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Comparison of Microchip Transponder and Noncontact Infrared Thermometry with Rectal Thermometry in Domestic Swine (*Sus scrofa domestica*)

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During disease outbreaks, core temperature is a useful health metric in swine, due to the presence of pyrexia especially during the acute phase of infection. Despite technologic advances in other facets of swine production and health management, rectal thermometry continues to be the 'gold standard' for measuring core body temperature. However, for various reasons, collecting rectal temperatures can be difficult and unsafe depending on the housing modality. In addition, the delay between insertion of the rectal thermometer and obtaining a reading can affect measurement accuracy, especially when the pig requires physical restraint. Clearly safer, faster, and more accurate and precise temperature acquisition methods that necessitate minimal or no handling of swine are needed. We therefore compared rectal thermometers, subcutaneous microchips, and an inexpensive handheld infrared thermometer by measuring the core body temperature of 24 male castrated piglets at random intervals over a 5-wk period. The core body temperature (mean ± 1 SD) was 39.3 ± 0.5 °C by rectal thermometry, 39.0 ± 0.7 °C by microchip transponder, and 34.3 ± 1.0 °C by infrared thermometry; these 3 values differed significantly. Although the readings obtain by using infrared thermometry were numerically lower than those from the other methods, it is arguably the safest method for assessing the core temperature of swine and showed strong relative correlation with rectal temperature.

Core body temperature is a valuable health metric in many species, including swine. During a disease outbreak, pyrexia often occurs during the acute phase of the infection; this association seems to imply that core temperature is a useful adjunct in the overall diagnostic process. However, variable results have been obtained when trying to correlate temperature elevations obtained by using various measurement devices during actual pathogen-induced infection in swine[1,14] or other species.[12,25]

Despite technical advances in most other facets of swine production and health management, rectal thermometry continues to be the 'gold standard' for assessing core body temperature primarily because of the low cost of this method and the perceived high precision and accuracy of the resultant measurements. Various other temperature-collection modalities have been tested previously in swine (with highly variable outcomes), including implantable microchip transponders[9] (implanted at various body sites), infrared thermography,[11,14,19,20] and infrared thermometry.[1,19,21] Infrared thermometry has been used in industry to measure objects without actually making contact with the object; this modality was first investigated for use in humans in 1985 but has since been tested in a variety of formats in other species.[10] In addition, infrared thermometry saw considerable use as a screening tool at airport terminals during the 2014 Ebola Zaire virus outbreak with mixed results due to the wide variation in positive predictive values, which was largely dependent on the device used.[3] Although infrared tympanic thermometry has been used in other species,[7,8,22] it does not lend itself well to swine temperature measurement, because the device requires a fairly clean ear canal to function correctly, and the pig must remain still while the device is inserted into the ear canal. These requirements make infrared tympanic thermometry highly impractical for pigs unless physical restraint techniques are used.

With the swine industry's movement away from housing swine in crates and small pens and toward large group housing, obtaining rectal temperatures can be difficult and unsafe for the person taking the measurement, depending largely on the housing system used, availability and use of restraint measures, and the sex, number, and size of pigs housed per pen. In addition, the time delay during the acquisition of core temperature when using a rectal thermometer can affect the accuracy of the reading, especially if considerable handling of the animal is involved. Handling swine can lead to an increase in temperature solely from the stress of the interaction, a phenomenon that also has been demonstrated in other species.[22]

Due to the issues inherent to collecting swine rectal temperature measurements, safer temperature acquisition methods are needed. Ideally, the method would also minimize or eliminate any handling of the animal being measured. This feature is especially important, because minimizing handling reduces stress on the animals as well as limits exposure to potential infectious agents, whether on the farm or in an experimental setting, thereby reducing the risk of a zoonotic disease outbreak. Alternative temperature-collection methods tested on

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multiple species show varying degrees of agreement among methods.[1,2,4,5,7-9,11-14,17,18,22,24,25] In particular, many methods exhibited large variations in measurement based on the location of the measurement,[13] lacked correlation between measurement modalities,[9,15] were not cost-effective, or did not have broad applicability beyond research settings.[20]

When looking at previous studies which assessed swine body temperatures, correlation between the various modalities has also shown large variability. One study that investigated the accuracy of implanted microchips at various sites in pigs found that, on average, the ear-base microchip temperature was 1 °C below rectal temperature; other anatomic locations exhibited more pronounced differences.[13] Given that an earlier study showed a greater lack of correlation between similarly placed microchips and rectal temperatures,[9] the increased correlation between the ear-base microchip and rectal temperatures[13] seems to indicate an improvement in microchip technology or placement during the 2 y between the 2 studies.

