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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

28 regression models were computed to identify factors that may affect the IVT before calving. Mean
29 gestation length was 291.5 ± 13.7 d (primiparous, 292 ± 14.1 d; multiparous, 289 ± 9.2 d). A
30 decrease ($P < 0.001$) in the average IVT was found from 60 h before calving until the expulsion of
31 the IVT device. A significant ($P < 0.05$) reduction in the IVT was noticeable from 24 h before until
32 parturition. The IVT drop to predict parturition 24 h before calving was 0.21°C (area under the
33 curve [AUC] = 0.72; Se = 66%, Sp = 76%). Furthermore, the IVT cut-off value to predict
34 parturition within 24 h was 38.2°C (AUC = 0.89; Se = 86%, Sp = 91%). None of the evaluated
35 fixed effects (parity, dystocia, season or length of gestation) affected ($P > 0.05$) the IVT variation
36 from 60 h before and up to calving. To conclude, the IVT average seems to be a better parameter
37 than the drop in temperature to predict parturition within 24 h. In this regard, a cut-off of 38.2°C
38 showed a high Se and Sp for predicting calving. This study demonstrates the usefulness of a
39 commercially available device to predict calving to improve management in stabled beef farms.

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

41 1- Introduction

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

54 broad variability in gestation length and the unclear identification of the beginning of parturition
55 affect the possibility of prompt calving assistance [10, 11].

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

70 Cattle show a decrease in body temperature (Tb) before calving [21- 26]. The Tb in beef cattle
71 decreases from 48 to 8 h before calving and is not affected by the environmental temperature [27].
72 Lammoglia et al. [27] suggested that the decrease in maternal Tb (eg. vaginal temperature) before
73 parturition is the consequence of the increased placental blood flow in the immediate precalving
74 period. This increased blood flow causes a raise in the foetal temperature, which may mitigate heat
75 loss by the neonatal calf in its new life ex utero. Interestingly, there is significant diurnal variation
76 in the rectal and vaginal temperature of up to 0.5 °C, which is lower in the morning (0.2-0.3°C) and
77 higher in the late afternoon (0.4-0.5°C), showing the importance of at least two repeated
78 measurements per day [25, 28]. Recently, the use of repeated Tb measurements (either rectal or
79 intravaginal) has become one of the most used tools of telemetry in livestock production due to its
80 easy assessment at the field level [28]. Variations in Tb has been used to predict the time of calving

81 with different results [30, 31, 25]. Furthermore, there are no publications about the possibility of
82 using a particular temperature cut-off to predict parturition.

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

94 **2- Materials and Methods**

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

103 The intravaginal electronic device (Medria Vel’Phone®, Châteaubourg, France) is an on-farm tool
104 designed to predict (and alarm) calving by the IVT variation and expulsion of the device just before
105 parturition. The device consists of a rigid tube with a plastic mandrel in which a temperature
106 detector (TDetector) is inserted, covered with a plastic shell with ridges (Figure 1a). The tool is
107 produced in two different sizes: large (for cows) and small (for heifers) (Figure 1b). Briefly, after

108 cleansing the device and the perineal area of the cow with a povidone-iodine solution (Betadine®),
109 the tubular support was gently inserted in the vulva and the TDetector was deposited deep into the
110 vagina (Figure 2). As indicated by the manufacturer, the TDetector should be introduced 7 d before
111 expected parturition, considered to be between 278 to 283 days in pregnancy depending on breed,
112 age, weight of the calf, milk yield, and season of parturition [34,35]. Once the TDetector is in the
113 cranial vagina, its thermometric sensor generates a radio wave signal which is transmitted to a
114 receiver (Figure 3) that analyzes the data and sends a text message via Global System for Mobile
115 (GSM) communication technology to the herd staff mobile phone; providing an alert of the
116 prediction (IVT variation) or the imminent beginning of calving (device expulsion, EXP).
117 Vel'phone monitors the IVT every 12 h (8:00 and 20:00), starting from the day of the device
118 insertion until delivery. A brief description of the Vel'Phone function process is described in Figure
119 4.

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

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

124 Dystocic parturitions were separated into two categories:

125 - *assisted*: calving in need of assistance with a weak or a strong traction from the farmer, or
126 requires intervention from a veterinarian.

127 - *caesarean*: parturition that requires a caesarean section.

128 *Statistical analysis*

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

135 variance uniformity for all continuous data (*stats* package). The statistical significance level was set
136 at $P < 0.05$.

