Objective—To measure the effect of warm compress application on tissue temperature in healthy dogs.

Animals—10 healthy mixed-breed dogs.

Procedures—Dogs were sedated with hydromorphone (0.1 mg/kg, IV) and diazepam (0.25 mg/kg, IV). Three 24-gauge thermocouple needles were inserted to a depth of 0.5 cm (superficial), 1.0 cm (middle), and 1.5 cm (deep) into a shaved, lumbar, epaxial region to measure tissue temperature. Warm (47°C) compresses were applied with gravity dependence for periods of 5, 10, and 20 minutes. Tissue temperature was recorded before compress application and at intervals for up to 80 minutes after application. Control data were collected while dogs received identical sedation but with no warm compress.

Results—Mean temperature associated with 5 minutes of heat application at the superficial, middle, and deep depths was significantly increased, compared with the control temperature. Application for 10 minutes significantly increased the temperature at all depths, compared with 5 minutes of application. Mean temperature associated with 20 minutes of application was not different at the superficial or middle depths, compared with 10 minutes of application. Temperature at the deep depth associated with 10 minutes of application was significantly higher, compared with 20 minutes of application, but all temperature increases at this depth were minimal.

Conclusions and Clinical Relevance—Results suggested that application of a warm compress should be performed for 10 minutes. Changes in temperature at a tissue depth of 1.5 cm were minimal or not detected. The optimal compress temperature to achieve therapeutic benefits was not determined. (Am J Vet Res 2013;74:448–451)
Materials and Methods

Animals—Ten healthy, purpose-bred, mixed-breed dogs were used for the study. The project was approved by the Kansas State University Animal Care and Use Committee prior to implementation of the study.

Data collection—The study protocol and animals used were identical to those used in a study measuring tissue temperature associated with cold compress application. After skin preparation, sedation, and ultrasonography, dogs were restrained in ventral recumbency for placement of 3 type T thermocouple needles coupled with a thermometer as used in the previous study. Two minutes after needle insertion, baseline temperatures were recorded for each depth, and then the warm compress was applied.

The warm compress consisted of a 16 × 8.5 × 3.5-cm commercial-grade plastic compress containing a commercial-grade gel warmed to 47°C in an incubator. In addition, to mimic a typical clinical scenario, we held the compress to our own skin to ensure that this temperature would not elicit a painful response. The weight of each compress was 0.64 kg, and the thickness of the material was 1.59 mm. The compresses were modified to allow passage of thermocouple needles through the center. There was no physical barrier between the compress and the surface of the skin. Dogs underwent application of warm compresses for periods of 5, 10, and 20 minutes each in a random order. Each compress was held in position by gravity, without external compression, overlaying the left epaxial region immediately adjacent to midline. The compress was applied to the epaxial region in a manner to allow for maximal surface contact; however, because of its rigid nature, there was not always full contact at the corners of the compress.

Temperature readings were recorded every minute for 10 minutes after removal of the warm compress, then every 5 minutes until the temperature returned to within 2% of the baseline value or until 80 minutes had elapsed. The cord adapter of each needle was color coordinated so that the individual recording temperature values (HAT) was not aware of which color corresponded to a given needle depth. Each dog also underwent a control data collection period, as in the previous study.

Statistical analysis—For each duration of compress application (5, 10, and 20 minutes) and for each depth of needle insertion, the largest change in temperature was determined by comparison of the maximum temperature recorded during the test period with the control temperature in each dog. Group mean values were compared at each tissue level between the control temperature and the experimental groups. No dog had a period of distress, and all dogs required minimal to no physical restraint during data collection. No dog had an adverse reaction at the warm compress or needle insertion sites. Rectal temperatures prior to and immediately following data collection periods did not differ significantly between control and experimental groups.

Mean maximum temperature change at the superficial depth was –1.52°C (–4.5%), 3.08°C (9.1%), 4.14°C (12.3%), and 4.56°C (13.4%) for 0, 5, 10, and 20 minutes of heat application, respectively. Mean maximum temperature change at the middle depth was –1.46°C (–4.1%), 0.8 (2.2%), 2.2°C (6.2%), and 2.03°C (5.6%) for 0, 5, 10, and 20 minutes of heat application, respectively. Mean maximum temperature change at the deep depth was –1.98°C (–5.2%), –0.48°C (–1.3%), 0.58°C (1.6%), and –0.02°C (–0.05%) for 0, 5, 10, and 20 minutes of heat application, respectively (Figure 1).

For each duration of compress application (5, 10, and 20 minutes) and for each depth of needle insertion, the largest change in temperature was determined by comparison of the maximum temperature recorded during the test period with the control temperature in each dog. Group mean values were compared at each tissue level between the treatment and control groups via repeated-measures ANOVA with the Newman-Keuls multiple comparison post hoc test. Group mean values for each tissue level were compared among time periods also via repeated-measures ANOVA with the Newman-Keuls multiple comparison post hoc test. Values of P < 0.05 were considered significant.

Results

No dog had a period of distress, and all dogs required minimal to no physical restraint during data collection. No dog had an adverse reaction at the warm compress or needle insertion sites. Rectal temperatures prior to and immediately following data collection periods did not differ significantly between control and experimental groups.

