

2011

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## Abstract

**Objective**—To evaluate the effect of cold compression therapy (CCT) on postoperative pain, lameness, range of motion of the stifle joint, and swelling following tibial plateau leveling osteotomy (TPLO) in dogs.

**Design**—Randomized, blinded, placebo-controlled clinical trial.

**Animals**—34 client-owned dogs with unilateral deficiency of a cranial cruciate ligament undergoing TPLO.

**Procedures**—Dogs were assigned to 2 groups. Group 1 (n = 17 dogs) received CCT in the 24-hour period following TPLO. Group 2 (n = 17 dogs) received no CCT. Degree of lameness, range of motion, and circumference of the stifle joint were measured before surgery and 1, 14, and 28 days after surgery. A modified composite Glasgow pain scale, visual analogue scale, and pain threshold score were used to evaluate signs of pain before surgery and 1, 14, and 28 days after surgery. Logistic regression and linear regression analysis were used to compare the measured variables.

**Results**—No complications were observed, and all dogs tolerated CCT. Use of CCT resulted in lower values for the visual analogue scale and Glasgow pain scale and lower pain threshold scores; lower lameness scores; less swelling; and an increased range of motion 24 hours after surgery. At 14 days after surgery, there were no significant differences between groups. At 28 days after surgery, too few data sets were available for comparison.

**Conclusions and Clinical Relevance**—CCT decreased signs of pain, swelling, and lameness and increased stifle joint range of motion in dogs during the first 24 hours after TPLO.

## Disciplines

Other Veterinary Medicine | Small or Companion Animal Medicine | Statistical Methodology | Veterinary Physiology

## Comments

This article is from *Journal of the American Veterinary Medical Association* 238 (2011): 1284, doi: [10.2460/javma.238.10.1284](https://doi.org/10.2460/javma.238.10.1284). Posted with permission.

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Tibial plateau leveling osteotomy is an orthopedic procedure commonly performed by veterinary surgeons to stabilize a CrCL-deficient stifle joint.<sup>1,2</sup> Tibial plateau leveling osteotomy involves an osteotomy that requires extensive soft tissue dissection to expose the medial aspect of the proximal portion of the tibia. After performing the osteotomy, a bone plate is applied to stabilize the tibial metaphysis.<sup>1</sup> Although owner satisfaction has been reported<sup>3</sup> to be as high as 93%, complications following TPLO have been reported<sup>3,4</sup> in 18% to 28% of cases. Most complications can be resolved without surgical intervention<sup>4</sup>; however, additional medical treatment and prolonged postoperative care may be needed for minor complications, such as swelling, limb edema, and postoperative pain.<sup>3,4</sup> Prevention of limb swelling and pain would allow a more rapid

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Supported by Cool Systems Incorporated. Cool Systems Incorporated provided the cold compression system used in the study. Address correspondence to Dr. Drygas (Kevind33@aol.com).

## ABBREVIATIONS

CCT	Cold compression therapy
CrCL	Cranial cruciate ligament
TPLO	Tibial plateau leveling osteotomy
VAS	Visual analogue scale

return to limb function and result in less need for postoperative care.

Most orthopedic surgeries routinely performed in humans and domestic animals require perioperative analgesic treatment.<sup>5–10</sup> Multimodal treatment, defined as the simultaneous use of different techniques or drugs, has been recommended because of its ability to act via various mechanisms, which results in additive or synergistic effects.<sup>11–13</sup> In 1 study,<sup>14</sup> investigators found that administration of a single drug is often not sufficient for controlling postoperative pain. The combination of different techniques, such as administration of systemically active drugs (opioids, NSAIDs, and local anesthetics), use of regional analgesia (epidural and intra-articular analgesia), and physical methods (compression, cryotherapy, and immobilization), results in balanced analgesia and better pain control.<sup>5,7,10,11,13</sup> A combination of perioperative administration of NSAIDs, incisional and intra-articular analgesia, and postoperative cryotherapy has been successfully used for patients undergoing CrCL repair.<sup>5,7,10,13</sup>

Cryotherapy consists of the use of cold to decrease pain and inflammation during the postinjury period.<sup>15,16</sup> The primary therapeutic objective of this modality is to suppress the metabolic rate of traumatized tissue by decreasing tissue temperature.<sup>17</sup> Decreasing the tissue temperature results in vasoconstriction as well as decreases in motor and sensory nerve conduction<sup>18,19</sup> and a reduction in swelling and provision of analgesia.<sup>19</sup> Additionally, hypothermia decreases postoperative pain by reducing concentrations of tumor necrosis factor and nitric oxide, which are 2 important inflammatory mediators.<sup>20</sup> Other benefits include the downregulation of muscle excitability, which leads to a decrease in pain-inducing muscle spasms.<sup>21</sup> In studies<sup>22,23</sup> in humans, treatment with ice decreased pain and improved limb function after orthopedic surgery.

