Comparison of auricular and rectal temperature measurement in normothermic, hypothermic, and hyperthermic dogs

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Key words
Infrared ear thermometry, rectal thermometry, canine, correlation

Summary
Objective: Measurement of rectal temperature is the most common method and considered gold standard for obtaining body temperature in dogs. So far, no study has been performed comparing agreement between rectal and auricular measurements in a large case series. The purpose of the study was to assess agreement between rectal and auricular temperature measurement in normothermic, hypothermic, and hyperthermic dogs with consideration of different environmental conditions and ear conformations. Materials and methods: Reference values for both methods were established using 62 healthy dogs. Three hundred dogs with various diseases (220 normothermic, 32 hypothermic, 48 hyperthermic) were enrolled in this prospective study. Rectal temperature was compared to auricular temperature and differences in agreement with regard to environmental temperature, relative humidity, and different ear conformations (pendulous versus prick ears) were evaluated using Pearson’s correlation coefficient and Bland-Altman analysis. Results: Correlation between rectal and auricular temperature was significant (r: 0.892; p < 0.01). However, Bland-Altman plots showed an unacceptable variation of values (bias: 0.300 °C; limits of agreement: −0.606 to 1.206 °C). This variation was above a maximal clinical tolerance of 0.3 °C, which was established by experts’ opinion (n = 16). Relative humidity had a significant influence (p = 0.001), whereas environmental temperature did not. Conclusion: Variation between the two methods of measuring body temperature was clinically unacceptable. Clinical relevance: Although measurement of auricular temperature is fast, simple, and well tolerated, this method provides a clinically unacceptable difference to the rectal measurement.

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Schlüsselwörter
Infrarote Ohr-Thermometrie, rektale Thermometrie, kanin, Korrelation

Zusammenfassung

Vergleich zwischen aurikularer und rektaler Temperaturmessung bei normothermen, hypothermen und hyperthermen Hunden
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Introduction

Determination of body temperature is an important part of the physical examination in veterinary medicine (8, 13, 16, 17). Traditionally, rectal temperature measurement has been the most common method for obtaining body temperature in dogs and cats and is considered to be the gold standard. Auricular thermometers have originally been developed for human use to provide temperature measurements less invasively (5, 10). Studies show that auricular thermometry is fast and well tolerated in dogs and cats (6, 13, 16, 17).

Only few studies with low case numbers exist, which have examined the accuracy of different temperature measurements in hypothermic and hyperthermic dogs (10, 17). The results of recent investigations are indicative that auricular and rectal temperature readings should not be interpreted interchangeably in dogs and cats, but rather compared against a reference range of temperatures for that particular site (6, 11, 16). So far, no study has been performed examining the influence of different environmental conditions and ear conformations on both methods of temperature measurements.

The purpose of this study was to evaluate agreement between rectal and auricular temperature measurement in a large case series of normothermic, hypothermic, and hyperthermic dogs with consideration of environmental conditions (environmental temperature, relative humidity) and ear conformations (pendulous versus prick ears; Fig. 1).

Materials and methods

Establishment of reference ranges and experts’ opinion

Reference values for the rectal and auricular temperature measurements were established to subsequently classify the patients and to investigate different temperature ranges. For the establishment of reference values, 62 healthy staff-owned dogs were used. These dogs were assessed to be healthy according to the history and physical examination. Temperature measurements were obtained in exactly the same matter as described for the patients in the paragraph below.

Experts’ opinion (n = 16) was established to define the maximal clinically acceptable difference between rectal and auricular temperature measurements. Experts compassed Diplomates of ECVIM-CA (n = 11), ECVS (n = 2), ECVN (n = 1), ECVA (n = 1), and ECVDI (n = 1).

Animals

A total of 300 dogs (220 normothermic, 32 hypothermic, 48 hyperthermic) were included in this prospective study. In a retrospective power analysis the sample size of each patient group was sufficient to detect the significant difference at the level of 0.05 with a power of 99%.

Between November 2010 and August 2012, dogs were presented at the Clinic of Small Animal Medicine, Department of Veterinary Medicine, University of Munich and at the Small Animal Clinic Haar for either routine vaccination and health care or for the management of various diseases including internal medicine and surgical cases. There were no exclusion criteria. Also dogs with otitis externa were not excluded, because a previous study has shown, that otitis externa does not affect the accuracy of auricular thermometry (7). Neither were dogs excluded, that underwent anesthesia, because it was assumed that anesthesia-induced hypothermia would equally affect rectal and auricular temperature.

