Comparison of temperature readings from a percutaneous thermal sensing microchip with temperature readings from a digital rectal thermometer in equids

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Objective—To compare temperature readings from an implantable percutaneous thermal sensing microchip with temperature readings from a digital rectal thermometer, to identify factors that affect microchip readings, and to estimate the sensitivity and specificity of the microchip for fever detection.

Design—Prospective study.

Animals—52 Welsh pony foals that were 6 to 10 months old and 30 Quarter Horses that were 2 years old.

Procedures—Data were collected in summer, winter, and fall in groups 1 (n = 23 ponies), 2 (29 ponies), and 3 (30 Quarter Horses), respectively. Temperature readings from a digital rectal thermometer and a percutaneous thermal sensing microchip as well as ambient temperature were recorded daily for 17, 23, and 19 days in groups 1 through 3, respectively. Effects of ambient temperature and rectal temperature on thermal sensor readings were estimated. Sensitivity and specificity of the thermal sensor for detection of fever (rectal temperature ≥ 39.9°C [103.8°F]) were estimated separately for data collection at ambient temperatures ≤ 15.6°C (60°F) and > 15.6°C.

Results—Mean ambient temperatures were 29.0°C (84.2°F), −2.7°C (27.1°F), and 10.4°C (50.8°F) for groups 1 through 3, respectively. Thermal sensor readings varied with ambient temperature and rectal temperature. Rectal temperatures ranged from 36.2°C to 41.7°C (97.2°F to 107°F), whereas thermal sensor temperature readings ranged from 23.9°C (75°F) to 42.2°C (108°F). Sensitivity for fever detection was 87.4%, 53.3%, and 58.3% in groups 1 to 3, respectively.

Conclusions and Clinical Relevance—The thermal sensor appeared to have potential use for initial screening of body temperature in equids at ambient temperatures > 15.6°C. (J Am Vet Med Assoc 2008;233:613–617)

Quick, accurate, and easily obtained measurements of body temperature can assist in the early detection of the first case of a contagious disease and is an important part of an effective equine biosecurity program.1,2 Traditionally, body temperature determination in equids is measured by use of a rectal thermometer.3

The use of a rectal thermometer to assess body temperature has some limitations, including the need for personnel to put themselves in a precarious position, especially when working with young horses or those with limited training; the risk of contamination of the thermometer or hands of personnel with disease causing bacteria; and the time required to obtain the measurement.

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To our knowledge, the only other currently used method for clinically measuring body temperature in equids is by use of an auricular thermometer, which measures the temperature of the tympanic membrane.2 This method of assessing body temperature may limit the spread of contagious diseases by avoiding contact with fecal organisms, but there is also the risk of intolerance of the procedure and lack of suitability for use in horses and ponies not accustomed to handling. An accurate, safe, hygienic, and more rapid means of determining body temperature in equids would have a potential place in a biosecurity program.2,3

Percutaneous implantation of thermal sensors provides the capability of sensing the body temperature of equids.4 Use of these thermal sensors has the potential to offer a safer, hygienic, and more rapid method of obtaining a temperature measurement in equids, provided that they are accurate, compared with temperatures obtained by use of rectal thermometers. In a single experimental study,1 microchips were evaluated as thermal sensing devices in 18 equids that were housed under field conditions. A limitation of that study4 was the lack of testing of the thermal sensors in equids that developed fevers. There have been several studies4–7 on the use of similar
data were measured over a short duration and in controlled environmental conditions.

To truly evaluate the usefulness of percutaneously placed thermal sensors as a component of a biosecurity program, thermal sensor performance needs to be evaluated in a variety of types of equids, under a range of environmental conditions to incorporate the potential effects of ambient temperature on thermal sensor performance, and over a body temperature range that encompasses febrile and afebrile animals. The purpose of the study reported here was to compare temperatures measured by use of a thermal sensor with the temperature measured via a digital rectal thermometer; to assess the potential effect of ambient temperature on thermal sensor measurements; and to estimate the sensitivity and specificity of the thermal sensor for detection of fever, defined in this study as a rectal temperature ≥ 38.9°C (102°F).

