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des Fachbereichs Veterinärmedizin  
der Freien Universität Berlin

**Validation and utilization of vaginal temperature measurement in the  
prepartum period of bitches**

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## **Meinem Mann & meinen Eltern**

“The most exciting phrase to hear in science, the one that heralds new discoveries, is not 'Eureka!' but 'That's funny...’”

(Isaac Asimov)



## 1 INTRODUCTION

Prediction of parturition of pregnant female dogs is advantageous in regard to a timely preparation of a whelping box and an adequate observation of the bitch to detect possible signs of dystocia. The parturition of a bitch can present itself to be an emotionally challenging situation and is often strongly anticipated by the owner (Arlt and Geiser, 2013). When attempting to determine parturition date in bitches veterinary practitioners and breeders are often faced with difficulties due to lacking information such as ovulation date, multiple mating's and variable pregnancy durations (Eilts et al., 2005; Luvoni and Beccaglia, 2006).

One of several parameters addressing signs of parturition (i.e. relaxation of abdominal muscles, restless behaviour or appetite reduction) in dogs is a marked drop in body temperature approximately 24 h before whelping (Long et al., 1978; Johnston et al., 2001; Verstegen-Onclin and Verstegen, 2008; England, 2010; Linde-Forsberg, 2010). The most traditional site for obtaining body temperature in dogs is via rectal thermometry (Goodwin, 1998). Further advancement in technology allows its implementation to novel approaches for obtaining body temperature data. To improve the prediction of the onset of parturition breeders are advised to measure rectal temperature (Kim et al., 2007; Johnson, 2008). This recommendation is based on older studies which detected a temperature drop by relying on rectal measurements taken twice daily or more (Concannon et al., 1977; Long et al., 1978; Tsutsui and Murata, 1982). However, some bitches fail to demonstrate a temperature decrease around the time of parturition (Veronesi et al., 2002) which questions the validity of this recommendation (Luvoni and Beccaglia, 2006). Currently only theories are available as to why temperature decreases around the time of parturition in bitches and can possibly be attributed to changes in hormone levels. Concannon et al. (1977) hypothesized that the prepartum hypothermia is most likely a response to decreasing plasma progesterone levels by approximately 12 h. The authors speculated that this event may represent the inability of thermoregulatory mechanisms to compensate for the rapid removal of the thermogenic effects of progesterone. However, no correlation between body temperature and circulating plasma progesterone, cortisol and prostaglandin F<sub>2α</sub> was found during parturition in the bitch (Veronesi et al., 2002). The authors suggest that the mechanism of the temperature drop is most likely multifactorial, very complex and that progesterone could play only a partial role. Until now, there is no sound scientific evidence concerning the mechanisms that cause a decrease in temperature before parturition.

The overall objective of this study was to develop a method to obtain continuous body temperature data in bitches and to focus on analysing temperatures before parturition. Specifically, I set out to acquire frequent body temperature values without causing potential bias due to handling the dogs during the measurement process.

### **1.1 Development of a new method of body temperature sampling in bitches**

In advance of the clinical use, validation procedures are necessary to establish efficiency and accuracy of new methods (Watson and Petrie, 2010). To evaluate the accuracy of temperature measurements as well as the applicability and feasibility of the chosen temperature loggers the first study consisted of an in vitro and an in vivo experiment. The accuracy of the temperature loggers were analysed in vitro in a water bath by comparing its values to a calibrated liquid-in-glass thermometer as a gold standard. Following this procedure an in vivo experiment was performed by placing the loggers into the vagina of five bitches to compare their values to rectal temperature measurements.

The results of this study are published in the journal of Reproduction in Domestic Animals (Impact factor in 2012: 1.392):

B. Maeder, S. Arlt, O. Burfeind and W. Heuwieser. (2012):

Application of vaginal temperature measurement in bitches. *Reprod Domest Anim.* 2012 Dec;47 Suppl 6:359-361.

### **1.2 Implementation of vaginal temperature measurement to predict parturition in bitches**

After establishing agreement between rectal and vaginal temperatures the temperature logger was inserted into the vagina of bitches during their late stage of pregnancy. Due to this, non-invasive continuous measurement method in bitches a larger amount of temperature data collection per dog could be obtained than was previously possible. This allowed calculation of sensitivity and specificity of a temperature decline to predict parturition in bitches. Additionally, for a more applicable clinical approach simulation of measuring temperature only once or twice daily were analysed for sensitivity and specificity for the prediction of parturition.

The results of this study are published in the Journal of Reproduction in Domestic Animals (Impact factor in 2013: 1.392):

B. Geiser, O. Burfeind, W. Heuwieser and S. Arlt. (2013): Prediction of parturition in bitches utilizing continuous vaginal temperature measurement. *Reprod Domest Anim.* 2014 Feb;49:109-114.



