Körpertemperaturmessung in Hunden unter Allgemeinanästhesie – Vergleich der Messung rektal, in der Nase sowie der Achselhöhle mit der ösophagealen Körperkerntemperatur

Body temperature measurement in anaesthetised dogs – comparison of nasal, axillary, rectal and oesophageal temperature

(Körpertemperaturmessung in Hunden unter Allgemeinanästhesie – Vergleich der Messung rektal, in der Nase sowie der Achselhöhle mit der ösophagealen Körperkerntemperatur)

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Abstract

Objective

To evaluate different methods of monitoring body temperature in anaesthetised dogs with comparison to core temperature obtained via oesophageal probe.

Methods

Client-owned dogs undergoing general anaesthesia for various procedures were included in this observational study. The temperature was taken sequentially every 10 minutes from the rectum, axilla, and nasal cavity with a digital thermistor thermometer, and compared to oesophageal core temperature via paired t-tests. Differences from the gold standard oesophageal temperature were assessed via Bland-Altman plots and further evaluated for factors like time under anaesthesia and presence of Hypo-/Normo- or Hyperthermia. In addition, it was analysed whether a correction factor for peripheral measurement sites (nasal cavity and axilla) would be applicable in a reliable representation of the body temperature. The level of significance in all tests was set at $p < 0.05$.

Results

In this study, 95 simultaneous temperature measurements at the 4 different sites were obtained from 30 dogs. Mean difference and limits of agreement from oesophageal temperature for the different measurement methods were 0.0 ± 0.72°C for rectal temperature, -1.2 ± 1.42°C for axillary and -1.0 ± 2.02°C for nasal temperature. Axillary and nasal temperatures were not significantly different ($p = 0.5721$ and $p = 0.9287$, respectively) from oesophageal temperature with a +1.2°C and +1°C correction factor, respectively.

Conclusion and Clinical relevance.

During perioperative temperature measurement in anaesthetized patients, rectal and oesophageal measurements can be used interchangeable. However, if these are not available, the use of axillary or nasal sites is only reliable after applying a correction factor.

Schlüsselwörter: Hund, anästhesie, überwachung, hypothermie

Zusammenfassung

Gegenstand und Ziel

Die Untersuchung verschiedener Methoden zur Messung der Körpertemperatur in Hunden in Allgemeinanästhesie sowie deren Vergleich zur gemessenen Körperkerntemperatur im Ösophagus.

Material und Methoden

In dieser Beobachtungsstudie werden Patienten (Hunde) unter Allgemeinanästhesie betracchtet.Im Rahmen der intraoperativen Narkoseüberwachung erfolgte die Temperaturmessung alle 10 Minuten gleichzeitig an verschiedenen Lokalisationen: Rektal, Achselhöhle und Nasenhöhle (mittels digitalem Thermistor-Thermometer). Die jeweiligen Messungen wurden mittels einem gepaarten t-Test mit der Körperkerntemperatur verglichen, welche mittels einer Thermistor-Temperatursonde im Ösophagus ermittelt wurde. Abweichungen vom Goldstandard (Ösophagustemperatur) wurden mit Bland-Altmann-Plots dargestellt und zusätzlich auf Faktoren wie Narkosezeit und Hypo-/Normo- oder Hyperthermie untersucht. Für die peripheren Temperaturmessungen Achsel- und Nasenhöhlen wurde gleichzeitig ermittelt, inwiefern ein Korrekturfaktor zuverlässig die Körpertemperatur widerspiegeln würde. Ein p-Wert < 0,05 wurde als statistisch signifikant bewertet.

Ergebnisse

Im Rahmen dieser Studie konnten 95 simultan ermittelte Temperaturmesswerte an vier verschiedenen Messlokalisationen eingeschlossen werden. Insgesamt wurden dafür 30 Hunde in Narkose untersucht. Die Abweichung (und „limits of agreement“) der verschiedenen Messlokalisationen von der Ösophagustemperatur waren: 0,0 ± 0,72°C (Rektal), -1,2 ± 1,42°C (Achselhöhle) und -1,0 ± 2,02°C (Nase). Die ermittelten Temperaturen der Achselhöhle und Nase unterschieden sich nach Anwendung eines Korrektionsfaktor von +1,2°C und +1°C nicht mehr signifikant von der Ösophagustemperatur (p = 0,5721 und p = 0,9287).