Rectal and auricular temperature measurements

Body temperatures were first obtained by rectal thermometry. The same digital thermometer was used for all dogs. Prior to temperature measurements, the digital thermometer was covered with a one-way plastic sheath made for the device. It was inserted a minimum of 2 cm into the rectum, where it remained until an audible endpoint signal was heard. The thermometer was not removed from the rectum and a second measurement was performed immediately after the first one. Mean rectal temperature was calculated from duplicate measurements with 95% confidence interval.

The auricular thermometry was performed immediately after rectal temperature measurements. A human infrared thermometer was chosen, because it was evaluated as the most reliable thermometer by Stiftung Warentest, an independent foundation testing product quality (18). After application of a probe cover designed to use for that thermometer, the infrared thermometer was positioned in the dogs’ ear canal as deep as possible until an au-

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1. Digitales Fieberthermometer, Scala SC 37 T, Scala Electronic GmbH, Grünwald, Germany
2. Infrarot-Ohr-Thermometer, ThermoScan IRT 4020, Braun GmbH, Kronberg, Germany
dible signal was heard indicating termination of measurement (▶ Fig. 2). For each ear a new probe cover was used, and the thermometer was shortly removed between each measurement to record the reading. Auricular measurements were also performed in duplicate in both ears of each dog. The mean auricular temperature was calculated from all four auricular measurement readings. Reproducibility of temperature measurements was examined and agreement between both methods was assessed.

**Potential influencing factors**

According to the established reference values, dogs were classified into three different temperature ranges based on their mean rectal temperature. Dogs with a mean rectal temperature ranging from 37.2 to 39.2 °C were classified as normothermic (n = 220), whereas dogs with lower and higher rectal temperature measurements were classified in the hypothermic (n = 32) and hyperthermic range (n = 48), respectively. Dogs that were classified in the hypothermic group had partially been under anesthesia for various reasons. Dogs that were grouped in the hyperthermic category were either hyperthermic due to various reasons (high environmental temperature, excitement, seizures) or they were febrile due to inflammatory, immune-mediated, or neoplastic diseases.

According to their ear conformations, dogs were classified in pendulous (n = 167) versus prick ears (n = 133).

The environmental temperature and relative humidity was recorded by use of a digital thermo-hygrometer for each temperature recording.

**Statistical analysis**

Correlations between duplicates and means of rectal and auricular measurements were calculated using Pearson’s correlation coefficient. Agreement between rectal and auricular temperature measurements was assessed using Bland-Altman plots, in which the differences between both methods were plotted against their average temperature and the limits of agreement calculated (1). Correlations between environmental temperature, relative humidity, ear conformations, and rectal and auricular temperature measurements were tested using linear regression and analysis of variance (ANOVA). The level of significance was set at 0.05. IBM SPSS Statistics 20 and GraphPad Prism 6 were used.

**Results**

**Reference ranges and experts’ opinion**

Mean rectal measurements of duplicate readings in 62 dogs used to establish reference ranges ranged from 37.2 to 39.3 °C (mean 38.1 °C, 95% confidence interval 38.0–38.3 °C). Mean auricular measurements in those 62 dogs ranged from 37.1 to 39.1 °C (mean 38.2 °C, 95% confidence interval 38.0–38.3 °C). Agreement between rectal and auricular temperature measurements was assessed using Bland-Altman plots, in which the differences between both methods were plotted against their average temperature and the limits of agreement calculated (1). Correlations between environmental temperature, relative humidity, ear conformations, and rectal and auricular temperature measurements were tested using linear regression and analysis of variance (ANOVA). The level of significance was set at 0.05. IBM SPSS Statistics 20 and GraphPad Prism 6 were used.