Cryotherapy in combination with intermittent pneumatic compression, a modality referred to as CCT, has been used in humans undergoing reconstructive surgery of an anterior cruciate ligament.<sup>24–26</sup> Simultaneous compression during cryotherapy improves contact between the cold source and patient, which enhances the beneficial effects and decreases local edema.<sup>19</sup> When CCT was compared with application of ice alone after knee surgery, patients who received CCT after surgery had less pain and swelling and an increased range of motion in the operated knee.<sup>25</sup> To the authors' knowledge, no studies have been conducted to evaluate the effect of CCT in dogs.

The objective of the study reported here was to determine the effect of CCT on signs of postoperative pain, swelling, range of motion of the stifle joint, and lameness in dogs after TPLO. We hypothesized that dogs that received CCT following TPLO would have less pain, swelling, and lameness and would have a greater range of motion in the operated stifle joint after surgery, compared with results for dogs that did not receive CCT.

## Materials and Methods

**Animals**—Between March 2008 and January 2009, 34 client-owned dogs undergoing unilateral TPLO for treatment of CrCL deficiency were included in the study. All owners provided informed consent for inclusion of their dogs in the study. Approval from an animal care and use committee was not deemed necessary because the dogs in the study received the accepted standard of care for the surgical procedure with regard to approved standards for analgesia in a private practice surgical specialty hospital and CCT would potentially only benefit canine patients and has been proven safe in equine and human medicine.

Physical examination, CBC, serum biochemical analysis, and evaluation of activated clotting times were performed in each patient. Diagnosis of CrCL deficiency was based on hind limb lameness, joint effusion, palpable cranial tibial thrust or cranial drawer sign, and radiographic evidence of stifle joint effusion. Deficiency of the CrCL was confirmed at the time of surgery by examination via an arthrotomy on the medial aspect of the stifle joint. Dogs were excluded from the study when they had concurrent orthopedic or soft tissue disease, appeared aggressive or highly anxious,

or had an unruly disposition. Dogs were also excluded from the study when there was trauma to the popliteal artery during surgery.

**Anesthesia and analgesia**—Food was withheld from each dog for a minimum of 8 hours prior to induction of anesthesia. All dogs received standard anesthetic and analgesic medications. Hydromorphone (0.05 mg/kg [0.023 mg/lb], SC), acepromazine maleate (0.01 mg/kg [0.0045 mg/lb], SC), and glycopyrrolate (0.01 mg/kg, SC) were administered 1 hour before induction of anesthesia. Anesthesia was induced by IV injection of diazepam (0.2 mg/kg [0.09 mg/lb]) and propofol (4.0 mg/kg [1.82 mg/lb]) and maintained with isoflurane in oxygen at a vaporizer setting of 1.5% to 3.0%. A balanced polyionic crystalloid solution<sup>a</sup> (10 mL/kg/h [4.5 mL/lb/h], IV) was administered during surgery. An ECG, indirect blood pressure, hemoglobin saturation, heart rate, esophageal temperature, respiratory rate, and end-tidal carbon dioxide concentration were monitored during anesthesia. Dogs received cefazolin (22 mg/kg [10 mg/lb], IV) at induction, every 90 minutes during surgery, and every 8 hours after surgery for 24 hours.

After surgery, dogs received hydromorphone (0.08 mg/kg [0.036 mg/lb], IV, q 6 h) for 24 hours, with the first dose given at the time of extubation. Tramadol (2 mg/kg [0.9 mg/lb], PO, q 8 h for 5 days) and deracoxib (2 mg/kg, PO, q 24 h for 14 days) were administered beginning 24 hours after surgery.