Schlussfolgerung und klinische Relevanz

Die perioperative Temperaturmessung an narkotisierten Hunden kann zuverlässig mittels rektaler Messung oder Messung im Ösophagus erfolgen. Beide Methoden sind vergleichbar. Sind diese Lokalisationen nicht zugängig, könnten Achselhöhle und Nase nur nach Anwendung eines Temperatur- Korrekturfaktors genutzt werden

Introduction

The measurement of body temperature during general anaesthesia is important as normal thermoregulation is disrupted by a variety of means. Commonly used perioperative drugs such as opioids and acepromazine alter the temperature set-point in the thermoregulatory centre of the hypothalamus [1]. In addition, acepromazine, propofol and volatile inhalational agents supress peripheral vasoconstriction, which normally limits heat loss. Conversely, α_2 receptor agonists cause peripheral vasoconstriction, which reduces the heat loss from the periphery [2] and helps to maintain core body temperature.

The adverse effects of both perioperative hypothermia and hyperthermia have been well documented. Hypothermia decreases sympathetic tone and causes bradyarrhythmias [3], impairs coagulation [4], increases wound infection rates [5], affects drug metabolism and clearance [6], and is associated with a prolonged recovery [7] which is a period of significant risk of mortality in veterinary medicine [8]. Hyperthermia is less common, but could result from malignant hyperthermia, thick coated dogs, high ambient temperature, or patients covered with many surgical drapes [9]. Severe hyperthermia may result in multiple organ failure and death if not promptly recognised and treated [10]. Accurate methods for monitoring body temperature during general anaesthesia is therefore important to guide drug dosing, active warming strategies and prepare recovery.

Various methods for measuring of body temperature in small animals have been reported, with rectal, tympanic, and axillary thermometers routinely used [11-13]. However, the accuracy and agreement between these different devices is variable [11, 14, 15]. Oesophageal temperature readings have been shown to reliably indicate the core body temperature measured in the pulmonary artery in humans [16] and dogs [17], although this method is limited to use in unconscious patients and requires specialised equipment.

Overall, rectal temperature appears to offer an acceptable approximation of core body temperature [18], however certain circumstances may render it unreliable, including patients with a large amount of faeces or air in the rectum [19]. In search of other suitable measurement site, the nasal cavity was hypothesised to provide a good estimate of body temperature in the dog due to the large surface area and excellent blood supply. It might be a suitable alternative in anaesthetized patients as it is often readily available to anaesthetists and, if performed with a standard rectal digital thermometer, does not require any specialised equipment.

The aim of this study is to measure body temperature in dogs under general anaesthesia at 3 different sites (rectal, axillary and nasal) and to compare it with oesophageal core body temperature to determine whether they are viable alternatives. Our hypothesis was that rectal and oesophageal (core) body temperature would show a high agreement, with wider discrepancies for nasal or axillary measurements.

Materials and Methods

The study was approved by the local ethics and welfare committee (CR284, Department of Veterinary Medicine, University of Cambridge, United Kingdom).

Study Design

This was an observational study performed in anaesthetized dogs routinely receiving temperature measurement as part of the standard perioperative monitoring. Sequential temperature recordings were obtained in the presurgical preparation time and compared with each other.

Animals and General Anaesthesia

The study cohort consists of dogs undergoing general anaesthesia for various surgical procedures at the Queen's Veterinary School Hospital, University of Cambridge, United Kingdom in a period between April 2018 and June 2019. Cases with an estimated presurgical preparation time of ≥ 30 minutes, lateral recumbency for presurgical preparation, and maintenance with volatile agents (Isoflurane/Sevoflurane) were eligible for inclusion. Dogs were included if equipment and lead investigator (RW) were available. Dogs with severe systemic disease (American Society of Anesthesiologists Classification > 3) and those with any rectal or nasal disease were excluded from this study.

All dogs received a suitable anaesthesia protocol (drug selection, doses) based on pre-anaesthetic examination, history, comorbidities, and surgical procedure. The attending anaesthetist was responsible for the choice of protocol and management of cases.

