Effect of cold compress application on tissue temperature in healthy dogs

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Objective—To measure the effect of cold 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 (superficial), 1.0 (middle), and 1.5 (deep) cm into a shaved, lumbar, epaxial region to measure tissue temperature. Cold (–16.8°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 cold compress.

Results—Mean temperature associated with 5 minutes of application at the superficial depth was significantly decreased, compared with control temperatures. Application for 10 and 20 minutes significantly reduced the temperature at all depths, compared with controls and 5 minutes of application. Twenty minutes of application significantly decreased temperature at only the middle depth, compared with 10 minutes of application.

Conclusions and Clinical Relevance—With this method of cold treatment, increasing application time from 10 to 20 minutes caused a further significant temperature change at only the middle tissue depth; however, for maximal cooling, the minimum time of application should be 20 minutes. Possible changes in tissue temperature and adverse effects of application > 20 minutes require further evaluation. (Am J Vet Res 2013;74:443–447)

Cryotherapy is the therapeutic use of cold and is frequently used for the treatment of pain, inflammation, swelling, and edema associated with soft tissue trauma. Direct application of a cold object (eg, a compress) to the skin will decrease the temperature of both superficial and deeper tissues.1–4 Lowering tissue temperature decreases tissue metabolism, edema formation, muscle spasm, and signs of pain and minimizes the inflammatory processes associated with soft tissue injury.5–8 Lowering the metabolic rate helps protect local and surrounding tissue from enzymatic reactions associated with the injury and subsequent inflammation.9,10 Cold reduces blood flow by increasing viscosity and vasoconstriction and reducing metabolic activity, which reduces edema formation at the site of injury.11,12 Analgesia results from alteration in cellular metabolism and slowing of nerve conduction velocity in local sensory neurons.13–16

Cryotherapy is performed during the postoperative healing period in many small animal surgical patients. The use of a cold compress is widespread and frequently justified because of the perceived beneficial results, low cost, and convenient use; however, there is area for improvement in cryotherapy recommendations.17–19 There is no definition of an optimal frequency and duration of treatment in the scientific literature.20,21 From clinical and research studies20,21 performed to evaluate the effectiveness of cryotherapy, the general consensus is that repeated applications of a cold compress for 10 to 30 minutes are effective at improving clinical outcome in humans. There is debate on the appropriate recommended method of application and duration of use as well the actual effectiveness of cold compress treatment in human patients.20 There is limited scientific information on this topic in dogs. One study22 found that cold treatment with intermittent pneumatic compression improved signs of pain, swelling, lameness, and range of motion during the first 24 hours following tibial plateau leveling osteotomy.

One area of uncertainty is the optimal temperature to which tissue should be cooled to limit secondary injury associated with soft tissue trauma. The supporting literature on this issue is limited. It is frequently assumed that greater cooling results in increased meta-
bolic suppression and is therefore more efficacious.3,8,10 Cryotherapy studies7,8,10,23 in humans have detected a wide range of temperature changes at various tissue depths, none of which have proven an optimal target temperature. Not all reported studies are controlled for method of sedation, area of cold application, method of cold application, subcutaneous tissue depth, artificia
total cold influence, or method of measuring depth and temperature.21 More clinical studies with standardized methods of controlling for variables would aid in improving cryotherapy recommendations.

Currently, application of cryotherapy in dogs is largely empirical, with minimal evidence-based research, and has been extrapolated from human recommendations. The purpose of the study reported here was to accurately establish the effect of a commonly used method of cold compress treatment on tissue temperature at various depths in healthy dogs and to establish recommendations on appropriate duration of application. We hypothesized that decreases in tissue temperature would be directly proportional to duration of cold compress application and that increasing tissue depth would result in a lower magnitude of temperature change.

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—A 10 X 20-cm area was shaved on the dorsal midline lumbar region of each dog. Ultrasonography was used to measure the distance from the skin surface to the deep border of the subcutaneous tissue in each dog. Each dog received hydromorphone (0.1 mg/kg, IV) and diazepam (0.25 mg/kg, IV) 10 minutes prior to each data collection period. Dogs were restrained in ventral recumbency on a soft padded surface. Three 24-gauge, type T thermocouple needlesa coupled with a thermometerb were inserted into the shaved epaxial region. The needle temperature sensors were located in the distal 1 mm of each needle. One needle each was inserted to a depth of 0.5 (superficial), 1.0 (middle), and 1.5 (deep) cm beneath the surface of the skin, immediately lateral to the dorsal midline and centered in the compress modification (an opening that permitted passage of the needle) overlying the left epaxial region. A plastic sleeve was placed over each needle. This allowed maintenance of accurate needle depth and avoidance of contact between the needle and compress. Each needle remained in place for the duration of the data collection period. Rectal temperature was obtained at the beginning and end of each data collection period. Two minutes after needle insertion, baseline temperatures were recorded for each depth.