**TPLO**—All surgeries were performed by the same board-certified veterinary surgeon (RLG), who was assisted by a surgical resident. Each stifle joint was inspected via a medial parapatellar arthrotomy.<sup>27</sup> After debriding the CrCL, menisci were evaluated. Damaged menisci were treated with a partial meniscectomy or hemimiscectomy. When the medial meniscus was grossly intact, it was released by transection at the meniscotibial ligament or allowed to remain intact. This decision was based on the degree of instability of the stifle joint and meniscal displacement. Meniscal release was selected when the caudal pole of the medial meniscus was entrapped during cranial tibial subluxation. After exploration of the stifle joint, TPLO was performed as described elsewhere.<sup>1</sup> Soft tissue dissection prior to the osteotomy included elevation of the cranial tibial and popliteal muscles to allow protection of the popliteal artery while performing the osteotomy. Three gauze sponges soaked in saline (0.9% NaCl) solution were packed under the elevated muscles on the caudolateral aspect of the tibia to protect regional soft tissue structures. Osteotomy and application of the bone plate were performed in a routine manner. Following closure of the subcutaneous tissues and prior to closure of the skin, 3 mL of a 0.5% solution of bupivacaine was injected into the stifle joint. A stockinette was placed over the surgically repaired limb prior to recovery from anesthesia; the stockinette was maintained in place with skin staples.

**Treatment protocol**—Dogs were assigned by use of a computer randomization schedule to 1 of 2 groups. Dogs in group 1 received CCT on the surgically repaired stifle joint (4 sessions [30 min/session] at 6-hour

intervals beginning immediately after surgery). The CCT was applied by use of a cold compression system<sup>b</sup> that consisted of a control unit, pressure hose, adjustable wrap, and insulated case to house the control unit. The control unit contained a chamber for ice and water and allowed for specific time, temperature, and pressure settings. The control unit was positioned outside each dog's cage during treatments and was connected to the adjustable wrap via the flexible pressure hose. The adjustable wrap was composed of an outer cloth sleeve and an inner chamber for water and air. Temperature and compression were set at 4.4°C (40°F) and 50 mm Hg, respectively. For dogs in group 2, the adjustable wrap was loosely placed on the stifle joint but without CCT for 4 sessions (30 min/session) at 6-hour intervals beginning immediately after surgery. In all dogs, the wrap was applied over the stockinette (Figure 1).

**Outcome measures**—The degree of lameness, signs of pain, range of motion of the stifle joint, and swell-

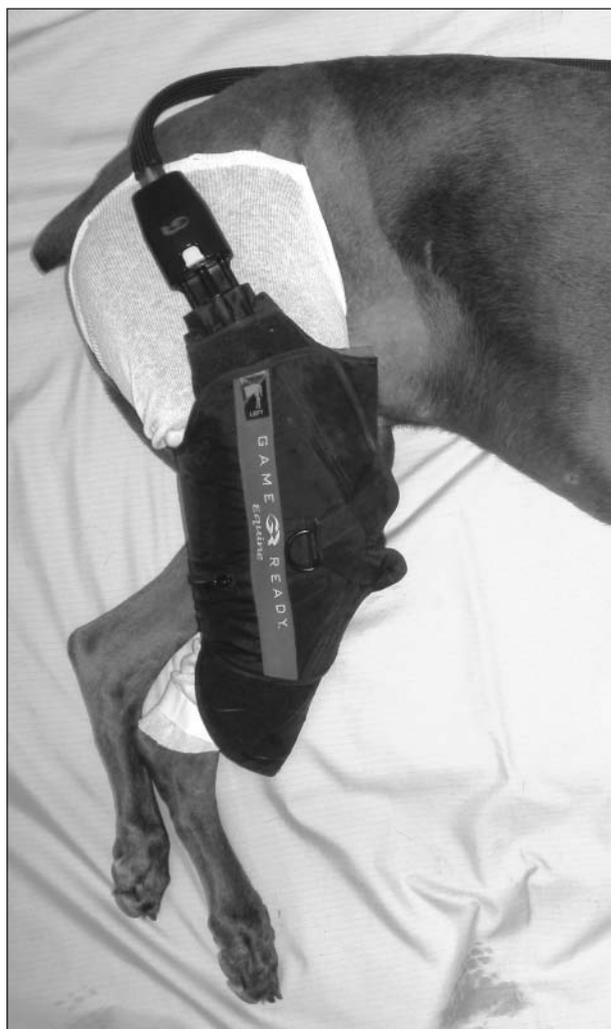


Figure 1—Photograph of an adjustable compression wrap applied to the right stifle joint of a dog after TPLO. Notice the pressure hose attached to the adjustable wrap; the hose attaches to the control unit (not shown). The adjustable compression wrap is applied over a stockinette that encompasses the dog's surgically repaired limb; the stockinette is secured in position with skin staples.

ing were evaluated before surgery and at 1, 14, and 28 days after surgery. Measurements on day 1 after surgery were performed approximately 6 hours after the last of the 4 CCT sessions to allow time for the dog's limb to return to body temperature. Degree of lameness was assessed by observing the dog walk for a distance of 20 m 4 times. A lameness score of 0 to 5 was assigned to each dog for the surgically repaired limb (0 = no lameness observed, 1 = intermittent weight-bearing lameness, 2 = consistent weight-bearing lameness, 3 = intermittent non-weight-bearing lameness, 4 = non-weight-bearing lameness, and 5 = nonambulatory).