### **1.3 Dystocia guideline for practitioners**

These research results have proved to be of clinical relevance for practitioners when assessing dogs in regard to dystocia. The results of the second study have therefore been published in a third article covering the broad spectrum of dystocia in bitches in the German journal of Kleintiermedizin to allow access of this science-based information by canine practitioners:

S. Arlt and B. Geiser. (2013): Geburtsstörungen beim Hund. Kleintiermedizin. 2013. 13:110-115.

The three papers are presented in the format outlined in the guide for authors of the respective journal.

## **2 RESEARCH PAPERS**

### **2.1 Application of vaginal temperature measurement in bitches**

B Maeder, S Arlt, O Burfeind and W Heuwieser. *Reprod Domest Anim.* 2012 Dec;47 Suppl 6:359-361.

#### **Application of vaginal temperature measurement in bitches**

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## **Contents**

Finding innovative, non-invasive methods for continuously measuring body temperature minimizing human interference is important for accurate data collection. The objective of this study was to assess feasibility and accuracy of continuous body temperature measurements with loggers placed in the vaginal cavity of bitches. First, an in vitro experiment was performed to compare values obtained by temperature loggers (n=26) to a calibrated liquid-in-glass thermometer. The mean differences between the two methods were low. Next, an in vivo experiment was performed using five healthy bitches and values obtained by the vaginal loggers were compared to measurements collected rectally with digital thermometers. The results show that rectal and vaginal temperatures were correlated. The mean differences between rectal and vaginal temperatures were negligible. We conclude that the utilized temperature loggers provide accurate and reliable data.

Keywords: Body temperature, validation

## **Introduction**

Measurement of body temperature is considered a fundamental element of physical examination in veterinary science (Goodwin, 1998) and research on minimal invasive methods is required (Greer et al. 2007; Quimby et al. 2009). Numerous technologies have been used to measure body temperature in mammals such as subcutaneously implanted microchip transponders (Greer et al. 2007), sensors implanted into the abdomen (Refinetti and Piccione, 2005; Miyazaki et al. 2002) and ingestible temperature sensors (Angle and Gillette, 2011). Another method of temperature measurement in cows utilized temperature loggers inserted into the vagina (Burdick et al. 2011, Burfeind et al. 2011). The objective of this study was to validate the application of temperature loggers (electronic devices which record and store data over time to continuously measure vaginal temperature) in bitches and to compare values obtained with rectal temperatures.

## **Material and Methods**

### **Experiment 1**

Temperature measurements obtained by the loggers in vitro were compared to a calibrated liquid-in-glass thermometer, which was defined as the gold standard. Twenty-six temperature loggers (DST micro-T<sup>®</sup>, Star Oddi, Gardabaer, Iceland) were used. The temperature loggers weighed 3.3 g and had a diameter of 8.3 mm and a length of 25.4 mm. The housing material consisted of implantable, biocompatible ceramic material. The temperature loggers were programmed to measure changes in temperature at 10 second intervals. According to the manufacturer, the temperature loggers are capable of recording temperatures from 5.0° C to + 45.0° C, with an accuracy of  $\pm 0.2^\circ$  C and a resolution of 0.032° C and were. The liquid-in-glass thermometer was validated by the Office of Legal Metrology of the State of Hessen, Germany (Type E 0.1/0/50 DIN 12775; verification certificate 5-3636-09).

The devices were placed into the same water bath (F10 – UC, Julabo, Seelbach, Germany). Every 10 minutes the temperature of the water bath was increased by 1.0 °C covering a range from 30.0° C to 45.0° C. The values measured were compared to the value of the gold standard in 1 minute intervals. Values measured in the 60 seconds following each temperature adjustment were discarded from analyses to exclude errors due to acclimatization of temperature changes. To ensure precise matching of paired observations (i.e. measured by loggers and liquid-in-glass thermometer) temperature values were read from the liquid-in-glass thermometer using a stopwatch. Data from the temperature loggers were downloaded (Mercury Application Software<sup>®</sup>, Star Oddi, Gardabaer, Iceland) and entered with the corresponding liquid-in-glass thermometer data into Excel spreadsheets (MS Office 2003, Microsoft Corporation).

## **Experiment 2**

The second experiment consisted of 5 privately owned bitches which were non-spayed generally and gynecological healthy. An informed consent was obtained from the owner. The bitches were 7 months to 5 years old and represented following breeds: Boxer, English Setter, Rhodesian Ridgeback, German Shepherd Mix and Terrier Mix. The mean weight was 30.2 kg (range: 22.0 - 40.0 kg). Vaginal inspection was conducted via speculum (Model 63956, length 15 cm, diameter 2 cm, Storz, Tuttlingen, Germany). Vaginal cytology (Haema–Schnellfärbung, Labor+Technik, Berlin, Germany) was conducted before logger application and after logger removal.

