



THE UNIVERSITY *of* EDINBURGH

Edinburgh Research Explorer

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

Citation for published version:

Ward, R, McMillan, M & Gittel, C 2023, 'Körpertemperaturmessung in Hunden unter Allgemeinanästhesie – Vergleich der Messung rektal, in der Nase sowie der Achselhöhle mit der ösophagealen Körperkerntemperatur', *Tierärztliche Praxis Ausgabe K: Kleintiere / Heimtiere*, vol. 51, no. 3, pp. 161-167. <https://doi.org/10.1055/a-2103-3162>

Digital Object Identifier (DOI):

[10.1055/a-2103-3162](https://doi.org/10.1055/a-2103-3162)

Link:

[Link to publication record in Edinburgh Research Explorer](#)

Document Version:

Peer reviewed version

Published In:

Tierärztliche Praxis Ausgabe K: Kleintiere / Heimtiere

General rights

Copyright for the publications made accessible via the Edinburgh Research Explorer is retained by the author(s) and / or other copyright owners and it is a condition of accessing these publications that users recognise and abide by the legal requirements associated with these rights.

Take down policy

The University of Edinburgh has made every reasonable effort to ensure that Edinburgh Research Explorer content complies with UK legislation. If you believe that the public display of this file breaches copyright please contact openaccess@ed.ac.uk providing details, and we will remove access to the work immediately and investigate your claim.



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

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

5

6 R. Ward BSc BVM&S FHEA MRCVS ^{1,3}

7 M. McMillan BVM&S DipECVAA MRCVS ^{2,3}

8 C. Gittel DipECVAA MRCVS ³

9

10 1. Royal (Dick) School of Veterinary Studies, Easter Bush Veterinary Centre, Roslin, United
11 Kingdom

12 2. The Ralph Veterinary Referral Centre, Marlow, United Kingdom

13 3. Queen's Veterinary School Hospital, University of Cambridge, Cambridge, United
14 Kingdom

15

16 Corresponding Author

17 R. Ward

18 Royal (Dick) School of Veterinary Studies, Easter Bush Veterinary Centre, Roslin, United
19 Kingdom.

20 Email: Rob.Ward@ed.ac.uk.

21 Phone: +44 (0131) 6507650

22

23

24

25

26

27

28

29

30 Keywords (4-6): canine, anaesthesia, monitoring, hypothermia

31

32 Abstract

33

34 Objective

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

37

38 Methods

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

48 Results

49 In this study, 95 simultaneous temperature measurements at the 4 different sites were
50 obtained from 30 dogs. Mean difference and limits of agreement from oesophageal
51 temperature for the different measurement methods were $0.0 \pm 0.72^\circ\text{C}$ for rectal temperature,
52 $-1.2 \pm 1.42^\circ\text{C}$ for axillary and $-1.0 \pm 2.02^\circ\text{C}$ for nasal temperature. Axillary and nasal
53 temperatures were not significantly different ($p = 0.5721$ and $p = 0.9287$, respectively) from
54 oesophageal temperature with a $+1.2^\circ\text{C}$ and $+1^\circ\text{C}$ correction factor, respectively.

55

56 Conclusion and Clinical relevance.

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

60

61 Schlüsselwörter: Hund, Anästhesie, Überwachung, Hypothermie

62

63 Zusammenfassung

64

65 Gegenstand und Ziel

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

69

70 Material und Methoden

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

82

83 Ergebnisse

84 Im Rahmen dieser Studie konnten 95 simultan ermittelte Temperaturmesswerte an vier
85 verschiedenen Messlokalisationen eingeschlossen werden. Insgesamt wurden dafür 30
86 Hunde in Narkose untersucht. Die Abweichung (und „limits of agreement“) der verschiedenen
87 Messlokalisationen von der Ösophagustemperatur waren: $0,0 \pm 0,72^{\circ}\text{C}$ (Rektal), $-1,2 \pm 1,42^{\circ}\text{C}$
88 (Achselhöhle) und $-1,0 \pm 2,02^{\circ}\text{C}$ (Nase). Die ermittelten Temperaturen der Achselhöhle und
89 Nase unterschieden sich nach Anwendung eines Korrekturfaktors von $+1,2^{\circ}\text{C}$ und $+1^{\circ}\text{C}$ nicht
90 mehr signifikant von der Ösophagustemperatur ($p = 0,5721$ und $p = 0,9287$).