Signs of pain were evaluated by use of a modified composite Glasgow pain scale,<sup>28</sup> VAS,<sup>29</sup> and pain threshold score.<sup>30</sup> Scores for the modified composite Glasgow pain scale ranged from 0 to 24 (0 = no pain and 24 = maximal pain measurable) and were formulated on the basis of a standardized form that was completed by the investigators after observation and manipulation of each dog (Appendix).<sup>28</sup> The VAS involved an investigator placing a mark on a 10-cm line. The line represented the investigator's perception of the dog's pain, with the left end of the line representing no pain and the right end representing the worst pain possible. Scores were assigned by measuring the distance from the left end of the line to the point marked by the investigator.<sup>29</sup> Pain threshold score was measured by use of a sonic palpometer.<sup>c</sup> A digital pressure transducer was placed over the tip of an investigator's index finger. The transducer allowed for a repeatable and specific pressure to be applied to the limb. The transducer was then placed on the dog's skin at the level of the proximal portion of the tibia on the medial aspect of the limb, a pressure of 400 gram-force/cm<sup>2</sup> (which was confirmed by an audible signal from the transducer system) was applied, and the dog's response was recorded. Pain threshold scores were assigned as follows: 0 = no response, 1 = withdrawal of limb, 2 = vocalization, and 3 = aggressive response (ie, attempts to bite).

Range of motion was measured with a goniometer<sup>d</sup> by use of a method described elsewhere.<sup>31</sup> Briefly, the stifle joint was moved through a range of motion several times to determine the center of joint rotation; the goniometer was then placed on the lateral aspect of the affected stifle joint with the center of the goniometer positioned over the estimated center of motion. The plastic arms of the goniometer were then aligned with the long axis of the tibia and femur by use of the lateral malleolus and greater trochanter, respectively, as reference points. To determine the extension angle, the stifle joint was gently extended until palpable resistance was detected or signs of pain were displayed by the dog. To determine the flexion angle, the stifle joint then was gently flexed until palpable resistance was detected or signs of pain were displayed by the dog. Range of motion was calculated as the difference between the angles of extension and flexion.<sup>31</sup> Range of motion in the affected stifle joint prior to TPLO was used as the baseline value.

The circumference of the stifle joint was measured with the joint in extension and used to assess stifle swelling. A cloth tape measure was placed around the affected stifle joint at the level of the distal aspect of the

patella. All measurements and observations were made by the same investigator (RLG), who was not aware of each dog's group assignment.

Rescue analgesia was provided to any dog with a Glasgow pain scale score  $\geq 10$ , a VAS score  $\geq 6$ , or overt signs of discomfort and pain. Rescue analgesia consisted of additional doses of hydromorphone (0.08 mg/kg, IV). Dogs requiring rescue analgesia were removed from the study.

**Statistical analysis**—Explanatory variables included treatment (CCT vs no CCT), age, body weight, limb (left vs right), duration of injury prior to surgery, surgery duration, meniscal integrity (intact vs torn), excision of meniscus (yes vs no), and meniscal release (yes vs no). The outcome variables included lameness score, Glasgow pain scale score, VAS score, pain threshold score, range of motion, and circumference of the stifle joint. All data were entered into a spreadsheet program<sup>c</sup> and imported into a statistical software package<sup>f</sup> for analysis.

For each of the outcome variables (lameness score, Glasgow pain scale score, pain threshold score, VAS score, range of motion, and circumference of the stifle joint), response scores at 24 hours were compared with corresponding scores obtained before surgery as a covariate explanatory variable. Treatment, age, body weight, limb, duration of lameness, duration of surgery, meniscal integrity, excision of meniscus, and meniscal release were also used as explanatory variables.