Cold compresses consisted of a 16 X 8.5 X 3.5-cm commercial-grade frozen gel packc cooled to −16.8°C. The weight of each compress was 0.64 kg. Cold compresses were modified to allow passage of thermocouple needles through the center. A single-layer 140 cotton muslin surgical towel served as a barrier between the cold compress and skin. The towel had a similar modification to allow passage of the thermocouple needles. Dogs underwent application of cold compresses for periods of 5, 10, and 20 minutes each, in random order. Each compress was held in position by gravity, without external compression. The compress was applied 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 cold 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 who recorded the temperatures (HTM) was not aware which color corresponded to a given needle depth. Each dog also underwent a control data collection period, where tissue temperature was recorded as described, following administration of hydromorphone (0.1 mg/kg, IV) and diazepam (0.25 mg/kg, IV), and no cold compress was applied to the skin. There was a minimum of 48 hours between data collection periods for each dog. Each thermocouple needle was cold sterilized prior to each use.

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 lowest temperature recorded during the test period with the control temperature in each dog. Group mean values were compared at each tissue level between 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 and also by repeated-measures ANOVA with Newman-Keuls multiple comparison post hoc test. Values of P < 0.05 were considered significant.

Results

Ten healthy 1-year-old mixed-breed dogs were included in the study. There were 7 sexually intact fe-
males and 3 sexually intact males. Median body weight of the dogs at the time of the study was 10.45 kg (range, 8.5 to 17.0 kg). All dogs had a body condition score of 3 of 5. Median depth from the skin surface to the deep border of the subcutaneous layer was 0.4 cm (range, 0.3 to 0.6 cm). 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 cold compress or the needle insertion sites. The set ambient room temperature was 21.1°C for the duration of the study. Rectal temperatures prior to and immediately following data collection periods did not differ significantly between control and experimental groups.

Mean maximum reduction in temperature at the superficial depth was 1.52°C (4.5%), 3.19°C (9.4%), 6.91°C (20.6%), and 8.24°C (24.6%) for 0, 5, 10, and 20 minutes of cold application, respectively. Mean maximum reduction in temperature at the middle depth was 1.46°C (4.1%), 2.29°C (6.4%), 4.73°C (13.5%), and 6.45°C (18.3%) for 0, 5, 10, and 20 minutes of cold application, respectively. Mean maximum reduction in temperature at the deep depth was 1.98°C (5.2%), 1.75°C (4.7%), 3.91°C (10.4%), and 4.69°C (12.5%) for 0, 5, 10, and 20 minutes of cold application, respectively (Figure 1).

Temperature for the superficial depth was significantly decreased after 5 minutes of application, compared with control temperature. There was no difference in temperature change at the middle and deep tissue depths following 5 minutes of application, compared with the control temperature. Temperature at all tissue depths significantly decreased, compared with that for controls following 10 and 20 minutes of application. Temperatures associated with the 10- and 20-minute application periods decreased significantly more at all depths than did temperatures associated with a 5-minute application period. Increasing application time from 10 to 20 minutes did not significantly change the temperature at the superficial or deep depth; however, it did significantly decrease the temperature at the middle depth. Superficial tissue rewarmed at a quicker rate than did deeper tissue following removal of the cold compress (Figure 2).

Discussion

Results of this study indicated that application of a frozen gel pack for 10 to 20 minutes significantly reduced the temperature of the lumbar region at 0.5, 1.0, and 1.5 cm in medium-sized dogs of ideal body condition following sedation with opioid administration. Studies in humans have determined that superficial tissue undergoes the largest decrease in temperature, as was found in this study. Many studies consider data recorded from the skin surface as indicating the superficial temperature. Our most superficial level was 0.5 cm beneath the surface of the skin, which is 1 reason that superficial temperatures in previous studies were lower than those found in the study reported here. The temperature change at deeper levels in the present study was comparable to the temperature change in deeper tissue levels in humans.