Infrared thermometry is another alternative method of temperature collection that may be useful in swine. For example, assessment of an infrared thermography camera and an infrared thermometer revealed that body temperatures obtained from the back of the ear and around the eye using infrared methods were 4 to 6 °C lower on average than were rectal temperatures in corresponding animals.[19] Several other studies have evaluated infrared thermography in swine.[11,14,19,20] At present, the equipment required is impractical beyond the research setting, primarily because of the high cost involved. However, with the advent of inexpensive thermography applications for many of today's smart phone cameras, cost soon may cease to be a limitation to the use of infrared thermography.[6,16] Although infrared thermography remains prone to issues with interpretation (that is, several different temperature readings are obtained for the same anatomic site), handheld infrared thermometers have become inexpensive and widely available, with many sold at large hardware stores.

Despite being more expensive than other temperature measurement methods, subcutaneous microchips offer the additional ability to encode information, such as animal identification numbers. Microchips have been shown to correlate well with rectal temperature in swine, although they still require the investigator to get in close proximity to the animal to read the microchip.[13] Therefore, the goal of our study was to evaluate commercially available infrared thermometers and subcutaneous microchips compared with rectal thermometers over several weeks to determine whether either alternative method had the same accuracy and precision as a digital rectal thermometer at the population level. We used the best anatomic sites, measurement practices, and so forth (as identified in other studies) under semicontrolled environmental conditions to simulate more farm-like conditions as compared with more highly controlled laboratory conditions.

Materials and Methods

Animals. Healthy castrated male Chester White pigs (age, 3 wk; $n = 24$) were obtained from a commercial swine producer. Pigs were housed in randomly assigned groups of 6, with 2 groups per room. Although initial weights were not obtained, the mean weight at the end of the 5-wk study was 36.7 kg (range, 10.6 to 26.7 kg). Group size was determined according to the primary study in which each pig was enrolled, but is largely immaterial because all pigs were measured with all 3 methods at every measurement point throughout the study. All animal studies were conducted as approved by the Animal Care and Use Committee of the University of Georgia, an AAALAC-accredited institution.

Measurement tools. The body temperature of the pigs was assessed over 5 wk by using all 3 methods: a quick-read digital rectal thermometer (temperature range, 32.2 to 44.4 °C; model 112-757-000, MABIS Healthcare, Waukegan, IL), implantable microchip temperature transponder (temperature range, 32 to 43 °C; model IPTT-300, BioMedic Data Systems, Seaford, DE), and infrared temperature gun (temperature range, –60 to 550 °C; distance to target ratio, 12:1; ThermoWorks, American Fork, UT).[23] The 12:1 ratio for the infrared thermometer means that for every 12 cm between the gun and the target surface, the diameter of the target surface analyzed increases by 1 cm. The digital thermometer was assessed for accuracy by using a water bath to verify the digital readout display; the other 2 methods were used 'as is' because they are designed to be used without further calibration, and normalization beyond that provided by the manufacturer might introduce additional bias.

Two days before initiation of temperature measurement, microchips were implanted into the pigs by using the supplied needle delivery system between the subcutaneous fat and muscle layer in the left lateral cervical region, just in front of the cranial margin of the shoulder. The transponders were placed prior to study initiation to minimize any inflammation and allow the transponder to start attaching to the surrounding connective tissue. No swelling or erythema, indicative of infection or abscess formation, was observed at any time after microchip placement. The specific location for implantation was chosen in light of previous studies.[9,13]

For infrared thermometry, the temperature gun was aimed at the left or right lateral abdomen of the pigs. This region was used due to its large surface area, enabling a quick read with the gun, and the heat-retention characteristics of the abdomen, due to the large amount of liquid in the region. The gun automatically provided a mean temperature for the total time duration the trigger was depressed, which was standardized at 10 seconds. If a pig moved during the measurement process and caused the beam to deviate from the target location, the pig's temperature was measured again (and repeated as many times as necessary until a stable reading was obtained).