The outcome variables were reported as mean  $\pm$  SD. A univariate analysis was conducted on outcome variables. Logistic regression analysis was used for the categorical responses of lameness score, Glasgow pain scale score, and pain threshold score. Linear regression analysis was used for the continuous variables VAS score, range of motion, and circumference of the stifle joint. For the analysis of each response, both stepwise selection (with values to enter of  $P < 0.20$  and values for removal of  $P < 0.05$ ) and backward selection (with values for removal of  $P < 0.05$ ) were used to select the explanatory variables, with treatment forced into the model. For the analysis of each of the responses, the resulting models for both the stepwise and backward selection criteria were the same. Data for day 14 were regressed similarly with the inclusion of the data for day 1 in the model. There was insufficient data for day 28 after surgery to allow statistical analysis (only 10 dogs were returned for evaluation on day 28). For all analyses, a value of  $P < 0.05$  was considered significant.

## Results

**Animals**—Thirty-four dogs (mean age, 4.7 years) were included in the study. Body weight ranged from 23.4 to 73 kg (51.48 to 160.6 lb), with a mean  $\pm$  SD of  $38.3 \pm 10.5$  kg ( $84.26 \pm 23.1$  lb). Dogs included in the study comprised 11 Labrador Retrievers, 8 mixed-breed dogs, 3 Golden Retrievers, 3 German Shepherd Dogs, 3 Rottweilers, 2 Boxers, 1 English Mastiff, 1 Bull Mastiff, 1 Great Pyrenees, and 1 Foxhound. All dogs tolerated the treatments well. There were no complications or adverse effects associated with the use of CCT. Rescue analgesia was not required for any dog enrolled in the study.

**Explanatory variables**—A correlation was detected between treatment group and age ( $r = 0.450$ ) and between treatment group and weight ( $r = 0.397$ ). Mean  $\pm$  SD age of the 17 dogs in the CCT group was  $3.7 \pm 1.9$  years, which differed significantly ( $P = 0.008$ ) from that of the 17 dogs in the no CCT group ( $5.7 \pm 2.2$  years). Mean  $\pm$  SD body weight of dogs in the CCT group was  $42.8 \pm 12.6$  kg ( $94.16 \pm 27.72$  lb), which differed significantly ( $P = 0.021$ ) from that of the dogs in the no CCT group ( $34.4 \pm 6.1$  kg [ $75.68 \pm 13.42$  lb]). There was a strong correlation ( $r = 0.653$ ;  $P < 0.001$ ) between body weight and duration of surgery, with heavier dogs having a longer duration of surgery. There was a high correlation ( $r = 0.772$ ;  $P < 0.001$ ) for 20 dogs with intact menisci that were not excised and 14 dogs with torn menisci in which 10 were partially excised. Similarly, there was a high correlation ( $r = 0.392$ ;  $P = 0.022$ ) between meniscal integrity and meniscal release, with intact menisci being more likely to be released than excised, compared with the outcome for torn menisci.

**Univariate analysis of measurements obtained on day 1 after surgery**—Mean  $\pm$  SD lameness score for the limbs of dogs in the CCT group ( $2.8 \pm 0.7$ ) was significantly ( $P < 0.001$ ) lower than the score for the limbs of dogs that did not receive CCT ( $3.8 \pm 0.3$ ). Mean  $\pm$  SD Glasgow pain scale score for CCT dogs ( $3.9 \pm 2.1$ ) was significantly ( $P = 0.024$ ) lower than the score for the dogs in the no CCT group ( $5.5 \pm 1.5$ ). Mean  $\pm$  SD pain threshold score was significantly ( $P = 0.001$ ) lower in CCT dogs ( $0.12 \pm 0.33$ ) than in dogs in the no CCT group ( $1.0 \pm 0.94$ ). Mean  $\pm$  SD VAS scores on day 1 after surgery were significantly ( $P = 0.031$ ) different, with the CCT dogs having lower scores ( $4.1 \pm 1.3$ ) than did the dogs in the no CCT group ( $5.0 \pm 1.0$ ). The CCT dogs had a significantly ( $P = 0.004$ ) greater mean  $\pm$  SD range of motion on day 1 ( $93.5 \pm 13.1^\circ$ ), compared with range of motion of the dogs in the no CCT group ( $81.7 \pm 6.16^\circ$ ). Mean  $\pm$  SD circumference of the stifle joint in CCT dogs ( $34.1 \pm 4.8$  cm) did not differ significantly ( $P = 0.227$ ) from that of dogs in the no CCT group ( $32.4 \pm 2.9$  cm).