### Table 1

<table>
<thead>
<tr>
<th></th>
<th>Rectal 1 – rectal 2</th>
<th>Auricular right 1 – right 2</th>
<th>Auricular left 1 – left 2</th>
<th>Rectal – auricular</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson’s</td>
<td>0.998</td>
<td>0.963</td>
<td>0.964</td>
<td>0.892</td>
</tr>
<tr>
<td></td>
<td>p 0.010</td>
<td>0.010</td>
<td>0.010</td>
<td>0.010</td>
</tr>
<tr>
<td>Bland Altman</td>
<td>–0.058</td>
<td>–0.022</td>
<td>0.033</td>
<td>0.300</td>
</tr>
<tr>
<td></td>
<td>95% limits of agreement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>from (°C)</td>
<td>–0.196</td>
<td>–0.567</td>
<td>–0.501</td>
<td>–0.606</td>
</tr>
<tr>
<td>to (°C)</td>
<td>0.079</td>
<td>0.523</td>
<td>0.567</td>
<td>1.206</td>
</tr>
</tbody>
</table>

3 Digital Thermo-Hygrometer TFA 305011 Comfort Control, Dostmann GmbH, Wertheim, Germany
38.2 °C, 95% confidence interval 38.1–38.3 °C). Reference range for rectal thermometry was set at 37.2–39.2 °C.

By experts’ opinion the maximal clinically acceptable difference between rectal and auricular temperature measurements was defined at 0.3 °C.

Rectal and auricular temperature measurements

The mean of two repeated rectal measurements in 300 patients ranged from 34.0 to 40.9 °C (mean 38.2 °C). The mean of four auricular measurements in these dogs ranged from 34.3 to 40.7 °C (mean 38.1 °C). Table 1 includes Pearson’s correlation coefficients and results of Bland-Altman analysis of temperature measurements in 300 dogs showing a significant correlation between duplicate measurements of rectal temperature (r: 0.998; p < 0.01) and auricular temperature (r: 0.963–0.964, p < 0.01). Mean rectal and auricular temperature also correlated well (r: 0.892; p < 0.01). The scatter plots revealed almost no variation of values between duplicate rectal readings (Fig. 3a), but a wider variation of values between duplicate auricular measurements (Fig. 3b). The variation between mean rectal and mean auricular values is shown by a Bland-Altman analysis (Fig. 4). The plot shows the differences in temperature between rectal and auricular measurements plotted against their average temperature. The continued line represents the mean and is the best possible estimation of the unknown true temperature. The dashed lines represent the limits of agreement (loa: –0.606 to 1.206 °C). Regarding the limits of agreement, the variation between both methods was above the maximal clinical tolerance of 0.3 °C, which was established by experts’ opinion.

Results of auricular measurements were obtained within 3–4 seconds compared to rectal thermometry yielding readings approximately after 30 seconds. The auricular method was better tolerated in most dogs.

Influencing factors

Table 2 gives the difference versus average of the different temperature ranges and ear conformations between mean rectal and
Discussion

The measurement of body temperature is an important part of the physical examination in dogs to assess the overall condition of a patient and to monitor response to treatment during illness. Placing a mildly invasive contact thermometer against the rectal mucosa usually is the most common method for obtaining body temperature in dogs and is considered gold standard (7, 16, 17). Measurements gained by use of rectal thermometers provide the closest agreement with core body temperature compared to other devices (10). Most studies use surrogates as the rectal method, although the rectum might also suffer from disadvantages, as there is a lag between changes in arterial temperature and the reflection of this in the rectal temperature (9). However, rectal temperature measurement can be stressful for the patient, time consuming, can be influenced by feces in the rectum and can even be a source of cross contamination (5, 10, 13).

Auricular thermometers were originally developed for human use to obtain temperature less invasively (3, 5). The use of auricular non-invasive non-contact thermometers in veterinary medicine became recently popular due to better patient compliance and shorter time needed to obtain body temperature (16, 17). Auricular infrared thermometry measures core body temperature by assessing heat emanating from the tympanic membrane and inner surface of the external ear canal (13, 17). The tympanic membranes’ vascularization is provided by the internal carotid arteries that also perfuse the hypothalamus being responsible for body temperature regulation (2, 13, 17). Typically, tympanic thermometry readings are lower than the core body temperature (6, 8, 10, 13, 17). A possible explanation for this finding might be cerumen, fluid, or inflammation products coating the surface of the ear canal and tympanic membrane. Interestingly, auricular thermo-

Table 2  Comparison of rectal and auricular temperature measurements in normothermic, hypothermic and hyperthermic dogs with pendulous and prick ears (statistical method: Bland-Altman analysis). The temperature ranges were based upon the mean rectal temperature. SD = standard deviation.

