were constructed. For the first ROC curve, the average IVT were sorted into three groups, 0-12, 24-36 and 48-60 h before parturition, and used as the predictor variable. The classifier (calved/not calved) was set as the calving result in the average IVT at 0-12 h (calved), 24-36 h (not calved) and 48-60 h (not calved) before parturition. A second ROC curve was created in order to find the cut-off point which indicates the IVT drop difference with the greatest sensitivity and specificity. For this ROC curve, the average IVT difference between 0-12 h with 24-36 h before calving (predictor = calved) and the IVT difference between 24-36 and 48-60 h before calving (predictor = not calved) was used as the classifier.

After establishing the IVT cut-off point, factors associated with the drop in the IVT before parturition were investigated. For this, binomial mixed effect models (package *lme4*, function *glmer*) were constructed. The average IVT grouped at 0-12, 24-36 and 48-60 h before parturition were dichotomised as: below the cut-off point as a positive predictor for calving, and above the cut-off point as a negative predictor for calving. The fixed effects tested were ease of calving (eutocia, traction, caesarean), lactation number (primiparous, multiparous), gestation length (continuous variable), and season of calving (winter, spring, summer, fall). Moreover, the time (hours before the expulsion of the device) where the IVT before calving was measured was also included as fixed effect (IVT grouped at 0-12, 24-36 and 48-60 h before calving). All effects with *P*-values <0.2 (univariate) and their interactions were included in the final model, which was computed by backward stepwise elimination. Due to its better fit in the model (lowest Akaike and Bayesian information values), cow nested within farm was used as random effect. Results of the mixed effect models are expressed as odds ratio (OR) with their respective confidence intervals (CI).

3- Results

Initially, 248 Piedmontese cows were included in the study. Thirty-seven cows were excluded due to unavailability of data, or because the device remained in the vagina for less than three days before its expulsion. Therefore, for the final data analysis, a total of 211 cows were included (27 primiparous and 184 multiparous). Mean gestation length was 291.5 ± 13.7. (primiparous, 292 ± 14.1 days and multiparous, 289 ± 9.2, days). The TDetector was kept in the vagina an average of 8.5 ± 6 d. A total of 52.6% (111/211) of the subjects showed dystocia (assisted or caesarean); primiparous cows showed a higher tendency for dystocic calvings in comparison to multiparous cows (70.3% (19/27) vs 50.0% (92/184), P = 0.06). Although no statistical significance was found, primiparous cows had more caesarians and assisted deliveries in comparison with multiparous (25.6 % vs 23.9% , P>0.05).

The average IVT trend from 60 h before parturition until EXP, is shown by the Loess curve (Figure 5). ANOVA was applied to compare the average IVT between different time periods, from 0 to 60h before calving (Table 1). A significant decrease in the IVT was noticeable from 24 h before until EXP. The mean IVT was grouped at 0-12, 24-36 and 48-60 h before parturition (Table 2), and a significant drop was recorded from 24-36 h to 0-12 h (38.48 ± 0.25 vs 38.12± 0.25 °C). The ROC and AUC outputs used for defining the cut-off of IVT to predict parturition 24 h before the calving event are illustrated in Figure 6. Based on this analysis, the IVT cut-off to predict calving was set at 38.2°C (Se = 86%, Sp = 91%; PPV = 80%, NPV= 88%; AUC = 0.89) (Table 3). When a variation of IVT was considered as the value to predict parturition, the cut-off was -0.21°C (indicating a drop in IVT) with Se = 66%, Sp = 76%, PPV = 67%, and NPV = 69% (AUC = 0.72) (Table 3). Results of the binomial mixed effect models revealing the factors associated with a variation in the IVT before calving are illustrated in Table 4 and indicate that parity, type of calving, season, and length of gestation did not influence the change in intravaginal temperature before parturition.

4- Discussion

Although different IVT devices have been used in research for years, very few are present in the market for its use on commercial farms [9] and most of them lack evidence about the degree of effectiveness to predict parturition. This study is one of the first to use an intravaginal sensor system available on the market to evaluate the accuracy of IVT as calving predictor on commercial farms. In this system, IVT measurements were immediately and wirelessly recorded with a smartphone, allowing for better control and notification at the time of delivery than retrospective data collection (useful for research but not for commercial use). The TDetector stayed in the vagina for more than one week (in some cases up to 20 d), and did not cause any secondary effects or lesions in the cow (data not shown). Eventually, a temporary, mild vaginitis was observed. Piedmontese cattle have a gestation period which is slightly longer than other beef cattle [37], which was also demonstrated in our study by the average gestation length of 292.5 d. Thus, in agreement with the Piedmontese national association, Piedmontese cattle calved hyper mature or oversized newborn calves [39].

The physiological variability of the day of delivery makes it hard to foresee parturition, resulting in the threat of unassisted dystocia. For this reason, different ways to evaluate and anticipate the moment of parturition have been studied for years, including the development of various technologies [9]. Body temperature and IVT decreases have already been described in the scientific literature [25, 28, 22, 23, 27 24, 40]. Temperatures measured continuously by data logging thermometers were on average 0.5°C lower at parturition than when measured 48 h before delivery, in both dairy and beef cows [25,28]. Furthermore, when sensors were used to evaluate the drop of IVT as the delivery predictor, better accuracy for calving prediction within 24 h before parturition was reported [25, 28, 9]. In beef cows, Aoki and collaborators [25] found that the probability of calving within 36 h by continuous (every minute) sampling to detect a variation $\geq 0.3°C$ in IVT during seven days prepartum was over 83%. In our results, IVT starts to decrease from 60 h before parturition, but a significant reduction in temperature was seen only 24 h before parturition.