In the present study, there was rapid cooling of the superficial tissue, followed by more gradual cooling of the deeper tissues. The second law of thermodynamics mandates that heat is always transferred from an area of higher temperature to an area of lower temperature. The method in which tissue is cooled by cold compress treatment is not by transfer of cold into tissue; rather, heat from the tissue is transferred into the cooling apparatus. Deeper tissues are not in contact with the cooling apparatus, so they cool by transferring heat to the cooler, superficial layers of tissue. Superficial tissue can act as an insulator to the deeper tissue. As the thickness of tissue increases, so does the time needed for heat to be transferred through it. In addition to tissue thickness, contact area, weight of compress, and difference in starting temperature as well as the thermal conductivity of tissue influence the transfer of heat. The thermal conductivity and thermal diffusivity of adipose tissue are low, compared with those of other tissues, such as skeletal muscle. The time required for heat to travel through adipose tissue is greater than for other tissues, making it a more effective insulator, compared with surrounding tissues.

The present study revealed that a significant reduction in temperature at the measured depths was associated with 10 minutes of frozen gel compress application; however, there was a significant further decrease in temperature only at the middle tissue depth when application was continued for 20 minutes. This finding did not agree with our hypothesis of a direct relationship between time of application and decrease in tissue temperature. For tissue to become cooler, the heat loss must exceed production and heat gain. Additionally, transfer of heat can only occur when a temperature gradient exists. During the initial phases of application, the large temperature difference between the compress and superficial tissue results in relative rapid tissue cooling, as was detected following 5 minutes of application at only the most superficial level. Fourier’s law of heat conduction \( q = k \cdot A \cdot \Delta T / L \) states that the transfer rate of heat \( q \) is dependent on the thermal conductivity of material or tissue \( k \), cross-sectional area of heat path \( A \), temperature gradient in the direction of flow \( \Delta T \), and thickness of the conductor \( L \). Insulating effects increase as distance away from the compress increases. Although not as rapid, the deeper tissue eventually cools as heat is lost to the more superficial tissue. As tissue layers continue to cool, the temperature gradients begin to decrease, slowing the rate of cooling. This likely partially explains why there

Figure 2—Mean temperature (°C) for tissue depths of 0.5, 1.0, and 1.5 cm associated with 20 minutes of cold compress application in 10 dogs. Notice the difference in rewarming rates among tissue depths.

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was not a significant change in temperature between 10 and 20 minutes of application at the superficial level. At the most superficial level in this study, the gradients of heat loss and heat gain narrowed quickly because of the proximity to the cooling apparatus. At 10 minutes, the superficial tissue reached a state of equilibrium with the compress and did not undergo a significant change with further cold application. The large distance between the source of cooling and the deep layer resulted in an overall slower rate of cooling, compared with the more superficial levels. Significant cooling at the deep level may have continued with a longer application period. In comparison with the temperature change associated with 10 minutes of cold application at the middle level, there was a further significant decrease in temperature when the cold compress was applied for 20 minutes. To undergo continued significant cooling during the time period from 10 and 20 minutes, the middle depth had to have undergone greater heat loss than heat gain. The middle tissue level had not yet reached a state of relative equilibrium at 10 minutes and was not as insulated as the deep level, making it capable of significant cooling during the time period from 10 and 20 minutes.

In the present study, the more superficial tissue underwent rapid rewarming and the deeper tissue continued to decrease in temperature and then increased in temperature more gradually, following removal of the cold compress, similar to other findings. This pattern of rewarming can be explained by several factors, including removal of the source of cold on the skin, exposure of skin to room temperature, and flow of heat from the warmer deeper tissue to the cooler superficial tissue. This finding suggests that at least one of the sources of rewarming for the superficial tissue is heat exchange from the deeper tissue. Regions closer to the skin surface still have a large temperature gradient relative to deeper tissue regions. Heat transfer from deep to more superficial tissue results in a brief period of continued cooling of deeper tissue, with more rapid warming of superficial tissue following removal of the cooling device.

Despite the long-standing acceptance of its use for surgical patients, there still remains a large degree of variance in cryotherapy recommendations, in part because many studies have failed to control for numerous variables and because of questionable evidence of the ability of cooling to improve return to function following soft tissue injury. In the present study, the effect of temperature change of tissue with a common method of cryotherapy was evaluated in a uniform group of dogs with similar subcutaneous tissue depths. Effect of sedation, method of temperature measurement, cold application, and tissue depth measurement were controlled. A barrier was placed between the cold compress and the skin surface because this is commonly performed in a clinical setting to prevent frostbite injury and nerve damage during cold compression. A physical barrier will affect the rate of cooling; however, to mimic the most common clinical application, a standardized single-layer cotton muslin towel was used as a barrier between the compress and skin surface. Temperature change without clipping hair at the site was not evaluated because the most frequent use of cold compress treatment is over a surgical site with recently clipped hair. Not clipping hair would have likely resulted in a reduced rate of heat conduction. The temperature of the compress was chosen as –16.8°C to simulate a compress temperature that is commonly achievable with the use of a standard household freezer.