To prevent movement and potential displacement, temperature loggers were attached to a progesterone free modified Controlled Internal Drug Release (CIDR-blank, Pfizer, New York, NY) device for ewes. A transponder (1.4 cm x 0.2 cm, BackHome Bio Tec-Transponder, Virbac Corporation, Fort Worth, TX, USA) was placed under the silicon lining of the CIDR-blank. Utilizing a reading device (Minimax II<sup>®</sup>, Virbac Corporation, Fort Worth, TX, USA) the presence and position of the logger could be confirmed. The temperature loggers were programmed to

measure temperatures in 10 min intervals over a 3 day period. The logger was pushed through the speculum using a sterile swab and placed approximately 18 cm deep into the vagina. The dogs were kept in their familiar surroundings with no restrictions to their individual daily exercise routine.

To retrieve the logger a vaginal endoscopy was performed under carbon dioxide insufflation with a rigid endoscope (S 301-4037, Dr Fritz, Tuttlingen, Germany) consisting of a telescope (4 mm diameter, length 30 cm, 30° angled lens) and a sheath (7 x 5 mm diameter, length 25 cm). The temperature logger attached to the CIDR-blank was pulled out of the vagina by means of flexible biopsy forceps (5 Fr., 40 cm, Storz, Tuttlingen, Germany). Temperature data were downloaded after removal. Rectal temperatures measurements were recorded with a digital thermometer (VT 1831<sup>®</sup>, Microlife USA, Incl, Clearwater, FL, USA) and compared to the vaginal temperature measurements obtained by the logger at the same minute.

### **Statistical methods**

Data were analysed using SPSS<sup>®</sup> for Windows (Version 18.0, IBM Corporation, New York, NY, USA). In the in vitro experiment the mean difference between the temperature loggers and the liquid-in-glass-thermometer was calculated using a paired t-test. Furthermore, Pearson correlation was determined between the values measured by the loggers and the liquid-in-glass-thermometers. The same statistics were performed in the in vivo experiment comparing measures of rectal and vaginal temperature of the bitches. Since using correlation coefficients for clinical measurement comparison can be inappropriate, agreement between the liquid in glass-thermometer and the logger and vaginal and rectal temperatures, respectively, were analyzed graphically for both experiments using the method of Bland and Altman (1986).

## Results

In the first experiment, a total of 144 paired observations from each of the 26 temperature logger (total of 3744 paired observations) were generated and used for analysis. The mean difference between the temperature loggers and the gold standard was low (Mean  $\pm$  SD =  $0.1 \pm 0.1$  °C). An association existed between both measurements ( $r = 1.0$ ;  $p = 0.000$ ). The differences between the 26 loggers were small (CV = 0.0003). According to Bland and Altman mean difference was - 0.08, 95% CI:-0.02 to 0.05 (Figure 1).

In the second experiment, a total of 118 paired observations ( $23.60 \pm 11.37$  per bitch) were used for analysis. The vaginal and rectal temperatures were correlated ( $r = 0.79$ ,  $p < 0.05$ ). The mean difference was  $0.0 \pm 0.2$  °C ( $p = 0.07$ ). According to Bland and Altman mean difference was 0.03, 95% CI: -0.31 to 0.37 (Figure 2). The visual inspection of the vagina after removal of the logger did not show any macroscopic signs of inflammation. The percentages of neutrophil granulocytes in stained vaginal smear obtained immediately before logger application and after removal were 3% and 19%, 50% and 73%, 11% and 73%, 0% and 96%, 0% and 61%, respectively.

## Discussion

Exploring new, non-invasive methods for measuring body temperature in animals could provide easy and reliable techniques with minimal human interference (Angle and Gillette 2011; Sousa et al. 2011). This feasibility study presents precise agreement with the gold standard in the water bath and rectal measurements. Data collection in vivo demonstrated a close correlation to rectal temperature measurements. The application and removal of the temperature logger was well tolerated with no observation of vocalization or evasive body movements. An increase of neutrophil granulocytes was found in vaginal cytology after removal of the logger. This is in accordance to the findings of Ahmadi et al. (2007) who observed changes in percentage of neutrophils after CIDR application in dairy cows. However, the visual inspection of

the vagina showed no macroscopic signs of tissue irritation. The effects of this technique on tissue level in bitches should be further investigated.

The data obtained in vitro and in vivo demonstrated that the temperature loggers provide accurate, safe, easy, comfortable and reliable data. The described method may be valuable for research settings. It allows continuous sampling in females, thus collecting more data and reducing stress due to less handling of the dogs which could bias measured temperatures.

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### **Conflict of interest**

None of the authors have any conflict of interest to declare.

### **Author contributions**

BM participated in the design of the study and data acquisition, carried out clinical assessments and data collection, performed data analyses and drafted the manuscript. SA participated in the design of the study and helped to draft the manuscript. OB investigated the data analyses. WH participated in the design of the study and coordination, and helped to draft the manuscript.