**Regression analysis of measurements obtained on day 1 after surgery**—Linear regression analysis of the explanatory variables revealed that the CCT limbs had significantly ( $P = 0.001$ ) lower lameness scores than did the no CCT limbs. The modified Glasgow pain scale score for CCT dogs was significantly ( $P = 0.004$ ) lower than that of dogs in the no CCT group. The CCT dogs were significantly ( $P = 0.023$ ) more likely to have a lower pain threshold score than were the no CCT dogs. The VAS scores on day 1 after surgery were significantly ( $P = 0.017$ ) different, with the CCT dogs having a lower VAS score than did the no CCT dogs. Application of CCT resulted in a significantly ( $P < 0.001$ ) greater range of motion on day 1. Application of CCT significantly ( $P = 0.009$ ) decreased circumference of the stifle joint, compared with the circumference in limbs of the no CCT group. A higher circumference of the stifle joint before surgery was significantly ( $P < 0.001$ ) associated with a higher circumference on day 1 after surgery.

**Univariate and regression analysis of measurements obtained on day 14 after surgery**—No significant differences were found for lameness, pain scores, range

of motion of the stifle joint, or circumference of the stifle joint between the groups at 14 days after surgery.

## Discussion

In the study reported here, we investigated the effects of CCT in the immediate postoperative period. Application of CCT decreased signs of pain and swelling, improved limb use, and increased range of motion of the stifle joint during the first 24 hours after TPLO. Although the short duration of treatment likely affected the magnitude of the benefits observed, results of this study indicated that additional research is warranted to evaluate the effects of longer-term CCT.

Analysis of results of the study suggested that CCT can be successfully used in a multimodal therapeutic approach after TPLO. The application of CCT for 24 hours, in combination with perioperative administration of NSAIDs and opioids, significantly reduced swelling and signs of pain. No morbidity was associated with the use of CCT, which suggested that this treatment regimen can be used safely in medium- to large-breed dogs.

The CCT regimen was designed on the basis of reports<sup>19,22,23</sup> in human medicine and modified to fit the clinical setting of the dogs in the present study. The temperature of 4.4°C was selected for several reasons. First, this was the coldest setting achievable with the equipment by use of crushed ice and cold water and could be easily repeated and controlled. Second, the anesthetic and analgesic effect of cooling is related to slowing or eliminating the transmission of pain signals, and the relationship between cold treatment and analgesia is thought to be linear until a temperature of 10°C (50°F) is reached, at which point nerve conduction is blocked.<sup>32</sup> Finally, temperatures < 0°C (32°F) can cause localized tissue damage as a result of cold injury.<sup>32</sup>

Compression to 50 mm Hg was selected on the basis of studies<sup>25,26</sup> in humans. This pressure is reported to be safe in dogs<sup>33</sup> and was well tolerated by the dogs in the study reported here. The CCT duration and treatment intervals were selected on the basis of current recommendations for use of cold treatment in veterinary medicine<sup>32</sup> and the practicality of their application in a clinical setting.

In the present study, CCT caused significant effects only for the duration of the treatment. The lack of significant differences detected at the examination 14 days after surgery may have been caused by local inflammation rebounding after discontinuation of CCT<sup>32</sup> and progressing in a manner similar to that for the dogs that did not receive CCT. Tissue congestion during the postoperative period has been implicated as a cause of pain.<sup>32</sup> It is believed that increased capillary permeability results in increased pressures within the tissues, which leads to irritation of local nociceptors.<sup>25</sup> Intermittent pneumatic compression decreases venous stasis and increases arterial blood flow during the treatment period.<sup>33-35</sup> Cryotherapy also decreases edema and hemorrhage by decreasing capillary permeability and increasing blood flow in the treated area via a mechanism known as the hunting reflex,<sup>36</sup> which is a physiologic response intended to protect the body from cold dam-

age and that results in periodic bursts of vasodilation following the local application of ice. These factors, in combination with intermittent pneumatic compression, are the probable mechanisms through which CCT alleviates pain and inflammation. Following short-term treatment, the interstitial fluid may return to the surgical site.<sup>32</sup> The resultant edema and pain may explain the lack of significant differences for the measurements obtained at day 14 after surgery.

