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EVALUATION OF THE ACCURACY OF DIFFERENT METHODS OF MONITORING BODY TEMPERATURE IN ANESTHETIZED BROWN BEARS (*URSUS ARCTOS*)

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Abstract: There is some evidence that the handheld rectal thermometer does not accurately measure core temperature in bears. The objective of this study was to compare body temperature measured by the handheld digital thermometer (HDT), deep rectally inserted core temperature capsules (CTCs), and gastrically inserted CTCs in anesthetized brown bears (*Ursus arctos*). Twenty-two brown bears were immobilized with a combination of zolazepam-tiletamine and xylazine or medetomidine. After immobilization, one CTC was inserted 15 cm deep into the animal's rectum (DRTC) with a standard applicator, and another CTC was inserted into the stomach (GTC) via a gastric tube inserted orally. Temperature was measured every 5–10 min with an HDT. Paired temperature data points were analyzed with the Bland–Altman technique for repeated measurements and regression analysis with a significance level of 0.05. The mean difference ± SD of the difference between HDT and GTC readings was 0.27 ± 0.47°C and the 95% limits of agreement (LoA) were 1.20 and –0.66°C. The determination coefficient (r^2) found between these methods was 0.68 ($P < 0.0001$). The mean difference ± SD of the difference between HDT and DRTC readings was 0.36 ± 0.32°C and the 95% LoA were 1.0 and –0.28°C. The r^2 between HDT and DRTC was 0.83 ($P < 0.0001$). The mean difference ± SD of the difference between the two insertions of the VitalSense® capsules was –0.06 ± 0.24°C and the 95% LoA were 0.42 and –0.54°C. The r^2 found between GTC and DRTC was 0.91 ($P < 0.0001$). This study demonstrates that DRTC provided accurate measurement of core temperature and that HDT did not accurately measure core temperature, compared with GTC in anesthetized brown bears.

Key words: Agreement, anesthesia, brown bear, temperature, thermometer, *Ursus arctos.*

INTRODUCTION

The brown bear (*Ursus arctos*) is classified as a Least Concern species in the International Union for Conservation of Nature Red List of Threatened Species™.[16] There are several small populations of brown bears that are currently threatened due to recurrent contact with humans and human infrastructure.[15] These populations must be closely monitored to ensure the health and conservation of this species. Handling bears typically requires chemical immobilization to ensure staff safety. Hyperthermia is a commonly encountered complication during capture and handling of wild animals.[6,8,10,16] Hyperthermia commonly occurs in bears during capture and handling.[4,9,12,17,19] In some instances, hyperthermia was related to death in bears.[4,12] An accurate measurement of core temperature is required to correctly diagnose and treat hyperthermia. Currently, handheld thermometers are a commonly used method to monitor body temperature during anesthesia of bears.[3–5,9,12] The accuracy of this monitoring technique has not been established in bears.

Core temperature capsules (CTCs) are designed to be swallowed by human patients, as stomach temperature is an accurate measurement of core temperature.[14] Wild carnivores must be anesthetized and gastrically intubated for placement of these capsules into the stomach. The objective of this study was to compare body temperatures measured by handheld digital thermometer (HDT), deep rectal insertion of CTCs, and gastric insertion of CTCs in anesthetized brown bears. Our goal was to determine the accuracy of the

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current standard technique (HDT) against core temperature measured by gastrically inserted CTCs. A further goal was to determine whether deep rectally inserted CTCs will provide an accurate measurement of core temperature compared with gastrically inserted CTCs.