Dogs received premedication (if suitable) followed by administration of injectable induction agents. Following successful endotracheal intubation, dogs were connected to a suitable breathing system and anaesthesia was maintained with Isoflurane (IsoFlo 100% w/w Inhalation Vapour, Zoetis UK, UK) or Sevoflurane (SevoFlo 100% w/w Inhalation vapour, Zoetis UK, UK) in oxygen. A heat and moisture exchanger (Hydro-Therm™, Intersurgical, UK) appropriate for the patient size was used in each patient. Routinely, standard monitoring of cardiorespiratory parameters was performed (Mindray Beneview T5, Mindray Ltd, China) including ECG, pulse oximetry and sidestream capnography. The level of anaesthesia was assessed and adjusted as required. Anaesthesia management or recovery was not part of this study.

Temperature measurement

For this study, body temperature was measured and recorded simultaneously at four different locations (rectal, axillary, nasal, oesophageal) during the presurgical preparation whilst under general anaesthesia. Time points for measurement were predetermined: after induction of

anaesthesia and thereafter every ten minutes during presurgical preparation until transfer of the dog to the operating theatre.

Oesophageal temperature (OT) as indicator of core body temperature was continuously measured using a re-usable thermistor temperature probe attached to the multiparameter monitor (Mindray Beneview T5, Mindray Ltd, China). This probe was placed into the oesophagus approximately to the level of the thoracic inlet to measure core body temperature as measured prior to insertion. Once the probe was in place after induction, it was not moved until the study observation ended.

Additionally, three locations were sequentially used for temperature measurement: the axilla (AT), nasal passage (NT), and rectum (RT), always in that sequence. The same digital thermistor thermometer (Purfect Digital Flexible Thermometer, JAK Marketing, York, UK) with a 4 mm tip was used for all measurements. It was cleaned with a disinfectant wipe (Clinell Universal Wipes, GAMA Healthcare Ltd, Hertfordshire, UK) between each site and allowed to cool down to room temperature. At each of the three locations, a single reading was taken, and it was recorded once the thermometer gave an audible signal. Multiple readings would have resulted in more data points, however there was insufficient time for the thermometer to read multiple times at each site at each time point.

At the axilla, the thermometer was inserted under the uppermost forelimb into the axilla from a cranial to caudal direction with the patient in lateral recumbency. The limb was allowed to rest against the thermometer. To measure temperature in the nasal passage, the thermometer was gently inserted into either nostril without any pressure, aiming ventromedially into the middle meatus. The thermometer was inserted until the silver tip was completely in the nasal cavity. This procedure was aborted if any resistance to insertion was noted, however no difficulties or adverse events were recorded during this study. For rectal measurement, the thermometer was inserted a minimum of 2 cm into the rectum and the tip was gently pressed against the rectal mucosa for the measurement period. The presence of air or faeces was not recorded.

Prior to each animal, the agreement of the oesophageal probe and the respective digital thermometer was checked by immersion in warm water. A difference less than 0.1°C between both devices was considered acceptable accuracy.

Post-hoc data handling and statistical analysis

Statistical analysis was performed using the software package IBM SPSS Statistics 22. Data were analysed using descriptive statistics and reported as mean ± standard deviation (SD) unless otherwise stated. Normal distribution was assessed using the Shapiro-Wilk-test.

Differences between the different methods of temperature measurement were determined with Bland Altman plots with OT considered as the gold standard. In addition, peripherally

obtained temperature values (AT and NT) were compared against each other for agreement. A one-way analysis of variance followed by subsequent paired t-tests including collected temperatures from all dogs at all time points. A Pearson correlation analysis was applied to identify which temperature measuring methods were significantly related. Dogs with available complete temperature measurements with all four methods over at least 30 minutes were assessed with one-way repeated measurement ANOVA to analyse differences in the methods over time.

For all subsequent analysis, temperature obtained via axilla, nasal and rectal method was handled as the difference (ΔA, ΔN and ΔR, respectively) in comparison to the gold standard (OT) and assessed via t-test.

Available temperature data was split into early (at induction and ten minutes later) and late measurements (20 minutes after induction and onwards). An independent t-test was used to assess the difference between an early and late measurement of ΔA, ΔN and ΔR, respectively. Original OT values were classified into either hypothermic (< 37.2°C), normothermic (37.2-39.2°C) or hyperthermic (> 39.2°C). Corresponding ΔA, ΔN and ΔR values were analysed with an independent t-test to assess whether higher or lower temperature affects reliability of the different methods.