External compression on a cold compress results in cooler tissue temperatures, compared with gravity dependence. Gravity dependence was used in the present study because of the inherent difficulty in achieving a standardized pressure in a clinical setting. The compresses used in the study reported here were modified to allow passage of thermocouple needles. This ensured that the desired tissue depth was maintained accurately throughout data collection by allowing needles to be inserted perpendicular to the skin surface and avoiding artifactual temperature changes from contact with the compress.

In 1 study, superficial and deep tissue layer temperatures were measured after cold gel pack application in anesthetized dogs. Similar to the present study, rapid cooling of superficial tissues with a delayed and diminished cooling effect in deeper tissues was found. Rewarming periods were also longer in deeper tissue, compared with superficial tissue. That study revealed a similar temperature change for muscular tissue after 20 minutes of cold gel pack application; however, cooler subcutaneous temperatures were achieved. Cold compresses are not commonly applied to anesthetized dogs, so we chose to control for sedation in the present study. The other study failed to take into account the effects of general anesthesia on tissue temperature. Induction of hypothermia is a well-recognized adverse effect of anesthesia. A decrease in sympathetic tone causes generalized vasodilation, allowing substantial heat loss from the skin surface by radiation.

One of the limitations of the present study was the evaluation of only 1 method of cold treatment. The commercial gel pack was chosen because it is the most commonly used method of cold compression in the authors’ hospital. Other common methods of applying cryotherapy include the use of various sizes and shapes of ice; frozen produce; ice, water, and alcohol combinations; and personal recirculating cooling units. In addition to conduction, some heat may be transferred via different methods when other forms of cryotherapy are used. Melting of ice creates a wet interface on the skin, allowing for heat loss through evaporation. The fact that ice goes through a change of state as it melts also allows it to absorb more heat than a cooling modality that does not undergo a change in state such as a gel pack. Ice treatment decreases the temperature of skin significantly more than gel packs for application times of 30 minutes; however, at deeper tissue levels (> 1 cm), the differences are nonsignificant. The study reported here did not have a true skin temperature measurement. It is likely that the skin surface temperatures were significantly lower than the most superficial depth measured in this study. The compresses were modified to allow for maintenance of accurate depth measurements and avoidance of artifactual influence from cold. This necessitated that the area immediately adjacent to the insertion sites was not covered by the compress.
Had it been possible to avoid this modification, the temperatures may have been lower than the recorded values.

An additional limitation was the influence of sedation on tissue temperature. Administration of hydromorphone to dogs decreases body temperature. Specific opioid receptors are thought to induce different thermic responses. Adrenoceptor agonist opioids such as hydromorphone induce a thermoregulatory response that results in hypothermia in dogs. Results of the study reported here, with a decrease in temperature at the measured tissue depths in the control group, were supportive of a hypothermic response. The use of µ-adrenoceptor agonists has a strong association with hypothermia in dogs; however, such opioids are frequently used during the same time period that cold compress treatment would be applied in small animal surgical patients; thus, this methodology does resemble a typical clinical scenario. Diazepam is not a frequently used drug in most small animal patients after surgery. The specific influence on tissue temperature in our population of dogs was unknown. The use of muscle relaxants in human heatstroke patients has provided inconsistent results and is not routinely recommended to increase the rate of cooling.

This study did not evaluate effectiveness of cold compresses at improving clinical outcome, nor did it evaluate whether the tissue temperatures achieved with this methodology were optimal for the treatment of soft tissue injury. The study can serve as a basis for future studies involving the use of cryotherapy in small animal patients or to evaluate cryotherapy of various anatomical sites and in dogs with different body condition scores. Thickness of adipose tissue affects the time required to cool deeper muscular tissue. Additionally, evaluating temperature change following repeated application of cold could be performed.

Results suggested that a minimum time of application should be 10 minutes when this method is used on the epaxial region in dogs with an ideal body condition score. With this method, there was no significant change in temperature at the superficial and deep level by increasing time of application from 10 to 20 minutes; however, maximal tissue cooling at the deep depth occurred with an application time of 20 minutes. Changes in tissue temperature and adverse effects of application > 20 minutes require further evaluation.

References


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