MATERIALS AND METHODS

Captures

The present study was approved by the Animal Care Committee of the University of Calgary, Canada (protocol SHC11R-06) and the Ethical Committee on Animal Experiments, Uppsala, Sweden (application 07/12). Twenty-one subadult and adult brown bears of both sexes were captured for ongoing studies of the Foothills Research Institute's Grizzly Bear Program (FGBP) ($n = 8$) and the Scandinavian Brown Bear Research Project (SBBRP) ($n = 13$). Within the FGBP, the captures occurred in the province of Alberta, Canada, in June 2011 and May, June, and September 2012. Within the SBBRP, the captures occurred in the county of Dalarna, Sweden, in April and June 2011 and in April and August 2012. Within the SBBRP, the bears were chemically immobilized with a combination of 4.37 ± 1.49 mg/kg (2.5–8.3 mg/kg) [mean ± SD (range)] of zolazepam-tiletamine (Zoletil Forte vet., Virbac S.A., Carros 06510, France) and 0.15 ± 0.25 mg/kg (0.05–0.98 mg/kg) of medetomidine (Domitor® vet. or Zalopine, Orion Pharma Animal Health, Espoo FI-02101, Finland; 1 and 10 mg/ml, respectively). The bears captured within the FGBP were chemically immobilized with a combination of 5.10 ± 1.67 mg/kg (3.81–7.01 mg/kg) of zolazepam-tiletamine (Telazol®, Fort Dodge Animal Health, Fort Dodge, Iowa 50501, USA) and 3.37 ± 1.10 mg/kg (2.51–4.63 mg/kg) of xylazine (xylazine, Bow Valley Research Inc., Calgary, Alberta T2N 4G3, Canada; 300 mg/ml). These drugs were injected i.m. using a low-impact darting system following helicopter pursuit (all bears within SBBRP and two bears within FGBP) or capture with culvert traps (six bears within FGBP). At the end of the anesthetic procedure, all bears within the FGBP received atipamezole at a dose of 0.2 mg/kg (Antisedan®, Novartis Animal Health Canada, Inc., Mississauga, Ontario L5N 1V9, Canada; 5 mg/ml) i.m. All bears captured within the SBBRP received atipamezole (Antisedan® vet., Orion Pharma Animal Health; 5 mg/ml) i.m. at five times the dose of medetomidine, at the end of the anesthetic procedure.

Instrumentation

After immobilization, one CTC (Capsule Sensor, Mini-Mitter Company, Inc., A Respironics Company, Bend, Oregon 97701, USA) was inserted 15 cm deep into the animal's rectum (DRTC), with a standard applicator, and another capsule was inserted into the stomach via an orally inserted gastric tube (GTC). To ensure the gastric placement of the capsules, air was blown into the gastric tube to induce borborygmi in the stomach. The capsules were only inserted into the tube and blown into the stomach when the auscultation of borborygmi was positive. Gastric placement of the CTCs was only performed in bears captured within the SBBRP, due to animal use protocol restrictions within the FGBP. Before insertion, all capsules were activated with the VitalSense® (VS) monitor (Mini-Mitter Company, Inc., A Respironics Company). Transmission of data from the CTCs to the VS monitor began approximately 1 min after activation and continued remotely every 15 sec thereafter.

During the anesthetic procedure, heart rate (HR) was monitored via auscultation, respiratory rate (RR) was monitored via observation of respiratory movements, and rectal temperature was monitored with a standard HDT (DUOFLEX/PXR®, Rexall Brands Corp., Mississauga, Ontario L5M 0R4, Canada); these variables were recorded on a monitoring sheet.

Data from the DRTC and GTC were compared between each other and against the temperature measured with a standard HDT. The temperature was measured with a HDT as often as possible, at intervals of 5–10 min, to provide paired data. The HDT was inserted 8 cm into the bear's rectum, and its tip was directed toward the rectal mucosa to improve contact. The temperature was recorded after the audible alert, signaling the completion of temperature measurement by the HDT.

Data analysis

To guarantee equilibration of the capsule with body temperature, paired data points were included in the analysis only after three consecutive measurements without a difference greater than 0.05°C were observed. Paired data points were analyzed with the Bland–Altman's technique corrected for repeated measurements in the same subject.[1] The correction consists of estimating two variances: variance for the differences of each method in the same subject and variance for differences between the averages of the two methods across the subjects. These variances are then incorporated into the calculation of precision.[1]

Regression analysis was performed to obtain the determination coefficient (r^2) and to determine whether the temperature varied between methods in the same manner. The determination coefficient was considered significant if $P < 0.05$. All statistical analyses were performed on IBM SPSS 20 (IBM SPSS® Statistics for Windows, Version 20.0, Armonk, New York 10504, USA) or Prism 6 (GraphPad® Prism, Version 6 for Windows, GraphPad Software, La Jolla, California 92037, USA).

To determine whether the agreement between the two methods was clinically acceptable, the inherent accuracy of the CTCs, provided by the manufacturer, was summed to an acceptable agreement established for humans.[2] The accuracy of the CTCs according to the manufacturer is ±0.1°C. The acceptable agreement established for humans is a mean difference less than or equal to ±0.1°C and the 95% LoA within ±0.4°C.[2] Hence, in the present study, an acceptable agreement between the two methods was considered when the mean difference was within ±0.2°C and 95% LoA within ±0.4°C. This adjustment was made based on what is described in human subjects.[7]