Data collection. Temperatures were measured by using all 3 methods 2 to 5 times a week on random days and at random times to evaluate the devices across a broad range of environmental and husbandry conditions that might affect core temperature, including feeding time, room sanitation procedures, ambient outdoor temperature, and so forth. In addition, the temperature and humidity levels of the holding rooms were recorded at each measurement time point, because the pigs were housed in 2 rooms. Over the 5-wk study period, temperatures were measured for all animals by using all 3 methods on a total of 18 d, for a total of 18 measurements per pig (Figure 1).

To standardize the methods by which the temperatures were collected and to minimize any stress-induced rise in an individual pig's temperature, the infrared temperature gun was used before the pigs were handled. To minimize pig distress, the investigator quietly entered each pen and then held the gun 1 to 1.5 m away from an individual pig, resulting in a measurement area that was 8 to 12.5 cm in diameter when the aiming beam was centered on the lateral abdomen. The gun was aimed at either the left or right side of the lateral abdomen of each pig and the beam held there for 10 s to obtain the mean temperature reading. The temperatures of all 6 pigs in the group were collected by using this method before any of the pigs in the group were handled. The temperatures of the pigs were collected by using this approach, regardless of any extenuating environmental factors (wet skin, humidity level) and regardless of whether

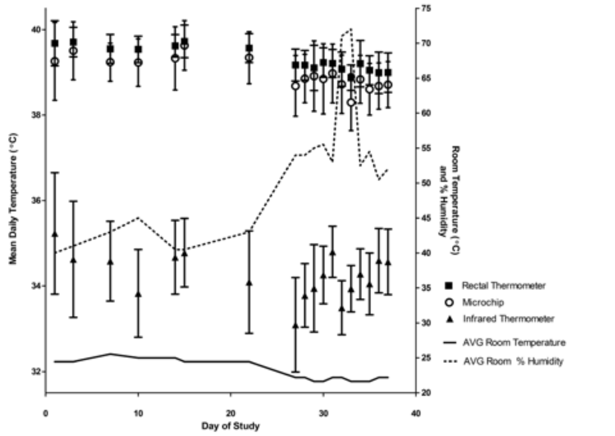

Figure 1. Daily core temperature of pigs as obtained by using each device (left *y* axis), average (AVG) room temperature, and mean humidity level (right *y* axis) throughout the study. All data are given as mean ± 1 SD. Temperature varied substantially not only among the 3 measurement devices but also depending on the day of the study, thus indicating the need for a repeated-measures analysis, where additional inputs regarding environmental temperature and humidity could be included (data not shown). Humidity levels—but not room temperatures—varied markedly throughout the study.

the pigs had recently been in contact with other surfaces (pen surfaces, other pigs). In this way, we tried to mimic the actual conditions under which the devices might be used as compared with the carefully controlled individual measurements for which all variables were minimized, a situation that is often impractical in the field or laboratory setting.

After infrared thermometry, the pigs were manually restrained in a dorsoventral position to maintain normal orientation and minimize struggling during restraint. Microchip readings were recorded immediately after the pigs were lifted. For the first 7 d, 2 additional infrared readings were collected: one with the gun held approximately 15 cm from the left side of the pig's abdomen, and the other on the left neck area directly over where the microchip was placed (data not shown). These readings were discontinued after the first 7 d because of the impracticality of this method, which mainly was due to the increased handling required and the perceived slight increase in animal stress levels (likely induced due to prolonged handling). Immediately after microchip thermometry, a quick-read rectal thermometer was inserted 2 to 4 cm along the lateral wall of the rectum and held against the rectal wall until the thermometer measured a stable temperature reading (signaled by a single beep).

Statistical analysis. All analyses were performed by using SAS version 9.3 (SAS Institute, Cary, NC). A repeated-measures analysis (PROC Mixed) was fit to examine differences between methods (laser, microchip, and rectal) of measuring pig body temperature. The full model included fixed factors of date and method, a date×method interaction, and a random factor of pig. An unstructured covariance structure was assumed for all repeated-measures models. Multiple comparisons were made by using the Tukey test for all repeated-measures models.

Pearson correlation analysis was used to test for correlations of room temperature and humidity with temperature for all 3 methods separately. To consider possible effects of room temperature and humidity on method-associated differences, a repeated-measures analysis was performed. The full model included fixed factors of date, method, and date×method interactions; continuous factors of room temperature and humidity; and a random factor of pig.