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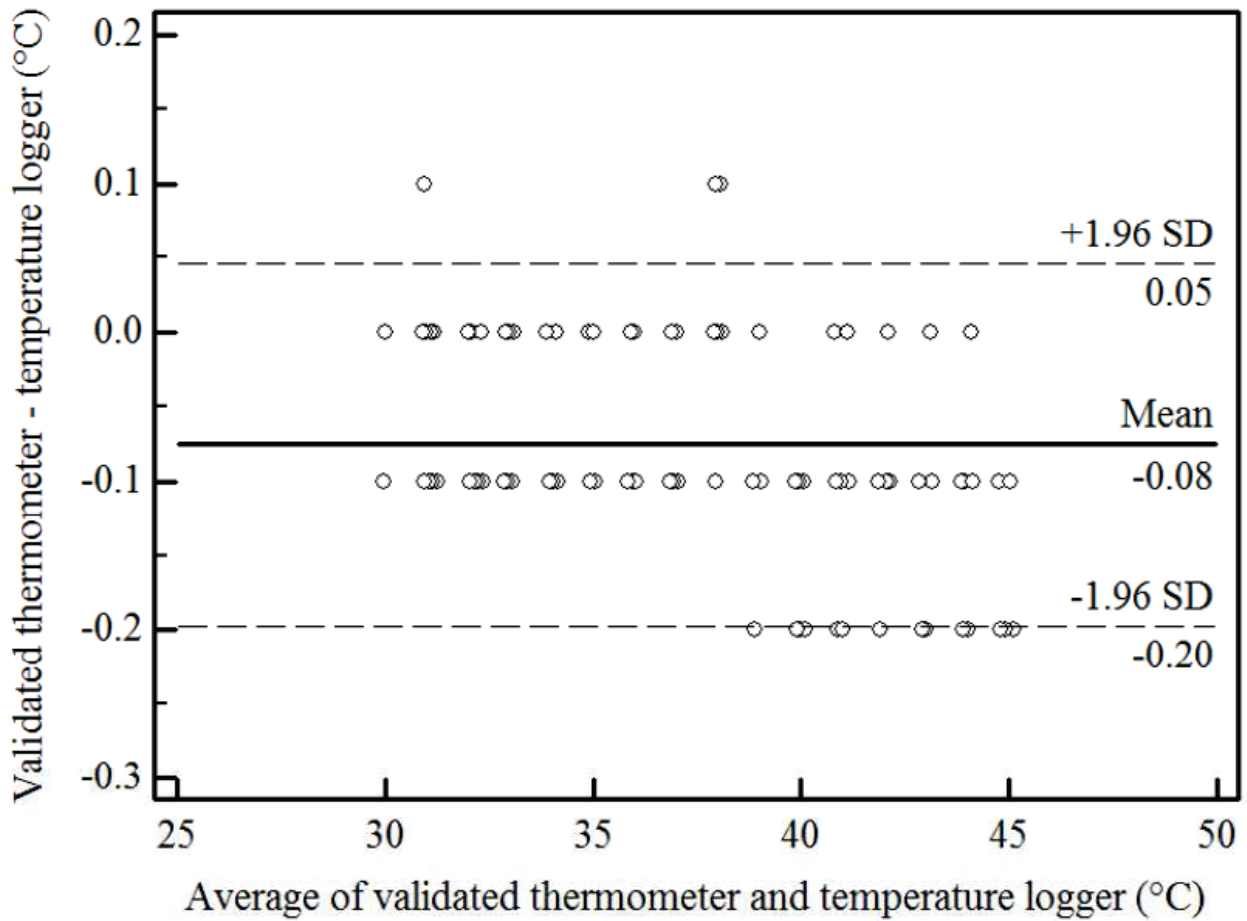


Figure 1. Differences between the temperature loggers and the validated thermometer vs the mean values of both methods.