RESULTS

Body temperature measured with HDT, DRTC, and GTC is summarized in Table 1. The the mean ± SD (range) HR and RR was 62 ± 15 (22–100) beats/min and 10 ± 5 (1–46) breaths/min, respectively. The mean difference ± SD (range) of the difference between HDT and GTC (GTC – HDT) readings was 0.27 ± 0.47°C, and the 95% LoA were 1.2 and –0.66°C (Fig. 1). The two methods had a significant positive correlation: $r^2 = 0.68$ ($P < 0.0001$) (Fig. 2). The mean difference ± SD (range) of the difference between HDT and DRTC (DRTC – HDT) readings was 0.36 ± 0.32°C, and the 95% LoA were 1.0 and –0.28°C (Fig. 3). The correlation between these methods was also positive and significant: $r^2 = 0.83$ ($P < 0.0001$) (Fig. 4). When comparing the two insertion methods of the CTCs (GTC – DRTC), the mean difference ± SD (range) of the difference was –0.15 ± 0.36°C, and the 95% LoA were 0.57 and –0.87°C. However, when observing the distribution of the paired samples, extreme outliers were identified. All outlier paired samples were collected from the same bear that had a gastric temperature that was remarkably lower than the deep rectal temperature. When outlier data were removed from the analyses, the mean difference ± SD of the difference changed to –0.06 ± 0.24°C, and the 95% LoA changed to 0.42 and –0.54°C (Fig. 5). The r^2 value found between GTC and DRTC after the exclusion of the outlier was 0.91 ($P < 0.0001$) (Fig. 6).

Table 1. Mean ± SD and range of temperatures measured by handheld digital thermometer (HDT), and gastrically (GTC) and deep rectally (DRTC) inserted core temperature capsules in anesthetized brown bears ($n = 21$).

Temperature monitor	Mean ± SD (°C)	No. of readings	Range (°C)
HDT	39.29 ± 1.02	217	36.50–40.56
GTC	37.02 ± 2.29	1,234	33.44–40.51
DRTC	37.48 ± 2.05	2,880	33.42–41.79

DISCUSSION

When the HDT was compared to core body temperature measured by the gastrically inserted CTCs, HDT had a greater mean difference and wider 95% LoA than that considered acceptable in the present study. There was a positive and significant correlation between the readings of the HDT and GTC; however, the agreement between them is not acceptable according to these stan-

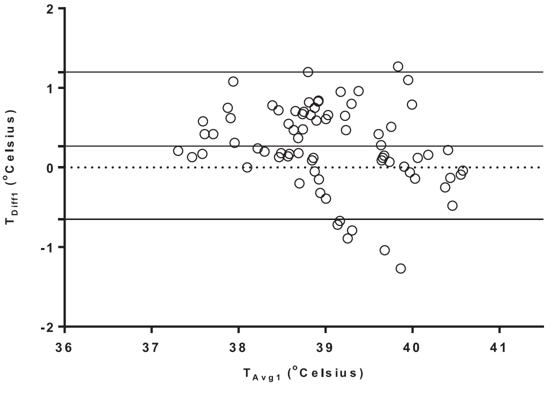

Figure 1. Bland–Altman plot of body temperature values measured concurrently by a handheld digital thermometer (HDT) and gastrically inserted core temperature capsules (GTC) in anesthetized brown bears ($n = 9$). T_{AVG1} is the average between simultaneous readings of the two methods [(HDT + GTC)/2]°C, and T_{DIFF1} is the difference between simultaneous readings two methods (GTC – HDT)°C. The central line represents the mean difference (0.27°C), the upper line represents the upper 95% limit of agreement (1.20°C), and the lower line represents the lower 95% limit of agreement (–0.66°C). The dashed line represents a reference for no difference between the methods.

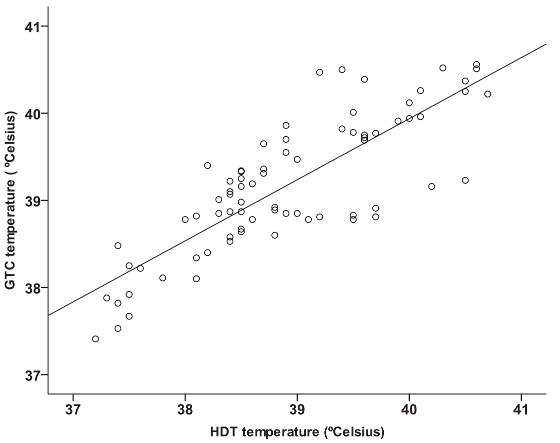

Figure 2. Linear regression plot between the readings of the gastrically inserted core temperature capsules (GTC) and those of the handheld digital thermometer (HDT) in anesthetized brown bears ($n = 9$), in degrees Celsius. The line represents the line of best fit ($r^2 = 0.68$, $P < 0.0001$).