Figure 1—Mean ± SD temperature (°C) change at superficial, middle, and deep tissue depths associated with 0 (Control), 5, 10, and 20 minutes of warm compress application in 10 dogs.
were minimal. Cooling of the tissues after removal of the compress was graphed (Figure 2). The warm compress underwent a cooling rate of 0.19°C/min, with a total decrease in temperature of 3.8°C at the end of 20 minutes.

Discussion

Application of a 47°C gel compress for 10 minutes significantly increased tissue temperature of the lumbar region at 0.5-, 1.0-, and 1.5-cm depths in medium-sized dogs of ideal body condition following administration of opioid sedation, without causing adverse tissue effects. Increasing the duration of application time from 10 to 20 minutes did not result in significantly warmer tissue temperatures at any of the measured tissue depths.

Significant changes in temperature were observed at the superficial and middle depths with a much smaller change at the deepest tissue depth. These findings are similar to those of human studies. At deeper subcutaneous tissue depths, heat transfer applied via various modalities for 10 to 20 minutes is substantially reduced. Additionally, the insulating effects of subcutaneous tissue in obese humans can result in potentially dangerous accumulation of applied heat in the dermis and epidermis. The rate of temperature change of the superficial and middle depths decreased following 10 minutes of application in the present study. This was likely a result of narrowing temperature gradients between the compress and skin surface as well as between tissue layers. Thus, following approximately 10 minutes of application, the compress had cooled to a point at which conduction of heat proceeded at a slower rate. Overall, the deep tissue depth had minimal to no increase in temperature after 10 minutes of application, compared with the more superficial tissue layers. This finding was also likely influenced by the narrow temperature gradients among the 3 depths. Additionally, heat conduction is reduced as the distance from the heat source increases.

Similar to cryotherapy, superficial heat is widely used with much variability in the method, frequency, and duration of application. There are few high-quality, evidence-based studies, and of those, only a few detected therapeutic benefits. In the study reported here, the effect of temperature change associated with a common method of superficial heat application in a uniform group of dogs with similar subcutaneous tissue thickness was evaluated. The study was controlled for effect of sedation and used standardized methods of temperature measurement and warm compress application as well as tissue depths.

The effect of heat on tissue can vary among species as well as within a given species. Specific conditions in humans that can increase the likelihood of thermal injury to skin include obesity, diabetes mellitus, impaired circulation, and reduced skin thickness. When determining the amount of heat that is acceptable to apply to a given tissue, both temperature and time are important factors. To mimic a typical clinical scenario, we held the compress to our own skin at varying temperatures to establish what felt acceptably warm without eliciting a painful response. It has been stressed by numerous studies examining thresholds for thermal damage that a cumulative thermal dose is the most important factor. The CEM, is the accepted measure for thermal dose assessment regarding thermal damage and is calculated as follows:

$$\text{CEM}_\text{dog} = \Delta T \cdot \text{R}^{-0.17}$$

where $\Delta T$ is the length of exposure in minutes, $T$ is the mean temperature ($^\circ$C) during the time interval, and $R$ is a constant equal to 0.25 for $T < 43^\circ$C and 0.4 for $T > 43^\circ$C. The temperature of the compress used in the study reported here was within the safe temperature range reported in a previous study. A thermal threshold study revealed no burns on human skin at a CEM of 240 minutes. The lowest thermal exposure reported to cause substantial injury in humans was associated with maintenance of skin temperature at 44°C for 200 minutes. In the study reported here, skin surface temperature was not measured; however, the highest possible CEMs applied to the skin for 5, 10, and 20 minutes was 56.6, 80, and 85.7 minutes, respectively. These CEMs durations are unlikely to result in clinically important thermal injury.

One limitation of this study was the effects of sedation method on tissue temperature. It has been well established that administration of the $\mu$-adrenoceptor agonist opioid hydromorphone can result in a hypothermic response in dogs, as was indicated by the temperature changes in the control group of the study reported here. Superficial heat is typically used to treat chronic injury in animals that are not concurrently receiving injectable opioid medications. In the present study, it is likely that warmer tissue temperatures would have been achieved if the hypothermic effects of hydromorphone were not present. The effect of diazepam on tissue temperature in this population of dogs was unknown. An additional limitation of this study was the rate of cooling of the warm compress. A different warming pattern may have been observed had a heating method that was capable of maintaining a constant temperature been used; instead, a method that is commonly used in clinical practice was used. A modification of the compress was made to allow for maintenance of accurate tissue depth measurements and to avoid artifactual influence of the heat: the skin immediately adjacent to the thermocouple needle insertion site was not covered by the compress. Different changes in temperature may have
been observed if this modification had not been used. Lastly, use of a warm compress that was malleable may have transmitted the heat more efficiently than the rigid compress that was used because it would allow full skin contact at the corners.

This study did not evaluate whether the tissue temperatures achieved with this method were optimal for treatment of injury or relief of pain, but could be used as a basis for future studies evaluating the use of therapeutic heat in small animal patients. Future studies may involve evaluating various methods of heat application, effects of body area treated, different subcutaneous tissue depths, different body condition score, and outcome in small animal patients with soft tissue injury or signs of chronic pain.

References