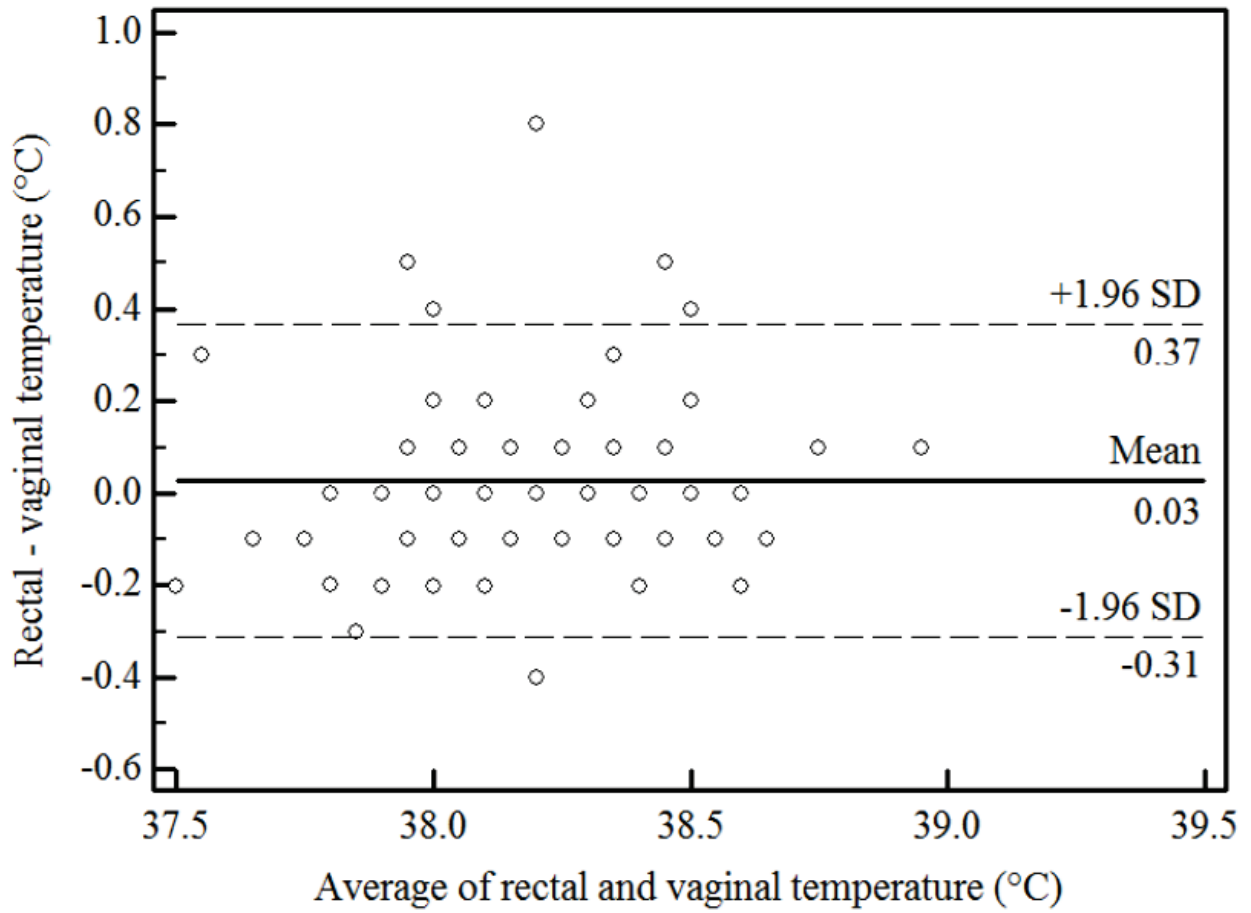


Figure 2. Differences between vaginal and rectal temperatures vs the mean values (°C) of both estimates.

## **2.2 Prediction of parturition in bitches utilizing continuous vaginal temperature measurement**

B Geiser, O Burfeind, W Heuwieser and S Arlt. *Reprod Domest Anim.* 2014 Feb;49:109-114.

### **Prediction of parturition in bitches utilizing continuous vaginal temperature measurement**

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**2.3 Geburtsstörungen beim Hund (Dystocia management of the bitch)**

S. Arlt und B. Geiser. Kleintiermedizin. 2013. 13:110-115.

**Geburtsstörungen beim Hund**

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### 3 DISCUSSION

An important tool of clinical examination and scientific research is the measurement of body temperature in mammals (Goodwin, 1998). Extensive recommendations have been published to predict time of parturition in bitches by instructing owners to record the temperature two to five times daily during the late stage of pregnancy (Johnston et al., 2001; Kim et al., 2007; England, 2010; Michel et al., 2011).

The main objective of this study was to calculate test characteristics (i.e. sensitivity and specificity) of a temperature decrease for the prediction of parturition. Until now, sensitivity and specificity of a decrease of body temperature in bitches for the prediction of parturition have neither been published for rectal nor for vaginal temperature measurements. This lack of information was addressed in my thesis by validating an innovative and non-invasive body temperature measurement method in the first study. The results indicate that the method of vaginal temperature measurement proved to be reliable regarding accuracy as demonstrated by the *in vitro* and *in vivo* experiment of the validation procedure. The macroscopic appearance of vaginal tissue examined via endoscope revealed no signs of inflammation after removal of the logger. Vaginal cytology, however, showed an increase of neutrophil granulocytes in comparison to cells obtained before logger application. Further studies should be performed to assess the side effects on the vaginal mucosa in short and long term use of the loggers.

This measuring technique supplied a large data volume and allowed the individual bitches to move freely without alterations in their behavior and was applicable in a non-invasive fashion. Biased temperatures induced by restraining or handling the bitches as present for rectal measurements are unlikely to occur. Due to these advantages the applied statistical analyses led to an improved evaluation of this prediction method for clinicians and breeders. To our knowledge, this is the first report of continuous temperature measurement before parturition of the bitch. Due to the data only being available retrospectively the loggers do not provide real time temperatures. Hence, they are currently not applicable in daily veterinary practice. Real time transfer via telemetry of data is under development and prototypes are already available on the market. Nevertheless, the practicability and overall usefulness have to be assessed in future trials.