Results

Temperature measurements. The temperature measurements from individual pigs varied widely between the 3 methods used (Figure 2 A through C). Simple linear regression was performed to compare our data with other studies' data (reviewed previously in reference 21). The R-squared value for the rectal thermometer compared with the infrared thermometer was 0.0589, rectal thermometer compared with microchip was 0.247, and infrared thermometer compared with microchip was 0.0540. These values imply low or no correlation. When the data were analyzed by using a repeated-measures analysis, our results showed that the temperature (mean ± 1 SD) recorded by each device was: rectal thermometer, 39.3 ± 0.5 °C; microchip, 39.0 ± 0.7 °C; and infrared gun, 34.3 ± 1.0 °C. All of these values differed significantly ($P < 0.001$) from one another (Figure 2 A through C).

Interestingly, we observed substantial variation in mean temperature readings by method and day for all 3 methods (Figure 1). This finding might be influenced by our incidental findings, which included a positive correlation between room temperature and body temperature for all 3 methods. However, there was a negative correlation between room humidity and body temperature for all 3 methods.

In addition, the microchip reader was able to obtain a reading from the left cervical area (the initial placement site for the transponders) of all pigs, indicating if any migration had occurred, it was so minimal as to still be within the range of the handheld reading unit.

Discussion

Although the readings from the microchips were slightly lower than those from the rectal thermometers, they still represent clinically relevant (albeit slightly less precise) core body temperatures at a population level, largely because the measured range falls largely within the normal clinical temperature range commonly used for swine (38.6 to 40 °C). However, microchips cannot be used in any pigs that might be sent to slaughter, thus limiting their use to terminal research studies. The readings from the infrared gun were significantly lower than those of either of the other methods and had a larger standard deviation among readings. We initially had postulated that the variation in other infrared thermometer studies was largely the result of scanning a target site with poor heat retention characteristics. However our choice to target the abdomen, an area with high heat retention, did not improve the infrared thermometer's direct correlation with rectal temperatures, even though the overall standard deviation became narrower (although still not to the levels of the other methods). However, the infrared thermometer is arguably the most useful and safest method to assess core temperature due to its relatively strong correlation with rectal temperature, as long as the user compensates for the expected difference between the reading obtained by using the infrared device and the core temperature. Infrared thermometry would be especially useful in a commercial setting, where monitoring the temperature of multiple animals in the population will offset any error inherent to an individual pig's measurement. In addition, infrared thermometers are readily available from several commercial vendors and have a laser sighting device that helps the user to ensure the correct pig is being scanned.

Although the environment of the pig (that is, whether it is wet or has been in close contact with another pig) will undoubtedly affect the temperature obtained by using the infrared gun, our study indicates that these factors do not prevent accurate assessment of body temperature over successive measurements on the same animals. The wide