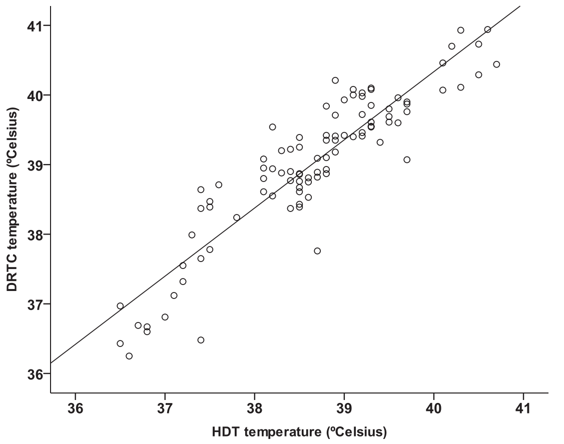

Figure 4. Linear regression plot between the readings of the deep rectally inserted core temperature capsules (DRTC) and those of the handheld digital thermometer (HDT) in anesthetized brown bears ($n = 18$), in degrees Celsius. The line represents the line of best fit ($r^2 = 0.83$, $P < 0.0001$).

dards. The results show that HDT could underestimate the core temperature by up to 1.0°C. Core hyper- or hypothermia may not be accurately diagnosed if body temperature is monitored only with a HDT. On the other hand, the DRTCs had a good agreement with the core temperature measured by GTCs. This demonstrates the accuracy of an easy technique to monitor core temperature in anesthetized brown bears, which will enable improved diagnosis of hypo- and hyperthermia.

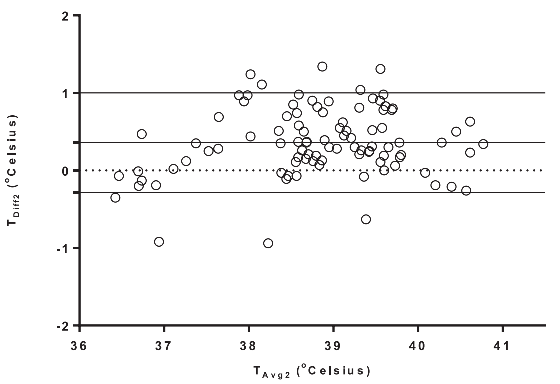

Figure 3. Bland–Altman plot of body temperature values measured concurrently by a handheld digital thermometer (HDT) and deep rectally inserted core temperature capsules (DRTC) in anesthetized brown bears ($n = 18$). T_{AVG2} is the average between simultaneous readings of the two methods [(HDT + DRTC)/2]°C, and TDIFF2 is the difference between simultaneous readings two methods (DRTC – HDT)°C. The central line represents the mean difference (0.36°C), the upper line represents the upper 95% limit of agreement (1.0°C), and the lower line represents the lower 95% limit of agreement (–0.28°C). The dashed line represents a reference for no difference between the methods.

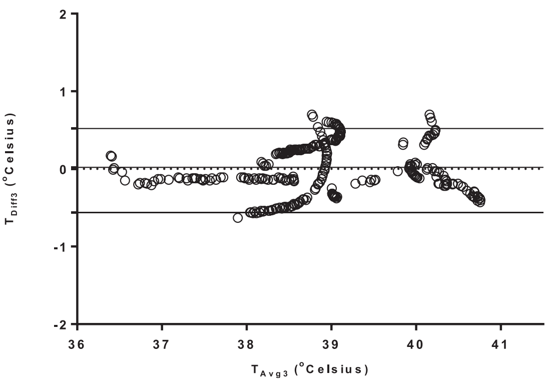

Figure 5. Bland–Altman plot of body temperature values measured concurrently by deep rectally (DRTC) and gastrically inserted core temperature capsules (GTC) in anesthetized brown bears ($n = 7$). T_{AVG3} is the average between simultaneous readings of the two methods [(GTC + DRTC)/2]°C, and T_{DIFF3} is the difference between simultaneous readings two methods (GTC – DRTC)°C. The central line represents the mean difference (–0.06°C), the upper line represents the upper 95% limit of agreement (0.42°C), and the lower line represents the lower 95% limit of agreement (–0.54°C). The dashed line represents a reference for no difference between the methods.

