Objective—To determine if transcostal thoracotomy closure resulted in less pain than circumcostal closure.

Study Design—Experimental cadaver and prospective clinical study.

Animals—Two canine cadavers and 13 adult, 22–29 kg dogs.

Methods—Phase 1: In 2 cadavers, 4 suture passage techniques were evaluated to determine the incidence of nerve entrapment in circumcostal intercostal thoracotomy closure. Phase 2: Pain after circumcostal closure (7 dogs) or transcostal closure (6 dogs) of a 4th intercostal space thoracotomy was evaluated by use of pain threshold scores, fentanyl administration rates, heart and respiratory rates, and numerical ratings for behavior. Arterial blood gas analyses were obtained 4 hours postoperatively. Transcostal closure was accomplished by drilling 5–6 small holes in the 5th rib and passing sutures through the holes and around the 4th rib to achieve closure. Pain threshold scores (PTS) were measured by an observer unaware of closure assignment, at 2, 4, 12, and 24 hours after closure by applying slowly increasing pressure to the incision line using a load cell. Rates of fentanyl administration were adjusted based on subjective impressions of dog comfort by a second observer unaware of closure assignment.

Results—A 70–100% incidence of nerve entrapment was found for all circumcostal techniques. PTS was higher ($P = .045$) and fentanyl infusion rates were lower ($P = .001$) for the transcostal group at 2, 4, 12, and 24 hour postoperatively compared with the circumcostal group.

Conclusion—There is a high incidence of nerve entrapment using circumcostal closure techniques. A transcostal technique appears to be associated with less pain during the first 24 hours postoperatively.

Clinical Relevance—Based on lower pain scores, transcostal thoracotomy closure may be preferable to circumcostal closure techniques.

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the suture and caudal rib. We are unaware of published reports evaluating the incidence of nerve entrapment with circumcostal sutures. Neurovascular entrapment and laceration of the intercostal artery is another important consideration with the circumcostal thoracotomy closure technique.

We hypothesized that sparing the neurovascular bundle by placing sutures through holes in the ribs should allow for a less painful recovery after an intercostal thoracotomy. Our objective was to evaluate pain associated with a transcostal suture technique as an alternative closure method for intercostal thoracotomy in dogs.

MATERIALS AND METHODS

Phase 1

Two cadavers were used to determine the incidence of nerve entrapment when passing suture around the rib caudal to the incision using 4 different circumcostal techniques: (1) passing needle pointed end first in immediate proximity caudal to the rib; (2) passing the needle blunt end first in immediate proximity to the rib; (3) passing the needle pointed end first far from the caudal rib; and (4) passing the needle blunt end first far from the caudal rib. Each technique was performed 10 times by one surgeon and then the tissues were dissected and the nerve was isolated to evaluate if it was entrapped.

Phase 2

In a prospective clinical trial, 13 adult dogs were studied; 7 dogs had transcostal closures and 6 dogs had circumcostal closures. All dogs had an exploratory thoracotomy with a partial or complete lung lobectomy. Baseline heart rate (HR) and respiratory rate (RR) were recorded when the dog was resting and before administration of medication or anesthesia. Dogs were premedicated with acepromazine (0.03 mg/kg subcutaneously), morphine (1 mg/kg subcutaneously), and glycopyrrolate (0.005 mg/kg subcutaneously). Anesthesia was induced with propofol (6–8 mg/kg intravenously [IV] to effect), and maintained with isoflurane (0.75%–2.25% inspired) in oxygen through a semi-closed system. Lactated Ringers solution was administered during anesthesia (10 mL/kg/h IV). After induction and every 90 minutes throughout surgery, cephazolin was administered (22 mg/kg body IV). Atracurium was administered (0.4 mg/kg IV) after induction and each dog was ventilated by intermittent positive pressure ventilation (11 cm H2O peak pressure, 5 cm H2O peak positive end expiratory pressure). End tidal CO2 and blood gases were evaluated intermittently to ensure adequate ventilation.

All dogs had a fourth intercostal thoracotomy. Dogs were randomly assigned to circumcostal suture (6) or transcostal suture (7) groups. For the transcostal group, a 0.062 in Kirschner wire was used to place 5–6 six holes through the center of the 5th rib. The pins were passed lateral to medial taking care to avoid puncturing pulmonary or cardiac tissues. Five to six sutures (2 polybutester) were passed around the 4th rib and through the holes in the 5th rib. For the circumcostal group, the same suture type was passed around the 4th and 5th ribs passing the blunt end of the needle in close proximity to the rib (Fig 1).

In both groups, a thoracotomy chest drain was placed through the dermis at the 10th rib and tunneled subcutaneously 3 ribs spaces cranially entering the thoracic cavity at the 7th intercostal space. Routine aspiration of the chest drain was performed. Intercostal nerve block was performed by injection of bupivicaine (2 mg/kg) just caudal to the rib heads at the 3rd, 4th, and 5th intercostal spaces. The thoracic muscles, subcutaneous tissues, and skin were closed in layers.

The dogs were recovered from anesthesia and analgesia was maintained using a constant rate infusion of fentanyl (1–5 μg/kg/h). Each dog was initially administered fentanyl (2 μg/kg/h), which was adjusted according to predetermined criteria used commonly in clinical assessment of pain. An observer unaware of group assignment adjusted fentanyl administration according to subjective assessments of vocalization and comfort level as well as HR and RR. If the HR was > 120 beats/minute or RR was > 15 breaths/minute, fentanyl administration was increased. If the dogs were vocalizing or appeared agitated or uncomfortable fentanyl administration was increased. Conversely, fentanyl administration was decreased if the dog appeared sedated or the HR or RR was less than the dog’s resting rates. Thoracic radiographs were taken to evaluate for pneumothorax 24 hours after surgery.