137 A scatter plot with a smooth curve fitted by Loess (*princurve* package) of all IVT measurements for
138 each cow by day was created based on measurements recorded from 60 h before parturition until
139 EXP. One-way ANOVA (*car* package) was used to assess temperature differences at 0, 12, 24, 36,
140 48 and 60 h before parturition (parturition = EXP). Next, the optimal IVT cut-off point to predict
141 calving (within 24 h), with the greatest summation of sensitivity (Se) and specificity (Sp) and its
142 respective positive predictive value (PPV) and negative predictive value (NPV), was calculated. For
143 this, two receiver operator characteristics (ROC) curves (*pROC* package) and the area under the
144 curve (*cvAUC* package) were constructed. For the first ROC curve, the average IVT were sorted
145 into three groups, 0-12, 24-36 and 48-60 h before parturition, and used as the predictor variable.
146 The classifier (calved/not calved) was set as the calving result in the average IVT at 0-12 h (calved),
147 24-36 h (not calved) and 48-60 h (not calved) before parturition. A second ROC curve was created
148 in order to find the cut-off point which indicates the IVT drop difference with the greatest
149 sensitivity and specificity. For this ROC curve, the average IVT difference between 0-12 h with 24-
150 36 h before calving (predictor = calved) and the IVT difference between 24-36 and 48-60 h before
151 calving (predictor = not calved) was used as the classifier.

152 After establishing the IVT cut-off point, factors associated with the drop in the IVT before
153 parturition were investigated. For this, binomial mixed effect models (package *lme4*, function
154 *glmer*) were constructed. The average IVT grouped at 0-12, 24-36 and 48-60 h before parturition
155 were dichotomised as: below the cut-off point as a positive predictor for calving, and above the cut-
156 off point as a negative predictor for calving. The fixed effects tested were ease of calving (eutocia,
157 traction, caesarean), lactation number (primiparous, multiparous), gestation length (continuous
158 variable), and season of calving (winter, spring, summer, fall). Moreover, the time (hours before the
159 expulsion of the device) where the IVT before calving was measured was also included as fixed
160 effect (IVT grouped at 0-12, 24-36 and 48-60 h before calving). All effects with P -values < 0.2
161 (univariate) and their interactions were included in the final model, which was computed by

162 backward stepwise elimination. Due to its better fit in the model (lowest Akaike and Bayesian
163 information values), cow nested within farm was used as random effect. Results of the mixed effect
164 models are expressed as odds ratio (OR) with their respective confidence intervals (CI).

165 3- Results

166 Initially, 248 Piedmontese cows were included in the study. Thirty-seven cows were excluded due
167 to unavailability of data, or because the device remained in the vagina for less than three days
168 before its expulsion. Therefore, for the final data analysis, a total of 211 cows were included (27
169 primiparous and 184 multiparous). Mean gestation length was 291.5 ± 13.7 . (primiparous, $292 \pm$
170 14.1 days and multiparous, 289 ± 9.2 , days). The TDetecter was kept in the vagina an average of
171 8.5 ± 6 d. A total of 52.6% (111/211) of the subjects showed dystocia (assisted or caesarean);
172 primiparous cows showed a higher tendency for dystocic calvings in comparison to multiparous
173 cows (70.3% (19/27) vs 50.0% (92/184), $P = 0.06$). Although no statistical significance was found,
174 primiparous cows had more caesarians and assisted deliveries in comparison with multiparous (25.6
175 % vs 23.9% , $P > 0.05$).

176 The average IVT trend from 60 h before parturition until EXP, is shown by the Loess curve (Figure
177 5). ANOVA was applied to compare the average IVT between different time periods, from 0 to 60h
178 before calving (Table 1). A significant decrease in the IVT was noticeable from 24 h before until
179 EXP. The mean IVT was grouped at 0-12, 24-36 and 48-60 h before parturition (Table 2), and a
180 significant drop was recorded from 24-36 h to 0-12 h (38.48 ± 0.25 vs 38.12 ± 0.25 °C). The ROC
181 and AUC outputs used for defining the cut-off of IVT to predict parturition 24 h before the calving
182 event are illustrated in Figure 6. Based on this analysis, the IVT cut-off to predict calving was set at
183 38.2°C (Se = 86%, Sp = 91%; PPV = 80%, NPV= 88%; AUC = 0.89) (Table 3). When a variation
184 of IVT was considered as the value to predict parturition, the cut-off was -0.21°C (indicating a drop
185 in IVT) with Se = 66%, Sp = 76%, PPV = 67%, and NPV = 69% (AUC = 0.72) (Table 3). Results
186 of the binomial mixed effect models revealing the factors associated with a variation in the IVT
187 before calving are illustrated in Table 4 and indicate that parity, type of calving, season, and length
188 of gestation did not influence the change in intravaginal temperature before parturition.