To assess whether a correction factor is suitable when measuring nasal or axillary temperature, the originally obtained values of the two methods were each corrected by adding the mean difference of the respective method to OT for each value. These corrected values for nasal and axillary temperature where then compared against the respective OT with a paired t-test.

The level of significance in all tests was set at $p < 0.05$. The clinically acceptable difference between measurement sites was set at 0.3°C.

Results

In total, 95 simultaneous temperature measurements at the 4 different sites were obtained during this study. Data were taken from 30 dogs (both sexes) of different breeds and health conditions, which underwent various elective surgical procedures (soft tissue and orthopaedic surgeries). No breeds were excluded from the study. Enrolled dogs were aged 3.6 ± 3.24 years, had a bodyweight of 19.7 ± 11 kg, and had a body condition score 4.9 ± 1.3 using a 9-point scale. All dogs had a simultaneous temperature reading at induction and 10 minutes later. At 20 minutes under anaesthesia only 21 dogs were assessed, whereas at minute 30 11 dogs remained and after 40 minutes under anaesthesia only data of 3 dogs were included. Overall, mean body temperature was 37.9 ± 0.68°C (OT), 37.9 ± 0.71°C for rectal measurement, 36.7 ± 0.84°C for axillary and 36.9 ± 0.98°C for nasal temperature (Table 1). The lowest recorded temperature was 34.0°C obtained via nasal temperature measurement

and the highest recording was 39.8°C via rectal temperature. One dog was hyperthermic at induction (OT = 39.5°C) and 10 minutes later (OT = 39.4°C), with concurrent hyperthermic rectal temperature readings. Three dogs were hypothermic by OT at induction and throughout the measurement period. However, one of these dogs was normothermic when assessing rectal temperature (T = 37.7°C at induction, T = 37.4°C 10 min later and T = 37.2°C 20 min later). Another three dogs became hypothermic in OT after induction (one each after 20 minutes, 30 minutes and 40 minutes of anaesthesia).

Mean difference and limits of agreement (LOA: Bias ± 1,96 SD) from the gold standard OT for the different measurement methods were 0.0 ± 0.72°C for rectal temperature, -1.2 ± 1.42°C for axillary and -1.0 ± 2.02°C for nasal temperature (Figure 1). Therefore, only rectal temperature was within the clinical acceptable difference of 0.3°C, with a strong positive correlation between OT and rectal temperature ($r(93) = 0.8595$, $p < 0.00001$).

Temperature reading obtained by axillary and nasal measurement differed significantly from OT ($p = 0.001$ for each). Axilla temperature showed a moderate positive correlation with OT ($r(93) = 0.5604$, $p < 0.00001$), whereas nasal temperature showed a weak positive correlation with OT ($r(93) = 0.2737$, $p < 0.007278$). Axilla and nasal temperatures were comparable with a bias and LOA of -0.2 ± 0.72°C.

Accounting for a correction factor for the peripheral measurement sites of +1.2°C for axilla temperature and +1°C for nasal temperature revealed that both corrected values were not significant different from OT ($p = 0.5721$ and $p = 0.9287$, respectively) (Figure 2).

Analysis of hypothermic OT readings showed a higher average agreement of -0.3°C for axillary and nasal temperature measurement than in normothermic patients (-1.3°C and -1.0°C, respectively). Hyperthermic temperature readings were not separately assessed as only 2 readings showed an OT above 39.2°C.

Differences in the different methods over time were assessed in 11 dogs with available data at induction and subsequently up to minute 30. The mean difference to OT for rectal and nasal temperature (ΔR and ΔN, respectively) did not differ over time. The smallest ΔA was at 20 minutes under anaesthesia (-1.1 ± 0.49°C), which was significantly different to other time points ($p = 0.0213$, $p = 0.0125$, $p = 0.02171$ compared to induction, minute 10 and 30, respectively).

Discussion

The aim of this study was to compare the body temperature obtained from anaesthetized dogs from four different locations; rectal, oesophageal, axillary, and nasal. These data show that in canine patients undergoing general anaesthesia rectal and oesophageal temperatures

correlate well, whereas axillary and nasal temperatures cannot be used for assessing core body temperature without application of a correction factor.