When attempting to predict parturition in bitches monitoring of body temperature can be a useful tool. However, clinicians and owners should be aware of the fact the prognosis of parturition not occurring is more reliable than parturition occurring. This can be determined by the high values of specificity and low values of sensitivity for the prediction of parturition within 24, 36 or 48 hours. When calculating test characteristics of a 24 hours decrease in vaginal temperature measured once daily at specific times the test is more useful when the

measurement is conducted in the evening hours from 20.00 to 1.00. Perhaps this phenomenon could be associated to the dogs decreased activity behavior and outside influences in this period. Consequently, when advising owners clinicians should consider recommending temperature measurements taken in the later evening hours.

A decline in temperature has to be considered an event not sensitive enough regarding a satisfactory prediction of the onset of parturition. Further research is warranted to study if a combination of further parameters (e.g. heart rates of bitches and fetal heart rate) provides a higher predictive diagnosis than body temperature alone. Nevertheless, we recommend that the owners should measure the body temperature of pregnant bitches twice daily from day 58. Method of choice is still rectal measurement. Even if the sensitivity is not high, the finding may support decision making in cases of dystocia in combination with other findings for instance vulvar discharge, straining and fetal heart rate. Hence, it should be considered as an additional parameter that may enable an improved appraisal of the bitch's condition.

The established method of nonsurgical body temperature measurement is possibly valuable for further scientific research. It allows a closer documentation of the circadian rhythm in dogs as this has currently been observed by intermittent rectal measurements only (Refinetti and Piccione, 2003; Piccione et al., 2005). Furthermore, the precise effects of heat stress in working dogs (e.g. rescue or sled dogs) under different environmental conditions could be investigated on a more detailed basis. This potentially could create new recommendations and protocols to prevent the risk of overheating and heat induced collapses in dogs.

## 4 SUMMARY

An early detection of parturition is generally desired to allow optimal preparation and close monitoring of the bitch in order to reduce the risk of overlooking signs of dystocia. Two studies were conducted to investigate and examine the parameter of a temperature decline in bitches before whelping and its diagnostic potential to predict parturition. In the first study a new method of body temperature measurement was applied which enables continuous sampling of vaginal temperature in bitches. A validation procedure was performed by an *in vitro* and *in vivo* experiment. The *in vitro* experiment consisted of utilizing a water bath to compare values measured by the temperature loggers with those measured by a calibrated liquid-in-glass thermometer as a gold standard. The loggers ( $n = 26$ ) were programmed to measure temperature in 10 second intervals. Every 10 minutes the temperature of the water bath was increased by 1 °C covering a range from 30.0 to 45.0 °C. The mean difference between the measured temperatures of the loggers and the gold standard was low (Mean  $\pm$  SD =  $0.1 \pm 0.1$  °C). An association existed between both methods ( $r = 1.0$ ;  $p = 0.000$ ). The differences between the temperature loggers were small (CV = 0.0003). The *in vivo* experiment was carried out with 5 healthy, privately owned, non-spayed bitches of different breeds. The loggers were programmed to measure temperatures in 10 minute intervals. For the application of the logger a sterile round speculum was inserted into the vagina. The logger was pushed through the speculum and placed approximately 18 cm deep into the vagina. This procedure as well as the logger retrieval after a three day period by means of endoscopy was well tolerated. No alterations were performed towards the bitches individual daily exercise routine or their surroundings. Rectal temperature measurements were documented with a digital thermometer by the owners of the dogs and compared to the vaginal temperature value obtained by the logger at the same minute. The vaginal and rectal temperature were correlated ( $r = 0.79$ ,  $p < 0.05$ ). The mean difference was  $0.0 \pm 0.2$  °C ( $p = 0.07$ ). The percentages of neutrophil granulocytes in stained vaginal smear obtained immediately before logger application and after removal were 3 % and 19 %, 50 % and 73 %, 11 % and 73 %, 0 % and 96 %, and 0 % and 61 %, respectively. The macroscopic visual inspection of the vagina presented no signs of inflammation after retrieval of the logger. Overall, the results of this study indicate that the data obtained *in vitro* and *in vivo* demonstrated that this technique is a useful and accurate noninvasive method for prolonged monitoring of body temperature in bitches.

Following the validation procedure of the first study the second study was conducted with 18 pregnant bitches of different breeds. The objective of this study was to record and document continuous vaginal temperature measurement and to determine sensitivity and specificity of a temperature decline to predict parturition in bitches. Sensitivity was defined as