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>bias (°C)</th>
<th>SD of bias (°C)</th>
<th>95% limits of agreement from (°C) to (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>temperature</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>normothermic</td>
<td>220</td>
<td>0.300</td>
<td>0.442</td>
<td>–0.566 – 1.167</td>
</tr>
<tr>
<td>hypothermic</td>
<td>32</td>
<td>0.059</td>
<td>0.657</td>
<td>–1.228 – 1.347</td>
</tr>
<tr>
<td>hyperthermic</td>
<td>48</td>
<td>0.465</td>
<td>0.306</td>
<td>–0.136 – 1.065</td>
</tr>
<tr>
<td>ear</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pendulous</td>
<td>167</td>
<td>0.365</td>
<td>0.384</td>
<td>–0.389 – 1.118</td>
</tr>
<tr>
<td>prick</td>
<td>133</td>
<td>0.219</td>
<td>0.537</td>
<td>–0.833 – 1.271</td>
</tr>
</tbody>
</table>

Table 3  Influence of environmental temperature and relative humidity on mean rectal and auricular temperature in 300 dogs (statistical method: linear regression and ANOVA). Beta = standardized coefficient; p = significance; R² = coefficient of determination.

<table>
<thead>
<tr>
<th></th>
<th>Mean rectal temperature</th>
<th>Mean auricular temperature</th>
<th>Pendulous ears</th>
<th>Prick ears</th>
</tr>
</thead>
<tbody>
<tr>
<td>environmental temperature</td>
<td>–0.036</td>
<td>0.041</td>
<td>–0.014</td>
<td>0.100</td>
</tr>
<tr>
<td>p</td>
<td>0.568</td>
<td>0.506</td>
<td>0.867</td>
<td>0.278</td>
</tr>
<tr>
<td>relative humidity</td>
<td>0.218</td>
<td>0.257</td>
<td>0.241</td>
<td>0.074</td>
</tr>
<tr>
<td>p</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>0.005</td>
<td>0.003</td>
</tr>
<tr>
<td>both</td>
<td>0.042</td>
<td>0.077</td>
<td>0.055</td>
<td>0.109</td>
</tr>
</tbody>
</table>

mean auricular temperature values. Results of Bland-Altman analysis were slightly better in the normothermic and hyperthermic range compared to the hypothermic range.

Dogs with pendulous ears had a lower variation between rectal and auricular temperature than patients with prick ears (Table 2), though still above the maximal clinical tolerance of 0.3 °C.

Environmental temperature ranged from 12.6 to 31.8 °C (mean 25.2 °C). Relative humidity ranged from 17.4 to 63.4% (mean 38.8%) and had a significant influence on mean rectal and auricular temperature, whereas environmental temperature did not. Differentiating the ear type did not alter these results (Table 3).
metry in dogs with otitis externa has been evaluated to provide accurate and reliable readings in one study (7). However, another study concluded that otitis externa did have a significant influence on external ear canal temperature in dogs (11), as did the amount of hair within the external ear canal (12).

The establishment of reference values in healthy dogs (n = 62) yielded mean rectal temperature measurements ranging from 37.2 to 39.2 °C. The upper limit of the rectal temperature considered to be normal in healthy dogs agrees with the data from literature (10, 14). However, the lower limit of the rectal temperature is poorly defined in veterinary literature. In humans and other species severe hypothermia is defined as a core body temperature below 35 °C (19). In the study of Greer et al. (10) using eight healthy dogs, hypothermia was defined as a core body temperature below 37.8 °C. However, this limit was not referenced. Reference values of auricular temperature measurements in healthy dogs have not been established in veterinary medicine.

Duplicate measurements of rectal temperature in 300 dogs with various temperature ranges highly correlated in Pearson’s correlation analyzes, and Bland-Altman plots displayed minimal variation. This high reproducibility of values shows a high degree of precision of the method. Correlation of duplicate auricular measurements was good; however, Bland-Altman analysis revealed variation in duplicate measurements giving this method a lower precision. Although association between means of both methods was good using Pearson’s correlation analysis, Bland-Altman plots showed an unacceptable variation of values (Table 1).

If a maximal discrepancy of 0.3 °C is considered clinically acceptable, which was established by experts’ opinion, this lack of accuracy is in accordance with previous studies (10, 16). In the literature, there is no standard defined, evaluating which difference of temperature between two methods is considered valid. Therefore the experts’ opinion was necessary.