Intravaginal and body temperatures may vary due to several extrinsic or intrinsic factors (i.e. environmental temperature, degree of physical exercise, and the metabolic state of the animal)

[25,28]. However, according to Lammoglia et al. [28] during the immediate precalving period (48 to 8 h before parturition) Tb is not influenced by the environmental temperature nor sex of the calf. In our study, physical exercise is minimal before parturition because they are confined in a calving pen. All cows were housed in farms from the same geographical area with similar management and furthermore were in the same metabolic state (just before delivery), therefore, we did not consider these variables in the statistical model used in this study. When season and length of pregnancy effects were evaluated, no effect on the change in intravaginal temperature before parturition was found.

Because a significant diurnal variation in the rectal and vaginal temperature has been reported [25, 28], in this study the intravaginal temperature was measured 2 times per day at 8 am and 8 pm. Consequently, the diurnal variation in temperature will not influence estimates of the change in temperature that occurs before parturition. Moreover, we indirectly demonstrate this with ROC curves which showed a relatively high Se and Sp.

When we used the ROC curves to calculate the best cut-off for IVT variation as the delivery predictor, a decrease of 0.21 °C was found to be the change in temperature with the highest Se and Sp. Similarly, Burfeind et al. [28] investigated IVT decreases as a calving predictor in dairy cows using a controlled internal drug release tool modified to operate as a simple thermometer in the vaginal cavity 6 ± 2 d prepartum. Burfeind et al. [28] found that a 0.2-0.3°C temperature decrease on the day of calving compared to 24 h before parturition, showed a higher Se (76%) but a similar Sp (79%) in comparison to our results. Therefore, in this aspect a low accuracy is obtained with a decrease of 0.2°C of IVT. Consequently, IVT variation may not be the ideal measurement to predict parturition in dairy or beef cattle. Because of the lack of accuracy in the trend of the IVT during the last 24 h as predictor parameter for parturition, we aimed to use the average IVT itself as a cut-off value to predict parturition within 24 h. The ROC curve for the IVT cut-off within 24 h prepartum showed that when the average IVT dropped to 38.2°C or below, parturition can be predicted with higher AUC and increased Se and Sp in comparison to a change in IVT during the last 24 h prepartum. It is important to mention that no other studies have considered an average IVT as the cut–off to predict calving; this novel approach appears to be more accurate than checking for a change in IVT.

As previously discussed, dystocia can have a large economic impact on farms due to calf death, veterinary costs, decreased rebreeding efficiency, and injury or death of the cow. Cow-calf Health and Productivity Audit (CHAPA) studies indicate that dystocia is responsible for 33% of all calf losses and 15.4% of beef cattle breeding losses. Anderson et al. [41] reported that 57% and 67% of calf losses in two studies conducted in Minnesota and Michigan were from dystocia. Our study showed Piedmontese cows have a similar percentage of dystocia (53%). Interestingly, not all the cows that underwent dystocia showed any calf losses at parturition (due to the prompt assistance). Although the genetic selection in the last decades has worked to improve easier calvings and smaller calf dimension, dystocic parturitions and mainly caesarians are still a problem in the reproductive management of Piedmontese cows; although in a lower percentage than in other double muscle breeds such as Belgian Blue [42]. Nevertheless, a precise and accurate prediction of parturition can improve availability of calving assistance: preventing newborn calf losses and improving future reproductive performance of the cow.

5- Conclusions

A simple commercial device to predict calving is a useful tool to improve management of parturition in modern beef farms. In this regard, the average IVT seems to be a better parameter to predict the parturition within 24 h than the drop in IVT. In farms where the percentage of dystocia is high, an accurate prediction of parturition can significantly improve farmers ability to assist cows at the time of delivery.

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Figure 1. Medria VelPhone® consist of a rigid tubular tube with a plastic mandrel in which is inserted a temperature detector (TDetector) covered by a plastic shell with ridges (A). The tool is produced in two different sizes: large for cows (right) and small for heifers (left) (B).

Figure 2. Medria VelPhone® generates a radio wave signal which is transmitted to a receiver that analyses the data and sends a text message via GSM technology to the herd staff mobile phone, providing an alert of the prediction or the imminent beginning of calving.

Figure 3. First, the TDetector device was plunged into a bucked filled with an antiseptic solution (A) and inserted in the tubular support (B). Before the introduction of the device into the vagina, the perineal region of the cow was cleansed with Betadine® (C). Next, the tubular support was gently inserted in the vulva (D) and the TDetector was deposited deep into the vagina (E).

Figure 4. Functional process of the Vel'Phone. At Phase 1 the TDetector is inserted into the vagina seven days before the expected parturition. Next, the Vel'Phone device starts to measure the intravaginal temperature (IVT) every 12 h (Phase 2), and Phase 3 starts when a variation in the IVT occurs 24 h prior parturition. Phase 4 consist of the expulsion of the Vel'Phone, and Phase 5 is the imminent calving. An SMS is sent to the farmer's cellphone at Phase 3 (IVT variation) and at Phase 4 (expulsion of the device).

Figure 5. Scatterplot with Loess curve of the average intravaginal temperature from day 30 before to the day of parturition.

Figure 6. Receiver operating characteristic curves showing the vaginal temperature drop (A) and (B) the average vaginal temperature cut-off points to predict calving within 24 h in Piedmontese cows (crosshair marks highest point for sensitivity and specificity).