There have been studies comparing temperature measurements from various sites in dogs and cats with varying results, however none have examined this combination or included temperature measurement from the nasal cavity previously. We chose to measure the core body temperature using an oesophageal probe and rectal thermometer as these have been previously shown to provide an accurate estimate of the core body temperature [11, 17, 19]. The most accurate assessment of core body temperature would be to place a thermistor-tipped catheter into the pulmonary artery [19]; however, this is not routinely performed as it is a highly invasive procedure which requires additional equipment and risks additional morbidity.

The use of rectal or oesophageal probes as measurement of central core body temperature is not always possible due to the location of the surgical site or other morbidities, therefore assessment of body temperature at peripheral sites might be attempted. There are also theoretical risks of complications with these more invasive measurement methods including one reported case in human medicine of oesophageal burns from a temperature probe [20], however these seem to be rare.

For comparison of different measurement sites, a consideration needs to be made that the peripheral compartment might be affected by centrally controlled vasoconstriction, and, therefore, peripheral body temperature might differ from central. This had been demonstrated by Greer et al [19] in eight dogs, where an implanted subcutaneous temperature monitoring system and auricular temperatures were not comparable to rectal or pulmonary artery temperatures.

The peripheral sites of axillary and nasal cavity were selected as they have either provided inconsistent data in the past [11, 14, 21, 22], or have not been examined in anaesthetised dogs. The peripheral temperature compartment in a conscious animal responds to thermoregulatory centres to control central temperature. If the central temperature increases then the periphery may increase also to promote vasodilation and heat loss, maintaining a level of normothermia. If the central temperature decreases then the peripheral compartment promotes vasoconstriction to reduce the heat loss [23]. This may lead to a large discrepancy between the core and peripheral temperatures, or it may cause an increase in the core compartment. During general or locoregional anaesthesia these homeostatic mechanisms are interrupted as the central temperature “set point” in the hypothalamus is altered, as well as increases losses from the periphery [24]. The anaesthesia protocol/drug selection was not

analysed in this study, as we aimed at comparing the measurement sites irrespective of underlying alterations by anaesthetic drugs/techniques.

Interestingly, nasal temperature tended towards being more accurate over time. This is hypothesised to be due to the nasal cavity being an area for heat exchange in the dog as air moves over the nasal turbinates. As this mechanism is bypassed in a dog with endotracheal intubation the nasal cavity is assumed to warm to body temperature over time. The effect of different anaesthetic protocols would be an area for further study as these may have an effect on nasal perfusion. α_2 receptor agonists cause peripheral vasoconstriction, whilst volatile anaesthetic agents cause vasodilation, therefore it would be of interest to monitor perfusion of the nasal cavity with regards to the temperature over time. While no adverse events were reported in this study with measurement of nasal temperature, it is possible that the introduction of the thermometer could damage the nasal turbinates and causes bleeding, particularly in brachycephalic dogs which have an abnormal turbinate conformation.

Regarding the used devices, both the electronic thermometer (used for rectal, axillary, and nasal temperature measurement) and the oesophageal probe use a thermistor to measure the temperature. In both cases the thermistor is located in the tip of the device, although the oesophageal probe is coated with smooth plastic to prevent trauma, whereas the thermometer has a metallic tip to aid thermal conductivity and decrease the time needed for an accurate result. It is important when recording the temperature to ensure that the device has had adequate time to equalise to the environment. In one dog during this study the oesophageal temperature was recorded as being lower in the oesophagus than in the rectum at time 0. This is hypothesised to be the result of an error with the oesophageal probe, due to insufficient time to equilibrate to the temperature or due to air in the oesophagus, rather than a true difference. These data were not excluded from the statistical analysis as we were observing for differences between the methods.