Materials and Methods

Study population—Measurements of body temperatures were obtained in 2 groups of outdoor-housed Welsh ponies and in 1 group of outdoor-housed Quarter Horses. Welsh ponies were 6 to 10 months old and were concurrently enrolled in vaccine challenge studies; group 1 consisted of 23 Welsh ponies that were studied from July 2006 to August 2006, and group 2 consisted of 29 Welsh ponies that were studied from January 2007 to February 2007. Group 3 consisted of 30 Quarter Horses that were 2 years old and enrolled in a Colorado State University colt training class during September 2006 to November 2006. This study was approved by the Animal Care and Use Committee at Colorado State University.

Data collection—Thermal sensors used in this study were International Standards Organization-American National Standards Institute compliant microchips (ie, 11,784 and 11,785 microchips; 134.2 kHz), as recommended by the Equine Species Working Group for the National Animal Identification System. All thermal sensors were placed percutaneously according to the recommendations of the manufacturer in the left side of the nuchal ligament, halfway between the poll and withers. In both groups of ponies, thermal sensors were placed while the ponies were restrained in stocks, sedated, and treated with local anesthesia to reduce the stress of handling and microchip placement, and surgical preparation was used at the implantation site. All thermal sensors were implanted by a single veterinarian (SBH). In Quarter Horses, thermal sensors were placed while the horses were restrained with halter and lead rope by a handler, no sedation or local anesthesia was used, and surgical preparation of the implantation site was not performed. All thermal sensors were placed in Quarter Horses by a single veterinarian (JBS). Data collection commenced a minimum of 2 days after thermal sensor placement.

In ponies, concurrent recording with the thermal sensor and a calibrated digital thermometer began prior to viral challenge and continued regularly until at least 14 days after challenge. In Quarter Horses, concurrent readings began a minimum of 11 days after thermal sensor placement. Data for groups 1 and 2 were collected by a single veterinarian (SBH). Ponies in groups 1 and 2 were housed in outside pens and were placed in stocks in a building with a shed roof and open sides just prior to data collection. Data for group 3 horses were collected by students; each set of students assigned to the training and care of a given horse collected all temperature data for their assigned horse. Quarter Horses were housed in outside pens with 3-sided shelters during most of the study period, except for a brief period after arrival at the facility and during thermal sensor implantation, when they were housed in a nonheated metal barn. Quarter Horses were also stalled during data collection. Horses were brought into the barn just prior to data collection.

Data collected for individual equids included date and time of temperature readings, rectal temperature, thermal sensor reading, and coat color coded as light or dark. Ambient temperature was recorded as that reported by the Fort Collins, Colo, weather station within 30 minutes of the time of digital rectal thermometer and thermal sensor readings each day.

Data analysis—The effect of rectal temperature on thermal sensor readings was analyzed by use of multivariable linear regression, with generalized estimating equations. An exchangeable correlation structure was used to account for repeated rectal temperature and thermal sensor measurements from the same horses. Other variables eligible for inclusion in the analysis were ambient temperature, coat color, and group (1, 2, or 3). These variables were added to the model and retained if they significantly (P ≤ 0.05 on likelihood ratio testing) improved model fit. After the main effects model was completed, all possible 2-way interaction terms were added singly to the model, and retained if they significantly (P ≤ 0.05 on likelihood ratio testing) improved model fit. The effect of removal of outliers (outliers were defined as thermal sensor reading < 35°C [95°F] or > 42.2°C [108°F]; ie, outside the range of physiologic plausibility for living equids) was assessed by comparing results with and without outliers.

Sensitivity was calculated as the proportion of febrile equids with thermal sensor readings ≥ 38.9°C, and specificity was calculated as the proportion of afebrile equines with thermal sensor readings < 38.9°C. Sensitivity and specificity were calculated separately for days with ambient temperatures ≤ 15.6°C (60°F) and > 15.6°C. To account for repeated rectal temperatures and thermal sensor measurements from the same horses or ponies, point estimates and 95% confidence intervals for sensitivity and specificity of the thermal sensor for detection of fever (rectal temperature ≥ 38.9°C) were estimated by use of the Rao and Scott method for the analysis of clustered binary data with a commercially available spreadsheet package. Briefly, a variance inflation factor is calculated from the data. The variance inflation factor is used to calculate an effective sample size for use in calculation of P values and confidence intervals. When the variance inflation factor is > 1, the effective sample size is less than the true sample size, accounting for the correlated nature of the data. Variance inflation factors were calculated separately for febrile and afebrile horses.
at ambient temperatures ≤ 15.6°C and > 15.6°C, and effective sample size was used in place of true sample size when the variance inflation factor was > 1. χ² Tests were used to compare the sensitivity and specificity of the thermal sensor's ability to detect fevers for days with ambient temperatures ≤ 15.6°C and > 15.6°C. All confidence intervals calculated were exact.13 The effect of removal of outliers (thermal sensor reading < 35°C or > 42.2°C) was assessed by comparing results with and without outliers. Values of P < 0.05 were considered significant.