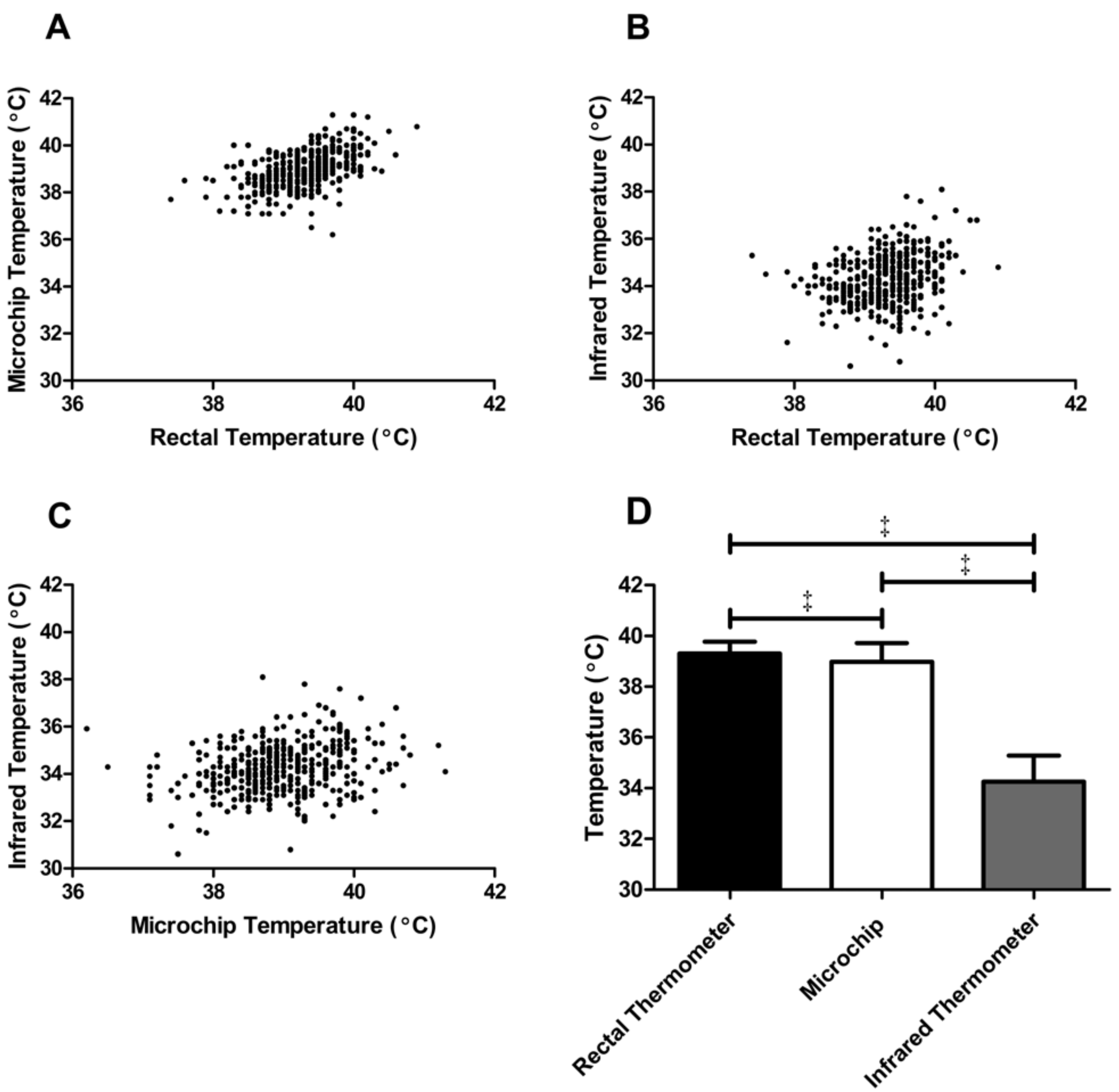

Figure 2. Comparison plots of individual temperature readings by measurement device. (A). Microchip transponder compared with rectal thermometer. (B) Rectal thermometer compared with infrared thermometer. (C) Microchip transponder compared with infrared thermometer. Simple linear regression on each plot (lines not shown) did not produce significantly correlated R-squared values. (D) Temperatures (mean ± 1 SD) for each measurement device differed significantly (‡, $P < 0.001$) from one another according to repeated-measures analysis.

variation of R-squared values observed in many studies including our own is likely multifactorial in nature and reflects the target site chosen for measurement, the device used, and the age and body composition of the pigs measured. Interestingly, we observed a substantial variation in temperature readings by day using all 3 methods (Figure 1), due in part to environmental temperature and humidity levels; these data indicate that using a narrow, non-seasonally based range for assessing pyrexia in a given group of animals may introduce unintended bias relative to the true temperature values. On the basis of the repeated-measures analysis, we can conclude that even though the mean temperatures of the individual methods are significantly different from one another, they correlate well with one another on a population level throughout the study duration and on a population level by day, even though the values do not appear to correlate well on the basis of the visual dispersion of the data. Although the value for any individual pig might fall outside of the normal range, the mean temperature for the group was relatively consistent at any given point and implies that multiple animals should be assessed and their resulting temperatures averaged to eliminate external influences affecting single body temperature measurements.

As such, rather than using a static core temperature range developed under fixed (or unknown) environmental conditions, assessing multiple individual pigs in a group on a given day to obtain a population mean and standard deviation and then identifying the outliers based on the data obtained may actually be the preferred way to assess an individual member of the population for pyrexia. In addition, moderate to severe hypothermia or hyperthermia might significantly alter the relative agreement of the 3 measurement devices used. However, when used to assess whether an individual pig is above or below the average normal temperature for the population at a given time, all 3 methods could be used successfully to screen for the outliers, which would be the primary goal in a field or farm setting.