Other factors may also influence heat loss and vasomotor control. Alpha-2 agonists result in peripheral vasoconstriction which reduces heat loss [25], which may result in a lower measured peripheral temperature, but may also have caused the increase in core body temperature noted in one dog. One study reported that weight, coat length, body condition score and breed size were significantly associated with the difference between the rectal and axillary temperature [11], however this was not assessed routinely in the literature, nor in this study. The use of heat and moisture exchangers to reduce the effects of cold carrier gases

has previously been examined however they did not have significant effects on heat loss [25, 26], and all cases in this study experienced a decrease of their body temperature. Active warming with either forced air blankets or heated mats has been shown to aid maintenance of body temperature [27] and may have been a source of error if the thermometer was placed too close to these devices, however neither of these interventions were used in this study. The temperature of the room may have influenced initial vasomotor tone during the premedication phase and this was not measured, although the same room was used for all procedures and the temperature maintained with an air conditioning system.

Several limitations are noted with this study. Firstly, only 30 dogs were included with the study, allowing for 95 paired values for analysis. A retrospective sample size calculation aiming at 80% power and a type I error rate of 5% revealed 182 measurements to be necessary to detect a difference of 0.2°C between OT and the measurement sites. However, due to the large discrepancy for axillary and nasal temperature in comparison to OT, the obtained number deemed to be sufficient to exclude comparability. Nonetheless, the results demonstrating there is no significant difference between rectal and oesophageal temperature need to be viewed with a certain amount of caution. A bias for the paired measurements cannot be excluded, as each dog was used more than once to obtain temperature recordings throughout anaesthesia. However, this bias can be neglected as the purpose of the study was to compare measurement sites. A loss of paired values over anaesthesia time due to patients moving to the surgical theatre occurred, which restricted analysis of comparability of central and peripheral measurement sites over time. The body condition and breed of the patient were not recorded for all patients. They have previously been shown to result in a difference between temperature measurement between central and peripheral sites [11].

Conclusion

Rectal temperature measurements appear to give an accurate representation of the core body temperature and can be used interchangeably with oesophageal temperature measurement. However, if these are not available, the use of axillary or nasal sites is reliable after applying a correction factor of 1.2 and 1.0°C respectively offering alternative locations for temperature monitoring should oesophageal and rectal measurements be unavailable.

Conflict of interest: The authors confirm that they do not have any conflict of interest.

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465
466 Table 1: Mean +/- standard deviations of temperature in dogs under general anaesthesia,
467 taken of four measurement sites across 40 minutes
468 Tabelle 1: Mittelwert +/- Standardabweichung für Temperaturen an Hunden in bis zu 40
469 Minuten Allgemeinanästhesie, gemessen an 4 verschiedenen Stellen
470

Site	Timepoint	N	Mean	Standard Deviation
Axilla	0	30	36.87	0.86
Axilla	10	30	36.74	0.89
Axilla	20	21	36.89	0.75
Axilla	30	11	36.32	0.71
Axilla	40	3	35.90	0.40
Nasal	0	30	36.58	1.21
Nasal	10	30	36.91	0.95
Nasal	20	21	37.17	0.76
Nasal	30	11	37.24	0.64
Nasal	40	3	37.07	0.42
Oesophageal	0	30	37.98	0.60
Oesophageal	10	30	38.01	0.66
Oesophageal	20	21	37.80	0.80
Oesophageal	30	11	37.69	0.71
Oesophageal	40	3	37.47	0.40
Rectal	0	30	38.09	0.63
Rectal	10	30	37.91	0.62
Rectal	20	21	37.71	0.91
Rectal	30	11	37.62	0.64
Rectal	40	3	37.50	0.36

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Figure 1: Bland-Altman plot comparing temperatures taken in 30 dogs at a) rectal b) axillary and c) nasal site versus gold standard (oesophageal) temperature. © C. Gittel

Abbildung 1: Bland-Altman-Graph der wiederholt gemessenen Körpertemperatur von 30 Hunden in Allgemeinanästhesie an verschiedenen Lokalisationen a) Rektal b) Achselhöhle c) Nasenhöhle) im Vergleich zum Goldstandard (ösophageale Temperatur) © C. Gittel

Figure 2: Box plot of temperature taken in 30 dogs at three different sites (oesophageal, axillary & nasal) at all times points after the correction factor has been applied. © C. Gittel

Abbildung 2: Box Plots der wiederholt gemessenen Körpertemperatur von 30 Hunden in Allgemeinanästhesie nach Applikation eines Korrektionsfaktors für die peripher gemessen Lokalisationen (Achselhöhle & Nasenhöhle) © C. Gittel