Results

Twenty-three ponies in group 1 (July 2006 to August 2006) were observed for 17 days to obtain 385 temperature recordings, and 29 ponies in group 2 (January 2007 to February 2007) were observed for 23 days to obtain 667 temperature recordings, resulting in a total of 1,052 temperature recordings over 40 days. Thirty 2-year-old Quarter Horses in group 3 (September 2007 to November 2007) were observed for a mean of 19 d/horse to obtain a total of 600 temperature recordings. The ambient temperature ranged from 21.7° to 32.7°C (71.1° to 90.9°F) with a median ambient temperature of 25.9°C (78.6°F) for group 1 ponies, from –6.7° to 12.6°C (1.9° to 54.6°F) with a median ambient temperature of –3.5°C (23.7°F) for group 2 ponies, and from –5° to 26.3°C (23° to 79.4°F) with a median ambient temperature of 11.6°C (52.8°F) for group 3 horses.14

No adverse reactions to thermal sensor placement were observed in the ponies or 2-year-old Quarter Horses. Thermal sensors functioned to provide rapid and reliable reading of the unique animal identification number assigned to each equid and assessment of body temperature throughout our study.

In all equids enrolled in the study, rectal temperatures were within plausible ranges for equine body temperature, ranging from 36.7° to 41.7°C (98.1° to 107°F) for group 1 ponies, 36.2° to 40.7°C (97.2° to 105.2°F) for group 2 ponies, and 36.6° to 39.8°C (97.8° to 103.7°F) for group 3 horses. Not all thermal sensor readings were within plausible ranges for live equids (temperatures < 35°C). Thermal sensor readings ranged from 34.4° to 42.6°C (94° to 108.6°F) for group 1 ponies, 26.2° to 41.7°C for group 2 ponies, and 23.9° to 39.9°C (75° to 109.3°F) for group 3 ponies. A total of 24 thermal sensor readings from 7 ponies were < 35°C (range, 1 to 12 readings/pony). A total of 9 thermal sensor readings from 4 of the 2-year-old Quarter Horses were < 35°C (range, 1 to 5 readings/horse).

Neither coat color nor group significantly improved model fit. Thermal sensor readings were significantly affected by rectal temperature or ambient temperature. The model did not change significantly with the removal of outliers, so all data points were included in the analysis. Changes in rectal and ambient temperatures explained 54% of the variability in thermal sensor readings. The best-fitting model for the relationship between rectal temperature, ambient temperature, and thermal sensor reading can be described as follows:

\[ \text{Sensor reading} = -0.17 + 0.03 \times (\text{ambient}) + 0.80 \times (\text{rectal}) \]

where the intercept occurs at an ambient temperature of –6.67°C (20°F) and a rectal temperature of 34.67°C (94.4°F). Ambient temperature is modeled as the number of degrees Celsius above –6.67°C, and rectal temperature is modeled as the number of degrees Celsius above 34.67°C. For each 0.56°C (1°F) increase in ambient temperature, sensor reading is expected to increase by 0.017°C (0.03°F), whereas for each 0.56°C increase in rectal temperature, sensor reading is expected to increase by 0.44°C (0.8°F).