189 4- Discussion

190 Although different IVT devices have been used in research for years, very few are present in the
191 market for its use on commercial farms [9] and most of them lack evidence about the degree of
192 effectiveness to predict parturition. This study is one of the first to use an intravaginal sensor system
193 available on the market to evaluate the accuracy of IVT as calving predictor on commercial farms.
194 In this system, IVT measurements were immediately and wirelessly recorded with a smartphone,
195 allowing for better control and notification at the time of delivery than retrospective data collection
196 (useful for research but not for commercial use). The TDetector stayed in the vagina for more than
197 one week (in some cases up to 20 d), and did not cause any secondary effects or lesions in the cow
198 (data not shown). Eventually, a temporary, mild vaginitis was observed. Piedmontese cattle have a
199 gestation period which is slightly longer than other beef cattle [37], which was also demonstrated in
200 our study by the average gestation length of 292.5 d. Thus, in agreement with the Piedmontese
201 national association, Piedmontese cattle calved hyper mature or oversized newborn calves [39].
202 The physiological variability of the day of delivery makes it hard to foresee parturition, resulting in
203 the threat of unassisted dystocia. For this reason, different ways to evaluate and anticipate the
204 moment of parturition have been studied for years, including the development of various
205 technologies [9]. Body temperature and IVT decreases have already been described in the scientific
206 literature [25, 28, 22, 23, 27 24, 40]. Temperatures measured continuously by data logging
207 thermometers were on average 0.5°C lower at parturition than when measured 48 h before delivery,
208 in both dairy and beef cows [25,28]. Furthermore, when sensors were used to evaluate the drop of
209 IVT as the delivery predictor, better accuracy for calving prediction within 24 h before parturition
210 was reported [25, 28, 9]. In beef cows, Aoki and collaborators [25] found that the probability of
211 calving within 36 h by continuous (every minute) sampling to detect a variation $\geq 0.3^{\circ}\text{C}$ in IVT
212 during seven days prepartum was over 83%. In our results, IVT starts to decrease from 60 h before
213 parturition, but a significant reduction in temperature was seen only 24 h before parturition.
214 Intravaginal and body temperatures may vary due to several extrinsic or intrinsic factors (i.e.
215 environmental temperature, degree of physical exercise, and the metabolic state of the animal)

216 [25,28]. However, according to Lammoglia et al. [28] during the immediate precalving period (48
217 to 8 h before parturition) Tb is not influenced by the environmental temperature nor sex of the calf.
218 In our study, physical exercise is minimal before parturition because they are confined in a calving
219 pen. All cows were housed in farms from the same geographical area with similar management and
220 furthermore were in the same metabolic state (just before delivery), therefore, we did not consider
221 these variables in the statistical model used in this study. When season and length of pregnancy
222 effects were evaluated, no effect on the change in intravaginal temperature before parturition was
223 found.

224 Because a significant diurnal variation in the rectal and vaginal temperature has been reported [25,
225 28], in this study the intravaginal temperature was measured 2 times per day at 8 am and 8 pm.
226 Consequently, the diurnal variation in temperature will not influence estimates of the change in
227 temperature that occurs before parturition. Moreover, we indirectly demonstrate this with ROC
228 curves which showed a relatively high Se and Sp.

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

243 cut-off to predict calving; this novel approach appears to be more accurate than checking for a
244 change in IVT.

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

258 **5- Conclusions**

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

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

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

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

379 **Figure 4.** Functional process of the Vel'Phone. At Phase 1 the TDetector is inserted into the vagina
380 seven days before the expected parturition. Next, the Vel'Phone device starts to measure the
381 intravaginal temperature (IVT) every 12 h (Phase 2), and Phase 3 starts when a variation in the IVT
382 occurs 24 h prior parturition. Phase 4 consist of the expulsion of the Vel'Phone, and Phase 5 is the
383 imminent calving. An SMS is sent to the farmer's cellphone at Phase 3 (IVT variation) and at Phase
384 4 (expulsion of the device).

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

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

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