A longer duration of CCT after TPLO may have additional benefits, including faster bone healing and improved mechanical properties of bone.<sup>35</sup> In 1 study,<sup>35</sup> investigators detected faster bone healing and enhanced bone formation in Beagles that received intermittent pneumatic compression (without cryotherapy) for 8 weeks following osteotomy of the radius, compared with results for dogs in the control group. A similar study<sup>34</sup> in the tibia of rabbits revealed that intermittent pneumatic compression enhanced callus mineralization and improved the biomechanical properties of a healing osteotomy. Intermittent pneumatic compression also provides benefits in addition to those evident in healing bone. Investigators in 1 study<sup>33</sup> evaluated the effect of long-term (4-week treatment period) intermittent pneumatic compression in rats with rupture of the gastrocnemius tendon. Treated tendons had signs of increased maturation, improved neurovascular ingrowth, and fibroblast proliferation, which resulted in faster healing.<sup>33</sup> Considering the invasive nature of a TPLO, the soft tissue healing properties gained from intermittent pneumatic compression may prove beneficial to patients during the postoperative recovery period.

Although we are not aware of any reports of the use of simultaneous cryotherapy with intermittent pneumatic compression in dogs, several studies have been performed in humans. Investigators in a randomized, prospective study<sup>25</sup> reported several advantages of continuous CCT over use of ice alone following repair of the anterior cruciate ligament. Application of CCT resulted in lower pain scores, reduced consumption of analgesics, and increased passive range of motion.<sup>25</sup> In another study,<sup>24</sup> investigators compared the effect of CCT with that of a Robert-Jones bandage and reported a decrease in postoperative blood loss in the group treated with CCT. Cold compression therapy has also been used successfully in patients undergoing total knee arthroplasty, with benefits that include improved range of motion, decreased blood loss, and decreased hospitalization time.<sup>16</sup> Despite these positive results, some investigators have questioned the effects of CCT. In a randomized, controlled trial conducted to compare compression bandaging alone with CCT after total knee arthroplasty, investigators found no difference between treatment groups.<sup>37</sup> Similarly, in another study,<sup>22</sup> overall pain scores were similar between control and CCT groups; however, patients receiving CCT reported less pain at night and improved sleep. We cannot explain the contrasting results reported in humans.

Accurate evaluation of pain in animals can be challenging.<sup>7</sup> Three pain scoring systems were used in the present study to compensate for potential inherent flaws in any single pain assessment system.<sup>38</sup> The VAS is a simple way of quantifying a patient's pain intensity.

It has been used in animal studies<sup>3,29</sup> and provides reproducible results in dogs.<sup>30</sup> One potential limitation of the VAS is that variables such as anxiety and delirium can affect animal behavior, thus resulting in a misleading pain score.<sup>30</sup> The Glasgow pain scale is a behavior-based scale that has been used to evaluate acute pain in dogs undergoing pain-inducing procedures.<sup>28,39</sup> This system uses a series of observations and interactions with the animal to quantify the amount of pain in the animal. The modified Glasgow pain scale used here has also been used successfully in other animal studies<sup>28</sup> to differentiate among severities of pain and to monitor changes in pain intensity over time. A mechanical pain threshold was also measured by observing each dog's response to a pressure stimulus. Pain threshold tests, if adequately controlled, are considered objective measures of pain in animals and have been used to measure postoperative pain in dogs.<sup>30,40</sup> They have also been used to differentiate among severities of pain in a hospital setting.<sup>28</sup> However, to obtain accurate results, the method for producing the stimulus must be carefully controlled. To ensure this, a sonic palpometer was used in the study reported here to provide an accurate, repeatable method for application of pressure.

Physiologic variables, including serum cortisol and catecholamine concentrations, heart rate, respiratory rate, and blood pressure, have been used for pain assessment in animals.<sup>30,41</sup> Although these variables can be used to evaluate the amount of pain for a patient, they can also be affected by numerous other variables, including fear, stress, and degree of anesthesia.<sup>30</sup> On the basis of reports that indicated little<sup>30</sup> or no agreement<sup>41</sup> between physiologic variables and the amount of pain in animals, we elected not to use them as outcome measures in the present study and instead focused on other more consistently reliable outcome measures.

In addition to pain scores, lameness, range of motion, and circumference of the stifle joint were assessed to further evaluate the effect of CCT. In humans undergoing total knee arthroplasty, weight bearing and limb use (kneeling, stair climbing, and squatting) are used as measures of limb function.<sup>25</sup> In dogs, subjective numeric rating scales and force-plate gait analysis have been used to evaluate limb function<sup>42,43</sup> in addition to evaluation of pain.<sup>13,29</sup> If unilateral CrCL rupture is the only orthopedic problem affecting a dog, lameness observed in the postoperative period after TPLO is directly related to the pain and inflammation caused by surgical trauma. This lameness can be quite severe during the 24 hours immediately after surgery. Although force-plate gait analysis may be considered as the criterion-referenced standard for the evaluation of lameness, it was not available in our hospital setting. It was indicated in 1 report<sup>43</sup> that numeric rating scales can accurately reflect force-plate gait analysis when lameness is severe. To improve the study design, force-plate gait analysis could be incorporated as a more objective assessment of limb function and pain.