The sensitivity of the thermal sensor for detection of fever (rectal temperature ≥ 38.9°C) significantly (P < 0.001) differed in warmer ambient temperatures (> 15.6°C), compared with colder ambient temperatures (≤ 15.6°C). On days when the ambient temperature was ≤ 15.6°C, the thermal sensor detected 19 of 37 (51.3%; 95% confidence interval, 32.4% to 67.6%) fevers and correctly classified 1,035 of 1,066 (97.1%; 95% confidence interval, 95.0% to 98.7%) afebrile readings. No differences were seen in the sensitivity of the thermal sensor when outliers were removed from the analysis. Of the 18 fevers the thermal sensor did not detect, 5 had thermal sensor readings within 0.28° of 38.9°C (0.5° and 102°F), 10 had thermal sensor readings between 37.8° and 38.6°C (100° and 101.5°F), and the remaining 3 had sensor readings ≤ 37.8°C. On days with an ambient temperature ≤ 15.6°C, the thermal sensor readings were 0.56°C less than rectal temperatures in equids with undetected fevers. On days when the ambient temperature was > 15.6°C, the thermal sensor detected 101 of 116 (87.1%; 95% confidence interval, 87.1% to 96.7%) temperature readings as afebrile. Of the 15 fevers the thermal sensor did not detect, 2 thermal sensor readings were within 0.28° of 38.9°C, 13 thermal sensor readings were between 37.8°C and 38.6°C, and no thermal sensor readings were ≤ 37.8°C. On days with an ambient temperature > 15.6°C, the thermal sensor readings were 0.47°C (0.85°F) less than rectal temperatures in equids with undetected fevers. The mean ambient temperature14 during the study of the group 1 ponies was 29.0°C (84.2°F) with a range of 24.8° to 35°C (76.7° to 95°F) during the time of data collection, whereas the mean ambient temperature for the group 2 ponies was –2.7°C (27.1°F) with a range of –16.7° to 12.6°C during data collection. The mean ambient temperature14 for the group 3 horses was 10.4°C (50.8°F) with a range of –5° to 26.3°C.

Discussion

Overall, the researchers were satisfied with the ease of use of the thermal sensor; it was easy to implant, exhibited little migration, and provided rapid readings of the animal ID number and body temperature. Results of a previous study2 on thermal sensors in ponies found that they provide a more variable reading than rectal thermometers. Our study revealed similar findings, with the thermal sensor readings having a wider range of readings than the rectal thermometer. In the previously cited study,2 the thermal sensor often provided temperature readings below those of the digital rectal thermometer; this finding is similar to that of the current study for thermal sensor readings obtained in ambient temperatures of < 15.6°C in afebrile horses.

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In the current study, the relationship between thermal sensor temperature readings and rectal temperature was strongly influenced by ambient temperature. Results of previous studies in horses and dogs indicate that thermal sensors often underestimate body temperatures as measured with a digital rectal thermometer. The study in dogs was performed in a controlled laboratory environment, where extremes in environmental temperature would not occur. The study in horses was performed with the horses housed in pastures and brought to a nearby location with a roof overhang for data collection to prevent effects of direct sunlight on body temperature. The reported ambient temperature during data collection in that study was either 15.6°C or 20.6°C (60°F or 69°F). In the present study, ambient temperatures ranged from −16°C to 35°C (1.9°F to 95°F) and fully represented the range of temperatures in which a thermal sensor in horses might be used. In the present study, the thermal sensor usually underestimated rectal temperatures ranging from 35°C to 41.1°C when ambient temperatures were ≤−3.9°C (23.5°F). At ambient temperatures in the −1.1°C to 12.8°C (30°F and 55°F) range, the thermal sensor typically underestimated rectal temperatures ranging from 37.2°C to 41.7°C (99°F to 107°F), but overestimated rectal temperatures that were <37.2°C. As ambient temperature increased, so did the balance point where the thermal sensor switched from overestimating to underestimating rectal temperature. At an ambient temperature of 21.1°C (70°F), the thermal sensor typically overestimated rectal temperatures <38.9°C, but underestimated rectal temperatures ≥38.9°C, whereas at an ambient temperature of 29.4°C (85°F), the thermal sensor typically overestimated rectal temperatures <40°C (104°F), but underestimated rectal temperatures ≥40°C.

Because ambient temperature affected the relationship between rectal temperature and thermal sensor reading, it also affected the ability of the thermal sensor to detect fevers. The sensitivity of the thermal sensor for detection of fevers was considerably lower during days when the ambient temperature was ≤15.6°C, compared with days when the ambient temperature was ≥15.6°C. By relying on the thermal sensor alone, >50% of fevers were missed in cooler ambient temperatures. In contrast, <15% of fevers were missed in the summer by reliance on the thermal sensor. The thermal sensor appears to be a useful tool for screening equids for fever; particularly when the ambient temperature is >15.6°C. However, because even at warmer ambient temperatures, the thermal sensor detected only 87% of fevers, and because of the effect of cool ambient temperatures on thermal sensor readings, the thermal sensor should not be the sole means of fever detection.