In addition, further studies in a variety of environmental temperature, humidity, and husbandry situations may support the development of a correction matrix, whereby body temperature, environmental temperature, humidity, and possibly air flow are all factored together to yield a temperature index or correction equation for each measurement method, given that both humidity and air flow are more likely to alter readings from infrared thermometry compared with more traditional methods. Similar systems are in use as heat indexes for humans as well as swine, in that many farms and slaughter facilities already use matrices that integrate environmental temperature and humidity to determine whether it is too hot or cold to safely transport pigs. However, similar matrices that consider the actual body temperatures of the pigs themselves are unavailable.

During the analysis, we also noted a positive correlation between room temperature and body temperature for all 3 methods; as mentioned previously, this effect is not surprising, given pigs' inability to thermoregulate effectively (particularly at younger ages) due to their inability to sweat, their percentage body fat, and other factors. Although room humidity and body temperatures were negatively correlated for all 3 methods, the possible effects on husbandry need to be considered further and likely vary depending on the specific ventilation system and environmental control parameters used in a given room or barn.

Microchips and infrared guns are effective devices for measuring body temperature in swine, provided that users establish baseline readings or correction factors as needed. Both methods provide consistent measurements over time at the population level in the context of a variety of environmental conditions. Although microchips cannot be used in swine destined for slaughter (the microchips themselves are classified as a meat adulterant), these devices may actually represent the preferred method for obtain core temperatures in research settings, given that (in most cases) their use does not require handling of the animals and that (as demonstrated here and in previous studies[9,13]), when implanted in the neck region, they yield readings very similar in accuracy and precision to those from rectal thermometry.

However, compared with microchips and rectal thermometers, infrared thermometers represent the safest method by far for the user, because they require no animal contact and can obtain accurate readings at considerable distance (when the ratio of target distance to spot diameter is high). One drawback to infrared thermometry is that it appears to require a correction factor if the user wants to compare values with those from a scale developed by using rectal or microchip-based temperatures. In addition, infrared thermometers are well suited to field use for assessing populations of pigs for which the user knows the expected temperature range and uses the infrared unit to identify animals exceeding that threshold as potentially febrile animals meriting further evaluation.