Loss of range of motion has been reported in dogs after TPLO.<sup>44</sup> The mechanism responsible for the loss of range of motion is thought to be multifactorial and related to delayed rehabilitation, inflammatory cells at the surgery site, and the deposition of fibrous tis-

sue near the femorotibial joint.<sup>44,45</sup> Understanding that these events may require > 24 hours or even > 28 days to become clinically evident,<sup>46</sup> loss of range of motion detected in the present study was likely caused by intra-articular effusion, local inflammation, and pain associated with the surgery. The improvement in range of motion in the CCT group, similar to results for other measured variables, would be primarily attributable to decreased inflammation and pain.

A potential limitation of this study was that dogs were not matched on the basis of age, body weight, and integrity of the medial meniscus. A computer randomization schedule performed prior to admission for surgery was used to assign dogs to study groups to remove bias in patient selection. This resulted in the CCT group having a significantly lower mean age and a significantly greater mean body weight. Assuming the effects of age and body weight were the same before surgery as after surgery, the multiple regression model that involved the use of scores obtained before surgery resulted in the effects of age and body weight being canceled. To the authors' knowledge, there are no reported data on the effect of age and body weight on postoperative function and pain in dogs.

Decisions for treatment of the medial meniscus were made on the basis of intraoperative evaluation. Meniscal integrity could be considered a factor that would affect postoperative pain. Meniscal injury in dogs has been implicated as a cause of lameness, pain, and degenerative joint disease.<sup>47,48</sup> However, another study<sup>42</sup> revealed that meniscal treatment did not affect postoperative limb function. A case-matched design in which patients are paired on the basis of age, body weight, meniscal integrity, duration of injury, and severity of CrCL should be used in future studies.

Because of an increasing concern for patient comfort in veterinary medicine, clinicians are moving toward a multimodal approach to analgesia. Clinical evidence promotes the use of early intensive physical therapy after TPLO to improve long-term limb function.<sup>49</sup> Results for the study reported here support the use of CCT as a therapeutic modality to decrease pain and increase limb function after TPLO. There are major benefits for application of CCT in the 24-hour period immediately after surgery; however, with further research, these benefits may prove to be even more substantial when incorporated into long-term physical therapy regimens.

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- a. Normosol R, Hospira Inc, Lake Forest, Ill.
  - b. Game Ready Cold Equine, Cool Systems Inc, Berkeley, Calif.
  - c. Sonic Palpometer, Palpometer Systems Inc, Victoria, BC, Canada.
  - d. Model No. A4889, Shor-Line, Kansas City, Kan.
  - e. Excel, Microsoft Corp, Redmond, Wash.
  - f. SAS software, version 9.1.3, Service Pack 4 of the SAS System for Windows, SAS Institute Inc, Cary, NC.
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## Appendix

Modified composite Glasgow pain scale<sup>28</sup> used by investigators as the primary endpoint for the assessment of signs of pain in dogs that underwent unilateral TPLO.

Section	Variable	Score	Description
A1	Vocalization*	0	Dog is quiet
		1	Dog cries or whimpers
		2	Dog groans
		3	Dog screams
A2	Attention to wound area*	0	Dog ignores wound or area
		1	Dog looks at wound or area
		2	Dog licks wound or area
		3	Dog rubs wound or area
B	Mobility†	0	Dog stands and walks normally
		1	Dog is lame
		2	Dog is slow or reluctant to move
		3	Dog is stiff
C	Response to touch	4	Dog refuses to move
		0	Dog does not respond
		1	Dog looks around
		2	Dog flinches
		3	Dog growls or guards area
D1	Demeanor	4	Dog attempts to bite
		5	Dog cries
		0	Dog is happy and content or happy and bouncy
		1	Dog is quiet
		2	Dog is indifferent or nonresponsive to surroundings
D2	Posture	3	Dog is nervous, anxious, or fearful
		4	Dog is lethargic or nonresponsive to stimulation
		0	Dog is comfortable
		1	Dog is unsettled
		2	Dog is restless
		3	Dog is hunched or tense
		4	Dog is rigid

\*Dog was in a kennel during this assessment. †Dog was put on a lead and led out of the kennel during this assessment.