Placement of the thermal sensor may have affected temperature readings. In a previous study on thermal sensors in ponies, the thermal sensor was percutaneously placed in the left side of the nuchal ligament halfway between the poll and withers; this location was chosen because it was recommended by the manufacturer and the Equine Species Working Group for the National Animal Identification System. The location is based on ease of reading the thermal sensor when standing beside the horse and is used to ensure exclusion of the thermal sensor during slaughter processing from horse meat products. Placement of the thermal sensor in this location is potentially more exposed to environmental factors and therefore more susceptible to the influences of extremes in ambient temperature. The performance of the thermal sensor in locations other than those recommended by the manufacturer was not evaluated in the present study. Placing the thermal sensor in another location in the body may achieve better correlation with rectal temperatures.

Explanations for the effect of ambient temperature on thermal sensor readings include the superficial location of the thermal sensor and the low blood flow within the nuchal ligament. In a previous study in which a portable infrared thermometer was used, the effect of ambient temperature on surface temperature in equine limbs was evaluated. The researchers found that ambient temperature affected proximal limb surface temperature at the shoulder and hip, but that the effect of ambient temperature was greater at the distal aspect of the limbs. It is possible that the relatively superficial placement of the thermal sensor was similarly affected by ambient temperature. Another possible explanation is that there is limited blood flow into ligamentous tissue, and because of this, the nuchal ligament area where the microchip was placed is not warmed or cooled by blood flow as well as areas with better blood flow. Future research into other implant locations is warranted should recommendations for location of microchips come forward from the Equine Species Working Group for the National Animal Identification System. It will be critical that if this option is explored, these other locations of thermal sensor placement should be readily accessible to allow reading of the microchip.

Because the current study was conducted in young ponies and 2-year-old Quarter Horses that were fairly uniform in condition and body condition, the findings in this study may not necessarily apply to thermal sensor performance in older ponies, ponies with more fat around the site of implantation, horses with higher or lower body condition scores than those included in this study, or draft-type horses. Further studies of the thermal sensor in other groups of equids in similar temperature ranges over longer periods and in different housing conditions are recommended.

Results of our study revealed a moderate fit between rectal temperature and the thermal sensor reading, suggesting that an implantable thermal sensor could be an easy and quick initial screening method to detect febrile equids as part of a biosecurity protocol as long as the impact of ambient temperature was taken into consideration when interpreting the thermal sensor reading.
References


Selected abstract for JAVMA readers from the American Journal of Veterinary Research

Estimation of left ventricular filling pressure by use of Doppler echocardiography in healthy anesthetized dogs subjected to acute volume loading
Karsten E. Schober et al

Objective—To identify Doppler echocardiographic (DE) variables that correlate with left ventricular filling pressure (LVFP).

Animals—7 healthy dogs (1 to 3 years old).

Procedures—Dogs were anesthetized and instrumented to measure left atrial pressure (LAP), left ventricular pressures, and cardiac output. Nine DE variables of LVFP derived from diastolic time intervals, transmirtal and pulmonary venous flow, and tissue Doppler images were measured over a range of hemodynamic states induced by volume loading and right atrial pacing. Association between simultaneous invasive measures of LVFP and DE measures of LVFP was determined by use of regression analysis. Receiver operating characteristic analysis was used to predict increases in mean LAP on the basis of DE variables.

Results—Mean LAP correlated with several DE variables: the ratio between peak velocity during early diastolic transmirtal flow and left ventricular isovolumic relaxation time (peak E:IVRT) during sinus rhythm (r = 0.78) and during right atrial pacing (r = 0.82), IVRT, the ratio between late diastolic transmirtal flow velocity and pulmonary venous flow duration, and the time interval between onset of early diastolic mitral annulus motion and onset of early diastolic transmirtal flow. Cutoff values of 2.20 and 2.17, respectively, for peak E:IVRT in dogs with sinus rhythm and atrial pacing predicted increases in mean LAP (≥ 15 mm Hg) with a sensitivity of 90% and 100% and specificity of 92% and 100%.

Conclusions and Clinical Relevance—Doppler echocardiography can be used to predict an increase in LVFP in healthy anesthetized dogs subjected to volume loading. (Am J Vet Res 2008;69:1034–1049)