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References

1. **Bowman AS, Nolting JM, Workman JD, Cooper M, Fisher AE, Marsh B, Forshey T.** 2016. The inability to screen exhibition swine for influenza a virus using body temperature. Zoonoses Public Health **63:**34–39.
2. **Brunell MK.** 2012. Comparison of noncontact infrared thermometry and 3 commercial subcutaneous temperature transponding microchips with rectal thermometry in rhesus macaques (*Macaca mulatta*). J Am Assoc Lab Anim Sci **51:**479–484.
3. **Centers for Disease Control.** [Internet]. 2014. Noncontact temperature measurement devices: considerations for use in port-of-entry screening activities. [Cited 13 August 2015]. Available at: http://wwwnc.cdc.gov/travel/files/ebola-non-contact-temperature-measurement-guidance.pdf.
4. **Chen PH, White CE.** 2006. Comparison of rectal, microchip transponder, and infrared thermometry techniques for obtaining body temperature in the laboratory rabbit (*Oryctolagus cuniculus*). J Am Assoc Lab Anim Sci **45:**57–63.
5. **Cilia J, Piper DC, Upton N, Hagan JJ.** 1998. A comparison of rectal and subcutaneous body temperature measurement in the common marmoset. J Pharmacol Toxicol Methods **40:**21–26.
6. **FLIR.** [Internet]. 2016. FLIR tools mobile app. [Cited 13 August 2015]. Available at: http://www.flir.com/instruments/display/?id=51975.
7. **Goodwin, S**. 1998. Comparison of body temperatures of goats, horses, and sheep measured with a tympanic infrared thermometer, an implantable microchip transponder, and a rectal thermometer. Contemp Top Lab Anim Sci **37:**51–55.
8. **Greer RJ, Cohn LA, Dodam JR, Wagner-Mann CC, Mann FA.** 2007. Comparison of 3 methods of temperature measurement in hypothermic, euthermic, and hyperthermic dogs. J Am Vet Med Assoc **230:**1841–1848.
9. **Hartinger J, Kulbs D, Volkers P, Cussler K.** 2003. Suitability of temperature-sensitive transponders to measure body temperature during animal experiments required for regulatory tests. ALTEX **20:**65–70.
10. **Hughes WT, Patterson GG, Thornton D, Williams BJ, Lott L, Dodge R.** 1985. Detection of fever with infrared thermometry: a feasibility study. J Infect Dis **152:**301–306.
11. **Kammersgaard, TS, Malmkvist J, Pedersen LJ**. 2013. Infrared thermography—a noninvasive tool to evaluate thermal status of neonatal pigs based on surface temperature. Animal **7:**2026–2034.
12. **Kort WJ, Hekking-Weijma JM, TenKate MT, Sorm V, VanStrik R.** 1998. A microchip implant system as a method to determine body temperature of terminally ill rats and mice. Lab Anim **32:**260–269.
13. **Lohse, L, Uttenthal Å, Enøe C, Nielsen J, Lohse L, Uttenthal Å, Enøe C, Nielsen J.** 2009. Implantable microchip transponders for body temperature measurements in pigs. Abstract from the 1st European Symposium on Porcine Health Management, Frederiksberg, Denmark 27–28 August 2009.
14. **Loughmiller JA, Spire MF, Dritz SS, Fenwick BW, Hosni MH, Hogge SB.** 2001. Relationship between mean body surface temperature measured by use of infrared thermography and ambient temperature in clinically normal pigs and pigs inoculated with *Actinobacillus pleuropneumoniae*. Am J Vet Res **62:**676–681.
15. **Nguyen AV, Cohen NJ, Lipman H, Brown CM, Molinari NA, Jackson WL, Kirking H, Szymanowski P, Wilson TW, Salhi BA, Roberts RR, Stryker DW, Fishbein DB.** 2010. Comparison of 3 infrared thermal detection systems and self-report for mass fever screening. Emerg Infect Dis **16:**1710–1717.
16. **Opgal Optronic Industries Ltd.** [Internet]. 2015. Android thermal imager for professionals. [Cited 13 August 2015]. Available at: http://therm-app.com/.
17. **Quimby JM, Olea-Popelka F, Lappin MR.** 2009. Comparison of digital rectal and microchip transponder thermometry in cats. J Am Assoc Lab Anim Sci **48:**402–404.
18. **Robinson TR, Hussey SB, Hill AE, Heckendorf CC, Stricklin JB, Traub-Dargatz JL.** 2008. Comparison of temperature readings from a percutaneous thermal sensing microchip with temperature readings from a digital rectal thermometer in equids. J Am Vet Med Assoc **233:**613–617.

19. **Schmidt M, Lahrmann K-H, Ammon C, Berg W, Schon P, Hoffmann G.** 2013. Assessment of body temperature in sows by 2 infrared thermography methods at various body-surface locations. Journal of swine health and production **21:**203–209.
20. **Scolari, SCC, Clark SG**, **Knox RV, Tamassia MA.** 2011. Vulvar skin temperature changes significantly during estrus in swine as determined by digital infrared thermography. Journal of swine health and production **19:**151–155.
21. **Soerensen DD, Pedersen LJ.** 2015. Infrared skin temperature measurements for monitoring health in pigs: a review. Acta Vet Scand **57:**5.
22. **Stephens Devalle, JM**. 2005. Comparison of tympanic, transponder, and noncontact infrared laser thermometry with rectal thermometry in strain 13 guinea pigs (*Cavia porcellus*). J Am Assoc Lab Anim Sci **44:**35–38.
23. **ThermoWorks.** [Internet]. Industrial infrared thermometer model #IR-GUN-S. [Cited 13 August 2015]. Available at: http://thermoworks.com/products/ir/irgun.html.
24. **Torrao NA, Hetem RS, Meyer LC, Fick LG.** 2011. Assessment of the use of temperature-sensitive microchips to determine core body temperature in goats. Vet Rec **168:**328.
25. **Warn PA, Brampton MW, Sharp A, Morrissey G, Steel N, Denning DW, Priest T.** 2003. Infrared body temperature measurement of mice as an early predictor of death in experimental fungal infections. Lab Anim **37:**126–131.