the proportion of positive events (occurrence of delivery within 24 h, 36 h and 48 h) correctly predicted by the test (decrease of vaginal temperature). Specificity was defined as the proportion of negative events (absence of delivery within 24 h, 36 h or 48 h) correctly diagnosed as negative by the test (no decrease of vaginal temperature). Furthermore, different scenarios of measuring only once or twice daily were calculated for sensitivity and specificity for the prediction of parturition. The logger was applied into the vagina of each of the bitches on day 56 – 61 after estimated ovulation or first mating date. This procedure was performed in the dog's familiar environment with no restrictions to their daily exercise routine. The logger was spontaneously expelled from the vagina before delivery of the first pup. This event was defined as the time of onset of parturition. In the last 24 h before parturition mean temperature was lower ( $37.3 \pm 0.3$  °C) than 24 to 48 h ( $37.6 \pm 0.2$  °C), 49 to 72 h ( $37.7 \pm 0.1$  °C), 73 to 96 h ( $37.7 \pm 0.1$  °C) and 97 to 120 h ( $37.8 \pm 0.1$  °C,  $P < 0.05$ ) earlier. Although bitches may display a decrease in vaginal temperature around the time of parturition, detecting this decrease does not determine the onset of whelping precisely. Overall the calculated values for specificity were higher than for sensitivity indicating that the prognosis of parturition not occurring is more reliable. In conclusion veterinarians and breeders should be advised that measuring temperature around the time of parturition may assist in providing additional information regarding the onset of parturition but should be conscious of the fact that the temperature decrease may only 0.3 °C or does not occur at all. When measuring once daily at specific times the values for sensitivity were lower in the times from 2.00 – 19.00 (33.3 - 69.2 %) in comparison to measurements taken within the time range of evening and night (20.00 – 1.00, 69.2 – 84.6 %). From 2.00 – 19.00 the specificity ranged from 66.7 – 95.7% and from 20.00 – 1.00 ranged it from 88.0 – 95.8%. When monitoring temperature for the prediction of parturition it is recommendable to conduct the measurements in the later evening hours.

## **Validierung und Einsatz vaginaler Temperaturmessung im präpartalen Zeitraum von Hündinnen**

### **5 ZUSAMMENFASSUNG**

Eine frühe Erkennung der nahenden Geburt ist generell erwünscht um eine optimale Vorbereitung und intensive Beobachtung der Hündin zu ermöglichen und um das Risiko zu reduzieren, Anzeichen einer Dystokie zu übersehen. Diese Dissertation umfasst die Untersuchung des Temperaturabfalls bei Hündinnen vor der Geburt und dessen Potential, die Geburt vorherzusagen. In der ersten Studie wurde eine neue Methode der Temperaturmessung untersucht, welche eine kontinuierliche Aufzeichnung der vaginalen Temperatur ermöglicht. Diese Methode wurde durch ein in vitro und ein in vivo Experiment validiert. In dem in vitro Experiment wurden durch Nutzung eines Wasserbads mit Temperaturregelung die Messwerte der Temperatur Logger mit denen eines kalibrierten Flüssigkeitsthermometers als Goldstandard verglichen. Die Logger (n = 26) wurden programmiert, die Temperatur in zehn Sekunden Intervallen zu messen. Alle zehn Minuten wurde die Temperatur des Wasserbades in einem Temperaturbereich von 30 °C bis 45 °C um 1 °C erhöht. Die mittlere Abweichung zwischen den Werten der Temperatur Logger und denen des Goldstandards war gering (Mittelwert  $\pm$  SD = 0,1  $\pm$  0,1 °C). Die Korrelation zwischen den beiden Messmethoden war sehr hoch (r = 1,0; p = 0,000). Auch die Unterschiede zwischen den einzelnen Temperatur Loggern waren gering (Variationskoeffizient = 0,0003). Das in vivo Experiment wurde mit fünf gesunden, nicht kastrierten Hündinnen unterschiedlicher Rassen durchgeführt. Die Logger wurden vaginal appliziert und programmiert, Messungen in zehn Minuten Intervallen durchzuführen. Für die Applikation des Loggers wurde ein steriles, rundes Spekulum in die Vagina eingeführt. Der Logger wurde durch das Spekulum geschoben und in ca. 18 cm Tiefe der Vagina platziert. Dieser Vorgang, wie auch die Entnahme des Loggers nach 3 Tagen mittels Endoskopie, wurde von den Hündinnen gut toleriert. Es wurden keine Veränderungen hinsichtlich der individuellen täglichen Bewegung und der Umgebung der Hündinnen vorgenommen. Die rektale Temperatur wurde von den Hundebesitzern mit einem digitalen Thermometer dokumentiert und mit den durch den Logger erhaltenen vaginalen Temperaturwerten der gleichen Minute verglichen. Die vaginal und rektal gemessenen Temperaturen korrelierten mit einem Wert von r = 0,79 (p < 0,05). Die mittlere Abweichung war 0,0  $\pm$  0,2 °C (p = 0,07). Die prozentualen Anteile der neutrophilen Granulozyten im angefärbten vaginalen Ausstrich vor Loggerapplikation und unmittelbar nach Entnahme des Loggers waren für Hündin 1: 3,0 % und 19,0 %, Hündin 2: 50,0 % und 73,0 %, Hündin 3: 11,0 % und 73,0 %, Hündin 4: 0,0 % und 96,0 % und Hündin 5: 0,0 % und 61,0 %. Die Untersuchung der Vagina ergab keine

makroskopischen Anzeichen einer Entzündung nach Entnahme des Loggers. Insgesamt zeigen die Ergebnisse dieser Studie *in vitro* und *in vivo*, dass diese Technik eine akkurate und nicht invasive Methode für die ausgedehnte Aufzeichnung der Körpertemperatur bei Hündinnen ist.