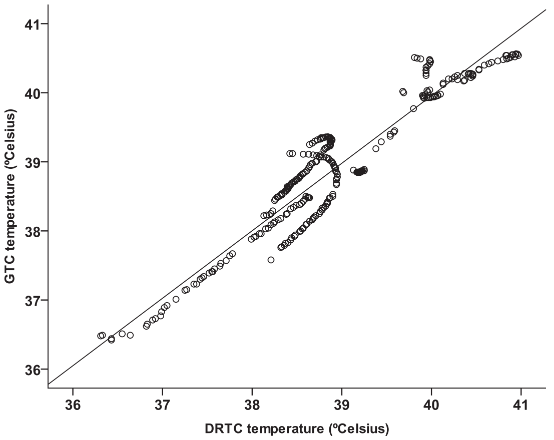

Figure 6. Linear regression plot between the readings of the gastrically (GTC) and deep rectally inserted core temperature capsules (DRTC) in anesthetized brown bears ($n = 7$), in degrees Celsius. The line represents the line of best fit ($r^2 = 0.91$, $P < 0.0001$).

The mean difference between the HDT and the gastric temperature found in this study was similar to that in goats (0.4°C).[18] Contrarily, the SD (±0.1°C) and the 95% LoA (0.2 and –0.6°C) in the goat study were lower and narrower than that of the present study. Rectal temperature was measured in goats by an HDT and compared with core temperature measured by a data logger inserted in the abdominal cavity.[18] The goats were housed in controlled temperature enclosures and were not anesthetized before temperature monitoring was in place. These differences in results may be attributed to the controlled manner of the goat study, which may have decreased the variance among subjects.

When comparing HDT with both deep rectally and gastrically inserted CTCs, the results of this study were similar to those found in hypovolemic sheep.[13] Rectal temperature was measured using thermistor probes inserted 5 cm into the sheep's rectum, and the core temperature was measured using a thermistor tipped pulmonary artery catheter.[13] The authors concluded that rectal temperature was an accurate method of measuring core temperature in hypovolemic sheep, even though the mean difference was 0.55 ± 0.6°C, and the 95% LoA were 1.75 and –0.65°C. Based on these findings the HDT could underestimate core temperature in up to 1.75°C, which could affect the judgement of the staff regarding a clinical intervention in case of hypo- or hyperthermia.

Rectal temperature was used to validate indigestible temperature capsules.[7,14] In both studies, the capsule readings had good agreement with rectal temperature. The mean differences were 0.04 ± 0.03°C (with 95% LoA of 0.1 and –0.02°C) and 0.06 ± 0.35°C (mean difference ± 95% confidence interval), respectively.[7,14] These results are similar to those of the present study. In one of these studies, the rectal probes were inserted 10 cm into the rectum,[7] whereas in the other study the probes were only inserted 11 mm beyond the anal sphincter.[14] The good agreement between the techniques did not depend on the depth of rectal probe insertion in humans.

Rectal temperature measured with HDT inserted 3 cm into the rectum of dogs had good agreement with pulmonary artery temperature under conditions of normo-, hypo-, and hyperthermia; however, the absolute values of the mean difference and standard deviation of the difference were not reported.[11] The results of the present study disagree with the dog study in regard to the agreement between the readings of HDT and the core temperature. Size of the animal may be one of the reasons why HDT did not accurately estimate core temperature in bears, as deep rectal readings of CTCs agreed well with readings obtained from the stomach. A better agreement may be possible with the use of a longer HDT that could be inserted 15 cm into the rectum of the bear (as with the CTCs); however, a longer HDT would not have the advantage of continuous and remote monitoring that the VS monitor provides.

When analyzing the distribution of the difference between the DRTCs and the GTCs, it was possible to observe paired data points deviating extremely from normality. It was also observed that all these paired data points belong to the same subject. It was speculated that, possibly, this animal could have ingested cold water before capture, thereby lowering its gastric temperature. Even though it is not possible to verify this theory, the outlier data were removed from the analyses because they provoked such dramatic difference in the final results; the data appeared as an extreme outlier on the distribution plot, and the subject represented only 47 of 436 paired samples.

CONCLUSIONS

The handheld digital thermometer did not accurately estimate core temperature in anesthetized brown bears. The HDT accurately reflected the trend in temperature over time; however, it underestimated core temperature by up to 1.0°C. This must be kept in mind when considering whether or not to treat hyper- or hypothermia.

Deep rectally inserted core temperature capsules accurately measured core temperature in anesthetized brown bears. The advantages of this technique are its ease of operation, feasibility in field conditions, and continuous real-time monitoring.

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