91

92 Schlussfolgerung und klinische Relevanz

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

97 Introduction

98 The measurement of body temperature during general anaesthesia is important as normal
99 thermoregulation is disrupted by a variety of means. Commonly used perioperative drugs such
100 as opioids and acepromazine alter the temperature set-point in the thermoregulatory centre of
101 the hypothalamus [1]. In addition, acepromazine, propofol and volatile inhalational agents
102 suppress peripheral vasoconstriction, which normally limits heat loss. Conversely, α_2 receptor
103 agonists cause peripheral vasoconstriction, which reduces the heat loss from the periphery
104 [2] and helps to maintain core body temperature.

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

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

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

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

133

134 Materials and Methods

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

137

138 Study Design

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

143

144 Animals and General Anaesthesia

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

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

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

166

167 Temperature measurement

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

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

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

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

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

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

201

202 Post-hoc data handling and statistical analysis

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

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

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

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

218 Available temperature data was split into early (at induction and ten minutes later) and late
219 measurements (20 minutes after induction and onwards). An independent t-test was used to
220 assess the difference between an early and late measurement of ΔA , ΔN and ΔR , respectively.
221 Original OT values were classified into either hypothermic ($< 37.2^{\circ}\text{C}$), normothermic (37.2 -
222 39.2°C) or hyperthermic ($> 39.2^{\circ}\text{C}$). Corresponding ΔA , ΔN and ΔR values were analysed with
223 an independent t-test to assess whether higher or lower temperature affects reliability of the
224 different methods.

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

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

232

233 Results

234 In total, 95 simultaneous temperature measurements at the 4 different sites were obtained
235 during this study. Data were taken from 30 dogs (both sexes) of different breeds and health
236 conditions, which underwent various elective surgical procedures (soft tissue and orthopaedic
237 surgeries). No breeds were excluded from the study. Enrolled dogs were aged 3.6 ± 3.24
238 years, had a bodyweight of 19.7 ± 11 kg, and had a body condition score 4.9 ± 1.3 using a 9-
239 point scale. All dogs had a simultaneous temperature reading at induction and 10 minutes
240 later. At 20 minutes under anaesthesia only 21 dogs were assessed, whereas at minute 30
241 11 dogs remained and after 40 minutes under anaesthesia only data of 3 dogs were included.
242 Overall, mean body temperature was $37.9 \pm 0.68^{\circ}\text{C}$ (OT), $37.9 \pm 0.71^{\circ}\text{C}$ for rectal
243 measurement, $36.7 \pm 0.84^{\circ}\text{C}$ for axillary and $36.9 \pm 0.98^{\circ}\text{C}$ for nasal temperature (Table 1).
244 The lowest recorded temperature was 34.0°C obtained via nasal temperature measurement

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

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

257 Temperature reading obtained by axillary and nasal measurement differed significantly from
258 OT ($p = 0.001$ for each). Axilla temperature showed a moderate positive correlation with OT
259 ($r(93) = 0.5604$, $p < 0.00001$), whereas nasal temperature showed a weak positive correlation
260 with OT ($r(93) = 0.2737$, $p < 0.007278$). Axilla and nasal temperatures were comparable with
261 a bias and LOA of $-0.2 \pm 0.72^\circ\text{C}$.

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

265 Analysis of hypothermic OT readings showed a higher average agreement of -0.3°C for
266 axillary and nasal temperature measurement than in normothermic patients (-1.3°C and -
267 1.0°C, respectively). Hyperthermic temperature readings were not separately assessed as
268 only 2 readings showed an OT above 39.2°C.

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

275

276 Discussion

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

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

282

283 There have been studies comparing temperature measurements from various sites in dogs
284 and cats with varying results, however none have examined this combination or included
285 temperature measurement from the nasal cavity previously. We chose to measure the core
286 body temperature using an oesophageal probe and rectal thermometer as these have been
287 previously shown to provide an accurate estimate of the core body temperature [11, 17, 19].

288 The most accurate assessment of core body temperature would be to place a thermistor-
289 tipped catheter into the pulmonary artery [19]; however, this is not routinely performed as it is
290 a highly invasive procedure which requires additional equipment and risks additional
291 morbidity.

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

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

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

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

317

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

329

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

342

343

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

351 has previously been examined however they did not have significant effects on heat loss [25,
352 26], and all cases in this study experienced a decrease of their body temperature. Active
353 warming with either forced air blankets or heated mats has been shown to aid maintenance of
354 body temperature [27] and may have been a source of error if the thermometer was placed
355 too close to these devices, however neither of these interventions were used in this study. The
356 temperature of the room may have influenced initial vasomotor tone during the premedication
357 phase and this was not measured, although the same room was used for all procedures and
358 the temperature maintained with an air conditioning system.