Nach dem Validierungsverfahren der ersten Studie wurde die zweite Studie mit 18 tragenden Hündinnen unterschiedlicher Rassen durchgeführt. Ziel dieser Studie war eine kontinuierliche Aufzeichnung vaginal gemessener Temperaturen, um Sensitivität und Spezifität eines Temperaturabfalls für die Geburtsvorhersage zu bestimmen. Sensitivität war definiert als der Anteil positiver Ereignisse, Eintritt der Geburt innerhalb von 24 Std, 36 Std und 48 Std, welcher korrekt vom Test (vaginaler Temperaturabfall) vorhergesagt wurde. Spezifität war definiert als der Anteil negativer Ereignisse, kein Eintritt der Geburt innerhalb von 24 Std, 36 Std und 48 Std, welcher korrekt vom Test (kein vaginaler Temperaturabfall), vorhergesagt wurde. Außerdem wurden Sensitivitäten und Spezifitäten für eine Geburtsvorhersage in verschiedenen simulierten Szenarien berechnet: bei täglich ein – oder zweimaliger Temperaturmessung. Die Logger wurden zwischen Tag 56 bis 61 nach erwarteter Ovulation oder nach dem ersten Deckakt in die Vagina der Hündinnen appliziert. Dieser Vorgang wurde in der gewohnten Umgebung der Hunde ausgeführt. Der Logger wurde vor Geburt des ersten Welpen bei allen Tieren spontan ausgeschieden. Dieses Ereignis wurde als Geburtsbeginn definiert. In den letzten 24 Std vor der Geburt war der Temperatur Mittelwert niedriger ( $37,3 \pm 0,3 \text{ }^{\circ}\text{C}$ ) im Vergleich zu 24 bis 48 Std ( $37,6 \pm 0,2 \text{ }^{\circ}\text{C}$ ), 49 bis 72 Std ( $37,7 \pm 0,1^{\circ}\text{C}$ ), 73 bis 96 Std ( $37,7 \pm 0,1 \text{ }^{\circ}\text{C}$ ) und 97 bis 120 Std ( $37,8 \pm 0,1 \text{ }^{\circ}\text{C}$ ,  $p < 0.05$ ) vorher. Obwohl die Hündinnen einen vaginalen Temperaturabfall um die Zeit vor der Geburt zeigen können, führt dessen Identifikation nicht zur genauen Prognose des Geburtsbeginns. Die berechneten Werte für die Spezifität waren höher als für die Sensitivität. Somit war die Prognose der nicht eintretenden Geburt in dieser Studie genauer. Zusammenfassend sollten Tiermediziner und Züchter beachten, dass die Temperaturmessung vor der Geburt Information zum zu erwartenden Geburtsbeginn liefern kann. Jedoch sollten sie sich bewusst sein, dass der Temperaturabfall deutlich geringer als bisher in der Literatur angegeben erfolgen oder ganz ausbleiben kann. Wenn täglich einmal zu einem bestimmten Zeitpunkt Temperatur gemessen wird, sind die Werte für Sensitivität in der Zeit von 2:00 – 19:00 Uhr (33,3 – 69,2 %) niedriger im Vergleich zu Messungen in den Abend - und Nachtstunden von 20:00 – 1:00 Uhr (69,2 – 84,6 %). In der Zeit von 2:00 – 19:00 Uhr erreichte die Spezifität Werte von 66,7 - 95,7 % und in der Zeit von 20:00 – 1:00 Uhr Werte von 88,0 – 95,8 %. Bei der Überwachung der Temperatur für die Vorhersage der Geburt ist es daher empfehlenswert, die Messungen in den späteren Abendstunden durchzuführen.

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## 9 DECLARATION OF INDEPENDENCE

Hiermit erkläre ich, dass ich alle Studien selbständig durchgeführt und die vorliegende Arbeit selbstständig angefertigt habe. Ich versichere, dass ich ausschließlich die angegebenen Quellen und Hilfen in Anspruch genommen habe.

This is to declare that I conducted all of the studies described herein myself and the manuscripts were produced independently. I confirm that I have used only the specified resources and tools to complete this thesis. My personal contributions to the research projects presented under this cumulative doctoral thesis are summarized in the following table.

Own Contribution	Research project 1	Research project 2	Research project 3
Study design	++ <sup>1</sup>	++	++
Data collection	+++	+++	+++
Data analyses	+++	+++	+++
Manuscript writing	+++	+++	+++
Manuscript editing	++	++	++

<sup>1</sup>Score: + = < 50%; ++ = 50 to 70%; +++ = > 70%

Berlin, 11.03.2014

Britta Geiser