To date, no study exists examining the agreement between auricular and rectal temperature measurement in such a large case series of dogs among different temperature ranges as in the current study. In the study of Sousa et al. (16), auricular and rectal temperature was measured in 88 healthy dogs. The authors found a lack of agreement between the two types of body temperature measurements arbitrarily considering an error greater than 0.5 °C to be clinically unacceptable. This finding agrees with the results of the present study, where the maximal acceptable discrepancy, though, was set at 0.3 °C. However, measurements among different temperature ranges, environmental conditions and ear types were not investigated in the previously mentioned study.

In the study of Greer et al. (10) the accuracy of a rectal thermometer, an infrared auricular thermometer, and a subcutaneous temperature-sensing microchip for measurement of core body temperature over various temperature conditions was assessed in eight research dogs. The variability between duplicate measurements was greatest for the auricular thermometer. The authors of this study concluded, that among the three methods of temperature measurement, rectal thermometry provided the most accurate estimation of core body temperature. However, another study concluded that there was a strong correlation between rectal and auricular temperature in a small group of hypothermic research dogs (n = 8) indicating auricular measurement to be an accurate estimate of core body temperature (17).

In the current study correlation between both methods was slightly better in dogs of the normothermic and hyperthermic range compared to dogs with hypothermic body temperature. This is in contrast to results of previous studies showing more accurate auricular thermometry at hypothermic temperatures in dogs, cats, and children (4, 10, 13, 17). The slightly worse correlation in the hypothermic range might be explained by centralization of the circulation during hypothermia leading to reduced auricular perfusion compared to the rectal mucosa.

Discrepancy between rectal and auricular temperature measurement was slightly higher in dogs with prick ears compared to dogs with pendulous ears (Table 2). This finding might be explained by the easier use of the infrared thermometer in dogs with pendulous ears. Pendulous pinnae are more applicable to fit the infrared thermometer in the external ear canal. In addition, prick ears might be more prone to convection than pendulous ears. However, temperature readings were still clinically unacceptable when compared to the rectal method. Comparison of auricular temperature measurements with respect to the dogs’ ear conformation was performed in two previous studies (6, 12). In one study the highest level of agreement was found among the dogs with upright ears, which contrasts the results of the present study. The author of the other study did not find any significant differences between dogs with erect and pendulous auricles (12).

Unlike the environmental temperature, the relative humidity did have a weak significant influence on the rectal and auricular temperature. The coefficient of determination (R²) indicates, that 4.2% of the rectal temperature and 7.7% of the auricular temperature were influenced by the environmental temperature and the relative humidity combined (Table 3), which is, however, clinically irrelevant. External influences on tympanic temperature have been studied in children (15) and in dogs (12). Results of the human and the canine study showed the opposite: There was a correlation between environmental temperature and tympanic temperature, but no significant correlation between relative humidity and external ear canal temperature. An influence of external factors, such as environmental humidity, upon auricular temperature is suspected as in warmer conditions evaporation might be an important method of heat loss. An influence of external factors for rectal temperature measurements has not been studied.

Conclusion for practice

Although measurement of auricular temperature in dogs is fast, simple, and well tolerated, this method provides a clinically unacceptable difference to the rectal temperature measurement.
For the present study, the above mentioned human infrared thermometer and the digital rectal thermometer were chosen by intention, because they were evaluated as the most reliable thermometers by Stiftung Warentest (18). However, the use of an infrared thermometer that is developed for use in humans might give inaccurate and inconsistent results when used in veterinary patients due to the difference in ear canal anatomy (7, 10, 13). Only few studies with few case numbers exist, in which a veterinary device was used (7, 10, 13, 17). The results were similar unacceptable. The discrepancy in accuracy between human and veterinary infrared thermometers measuring auricular temperature in dogs has not been studied and warrants further investigation.

The limitation of the present study is, that the extent to which rectal and auricular thermometry is or is not indicative of the "true" core body temperature, was not addressed. The rectal thermometry was used as gold standard, but this method also reflects only an estimation of the true core body temperature (8). Another limitation of the study is, that rectal and auricular thermometry was not performed simultaneously to avoid increased stress situations for the dogs. Rectal temperature measurement was performed immediately prior to auricular thermometry. Excitement and stress elicited by rectal thermometry might have influenced the readings of auricular temperature.

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

References