359

360 Several limitations are noted with this study. Firstly, only 30 dogs were included with the study,
361 allowing for 95 paired values for analysis. A retrospective sample size calculation aiming at
362 80% power and a type I error rate of 5% revealed 182 measurements to be necessary to
363 detect a difference of 0.2°C between OT and the measurement sites. However, due to the
364 large discrepancy for axillary and nasal temperature in comparison to OT, the obtained
365 number deemed to be sufficient to exclude comparability. Nonetheless, the results
366 demonstrating there is no significant difference between rectal and oesophageal temperature
367 need to be viewed with a certain amount of caution. A bias for the paired measurements
368 cannot be excluded, as each dog was used more than once to obtain temperature recordings
369 throughout anaesthesia. However, this bias can be neglected as the purpose of the study was
370 to compare measurement sites. A loss of paired values over anaesthesia time due to patients
371 moving to the surgical theatre occurred, which restricted analysis of comparability of central
372 and peripheral measurement sites over time. The body condition and breed of the patient were
373 not recorded for all patients. They have previously been shown to result in a difference
374 between temperature measurement between central and peripheral sites [11].

375

376 Conclusion

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

382

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

384

385 References

386

- 387 1. Monteiro ER, Junior AR, Assis HM et al. Comparative study on the sedative effects of
388 morphine, methadone, butorphanol or tramadol, in combination with acepromazine, in dogs.
389 Vet Anaesth Analg 2009; 36: 25-33. DOI: 10.1111/j.1467-2995.2008.00424.x
- 390 2. Grimm KA, Tranquilli WJ, Gross DR et al. Cardiopulmonary effects of fentanyl in
391 conscious dogs and dogs sedated with a continuous rate infusion of medetomidine. Am J Vet
392 Res 2005; 66: 1222-1226. DOI: 10.2460/ajvr.2005.66.1222
- 393 3. Frank SM, Fleisher LA, Breslow MJ et al. Perioperative maintenance of normothermia
394 reduces the incidence of morbid cardiac events. A randomized clinical trial. JAMA 1997; 277:
395 1127-1134.
- 396 4. Winkler M, Akca O, Birkenberg B et al. Aggressive warming reduces blood loss during
397 hip arthroplasty. Anesth Analg 2000; 91: 978-984. DOI: 10.1097/00000539-200010000-00039
- 398 5. Kurz A, Sessler DI, Lenhardt R. Perioperative normothermia to reduce the incidence
399 of surgical-wound infection and shorten hospitalization. Study of Wound Infection and
400 Temperature Group. N Engl J Med 1996; 334: 1209-1215. DOI:
401 10.1056/NEJM199605093341901
- 402 6. Brodeur A, Wright A, Cortes Y. Hypothermia and targeted temperature management
403 in cats and dogs. J Vet Emerg Crit Care (San Antonio) 2017; 27: 151-163. DOI:
404 10.1111/vec.12572
- 405 7. Reynolds L, Beckmann J, Kurz A. Perioperative complications of hypothermia. Best
406 Pract Res Clin Anaesthesiol 2008; 22: 645-657. DOI: 10.1016/j.bpa.2008.07.005
- 407 8. Brodbelt DC, Blissitt KJ, Hammond RA et al. The risk of death: the confidential enquiry
408 into perioperative small animal fatalities. Vet Anaesth Analg 2008; 35: 365-373. DOI:
409 10.1111/j.1467-2995.2008.00397.x
- 410 9. Bruniges N, Rioja E. Intraoperative anaesthetic complications in dogs undergoing
411 general anaesthesia for thoracolumbar hemilaminectomy: a retrospective analysis. Vet
412 Anaesth Analg 2019; 46: 720-728. DOI: 10.1016/j.vaa.2019.05.013
- 413 10. Lenhardt R, Grady M, Kurz A. Hyperthermia during anaesthesia and intensive care
414 unit stay. Best Pract Res Clin Anaesthesiol 2008; 22: 669-694. DOI:
415 10.1016/j.bpa.2007.11.001
- 416 11. Lamb V, McBrearty AR. Comparison of rectal, tympanic membrane and axillary
417 temperature measurement methods in dogs. Vet Rec 2013; 173: 524. DOI: 10.1136/vr.101806
- 418 12. Sousa MG, Carareto R, Pereira-Junior VA et al. Agreement between auricular and
419 rectal measurements of body temperature in healthy cats. J Feline Med Surg 2013; 15: 275-
420 279. DOI: 10.1177/1098612X12464873

- 421 13. Konietschke U, Kruse BD, Muller R et al. Comparison of auricular and rectal
422 temperature measurement in normothermic, hypothermic, and hyperthermic dogs. *Tierarztl*
423 *Prax Ausg K Kleintiere Heimtiere* 2014; 42: 13-19.
- 424 14. Gomart SB, Allerton FJ, Gommeren K. Accuracy of different temperature reading
425 techniques and associated stress response in hospitalized dogs. *J Vet Emerg Crit Care (San*
426 *Antonio)* 2014; 24: 279-285. DOI: 10.1111/vec.12155
- 427 15. Sousa MG, Carareto R, Pereira-Junior VA et al. Comparison between auricular and
428 standard rectal thermometers for the measurement of body temperature in dogs. *Can Vet J*
429 2011; 52: 403-406.
- 430 16. Lefrant JY, Muller L, de La Coussaye JE et al. Temperature measurement in intensive
431 care patients: comparison of urinary bladder, oesophageal, rectal, axillary, and inguinal
432 methods versus pulmonary artery core method. *Intensive Care Med* 2003; 29: 414-418. DOI:
433 10.1007/s00134-002-1619-5
- 434 17. Hayes JK, Collette DJ, Peters JL et al. Monitoring body-core temperature from the
435 trachea: comparison between pulmonary artery, tympanic, esophageal, and rectal
436 temperatures. *J Clin Monit* 1996; 12: 261-269. DOI: 10.1007/BF00857648
- 437 18. Bindu B, Bindra A, Rath G. Temperature management under general anesthesia:
438 Compulsion or option. *J Anaesthesiol Clin Pharmacol* 2017; 33: 306-316. DOI:
439 10.4103/joacp.JOACP_334_16
- 440 19. Greer RJ, Cohn LA, Dodam JR et al. Comparison of three methods of temperature
441 measurement in hypothermic, euthermic, and hyperthermic dogs. *J Am Vet Med Assoc* 2007;
442 230: 1841-1848. DOI: 10.2460/javma.230.12.1841
- 443 20. Parker EO, 3rd. Electrosurgical burn at the site of an esophageal temperature probe.
444 *Anesthesiology* 1984; 61: 93-95.
- 445 21. Goic JB, Reineke EL, Drobatz KJ. Comparison of rectal and axillary temperatures in
446 dogs and cats. *J Am Vet Med Assoc* 2014; 244: 1170-1175. DOI: 10.2460/javma.244.10.1170
- 447 22. Cichocki B, Dugat D, Payton M. Agreement of Axillary and Auricular Temperature with
448 Rectal Temperature in Systemically Healthy Dogs Undergoing Surgery. *J Am Anim Hosp*
449 *Assoc* 2017; 53: 291-296. DOI: 10.5326/JAAHA-MS-6500
- 450 23. Nakamura K. Central circuitries for body temperature regulation and fever. *Am J*
451 *Physiol Regul Integr Comp Physiol* 2011; 301: R1207-1228. DOI:
452 10.1152/ajpregu.00109.2011
- 453 24. Kuht J, Farmery A. Body temperature and its regulation. *Anaesthesia & Intensive Care*
454 *Medicine* 2014; 15: 273-278.

455 25. Khenissi L, Covey-Crump G, Knowles TG et al. Do heat and moisture exchangers in
456 the anaesthesia breathing circuit preserve body temperature in dogs undergoing anaesthesia
457 for magnetic resonance imaging? Vet Anaesth Analg 2017; 44: 452-460. DOI:
458 10.1016/j.vaa.2016.05.016

459 26. Hofmeister EH, Brainard BM, Braun C et al. Effect of a heat and moisture exchanger
460 on heat loss in isoflurane-anesthetized dogs undergoing single-limb orthopedic procedures. J
461 Am Vet Med Assoc 2011; 239: 1561-1565. DOI: 10.2460/javma.239.12.1561

462 27. Clark-Price SC, Dossin O, Jones KR et al. Comparison of three different methods to
463 prevent heat loss in healthy dogs undergoing 90 minutes of general anesthesia. Vet Anaesth
464 Analg 2013; 40: 280-284. DOI: 10.1111/vaa.12010

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

471

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

474 Abbildung 1: Bland-Altman-Graph der wiederholt gemessenen Körpertemperatur von 30
475 Hunden in Allgemeinanästhesie an verschiedenen Lokalisationen a) Rektal b) Achselhöhle
476 c) Nasenhöhle) im Vergleich zum Goldstandard (ösophageale Temperatur) © C. Gittel
477

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

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

483

484

485

486