All data were collected by a second observer unaware of treatment group. A numerical rating scale (Table 1) was used.

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**Fig 1.** Schematics are transverse images through the 4th and 5th ribs. Schematic A illustrates the transcostal closure. An 0.062 Steinman pin was used to drill the holes in the 5th rib. The suture is passed around the cranial aspect of the 4th rib and through the 5th rib and tied securely, thus avoiding the neurovascular bundle. Schematic B represents the circumcostal closure. The suture is passed around the 4th and 5th rib and tied securely. The neurovascular bundle is between the suture and the 5th rib.
to evaluate each dog at 2, 4, 12, and 24 hours postoperatively. Numerical rating scores ranged from 0 to 3 (0 = minimal to 3 = maximal response). The scores recorded by the observer were continuous data points (in increments of one-tenth of a point). Numerical rating scores were obtained first at each time, then measurements of HR, RR, pain threshold score (PTS), and arterial blood gas analysis were obtained from each dog. HR and RR were normalized by dividing each measured value by the resting (pre-anesthesia) value. If it was <1 it was scored as 0; if it was 1 or between 1 and 1.3 it was scored as 1; if it was between 1.3 and 1.7 it was scored as 2 and if it was ≥1.7 it was scored as 3. Fentanyl administration rates, RR, HR, and PTS were obtained at 2, 4, 12, and 24 hours postoperatively. Arterial blood gases were obtained 4 hours postoperatively. Arterial blood samples were obtained from an arterial catheter and evaluated for pH, partial pressure of arterial oxygen (PaO2), partial pressure of arterial carbon dioxide (PaCO2), and bicarbonate.

PTS was obtained by use of a load cell (Spring Action Load Device, Pain Diagnostics and Thermography, Great Neck, NY). A blunt-ended plunger was placed over the midpoint of the incision and pressure was increased slowly. When the dog turned its head, vocalized, or attempted to move away from the stimulus, the load cell recorded the maximum pressure in kilograms.

Statistical Analysis

Pain threshold score, fentanyl rates, comfort scores, movement scores, vocalization scores, appearance scores, unprovoked behavior scores, interactive behavior scores, HR, and RR were analyzed by 2-way ANOVA for repeated measures for the effects of time, treatment, and time–treatment interactions. Blood gas variables were analyzed by Mann–Whitney U tests. Values of $P < .05$ were considered significant. Unless otherwise noted, data were reported as mean ± standard error (SE).

RESULTS

Phase 1

A 70% incidence of nerve entrapment was found when using the blunt end of the needle passed in close proximity to the rib. All other techniques had a 100% incidence of nerve entrapment.

PTS was significantly higher ($P = .045$) for the transcostal group compared with the circumcostal group (Fig 2). Mean (± SE) PTS for the transcostal group were 220 ± 10, 130 ± 12, 132 ± 12, 137 ± 4 kg at 2, 4, 12, and 24 hours, respectively. Mean (± SE) PTS for the circumcostal group were 125 ± 32, 24 ± 25, 26 ± 27, 12 ± 25 kg at 2, 4, 12, and 24 hours, respectively. Fentanyl infusion rates were significantly lower ($P = .001$) for the transcostal group compared with the circumcostal group (Fig 3). Mean (± SE) fentanyl infusion rates for the transcostal group were 2.5 ± 0.25, 2.45 ± 0.25, 2.6 ± 0.27, 1.1 ± 0.47 μg/kg/h at 2, 4, 12, and 24 hours, respectively. Mean (± SE) fentanyl infusion rates for the circumcostal group were 3.5 ± 0.2, 3.5 ± 0.15, 4.2 ± 0.15, 2.64 ± 0.25 μg/kg/h at 2, 4, 12, and 24 hours, respectively. Comfort score, movement score, vocalization score, appearance score, unprovoked behavior score, interactive behavior score, and vocalization score were also analyzed by 2-way ANOVA for repeated measures. Values of $P < .05$ were considered significant. Unless otherwise noted, data were reported as mean ± standard error (SE).

### Table 1. The Numerical Rating Scale; Each Parameter was Observed and Recorded on a Scale 0–3

<table>
<thead>
<tr>
<th>Variable*</th>
<th>Criterion†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comfort level</td>
<td>Position. Resting or sleeping.</td>
</tr>
<tr>
<td>Movement</td>
<td>Degree of movement and normal or abnormal in character.</td>
</tr>
<tr>
<td>Appearance</td>
<td>Calm and relaxed in appearance or agitated.</td>
</tr>
<tr>
<td>Unprovoked behavior</td>
<td>Animal interaction with its surroundings on its own initiative.</td>
</tr>
<tr>
<td>Interactive behavior</td>
<td>Animal interaction with observer when its name is called or when it is approached and handled.</td>
</tr>
<tr>
<td>Vocalization</td>
<td>Self-explanatory.</td>
</tr>
</tbody>
</table>

*The numerical rating scale subjectively evaluates the patients’ level of pain using the variables above.

†Scores for each variable range from minimal (0) to maximal response (3).
behavior score, arterial blood gas, HR, and RR were not found to be significantly different between the transcostal and intercostal closure groups (Table 2). Pneumothorax was not observed on radiographs.

**DISCUSSION**

The transcostal closure technique appears to be associated with less pain in the first 24 hours and so could be an alternative to the standard circumcostal technique when closing an intercostal thoracotomy. The immediate postoperative effects of anesthesia and intercostal bupivacaine may have confounded our results during the first 4 hours postoperatively. After 4 hours, the differences between the PTS associated with the 2 closure techniques becomes more evident.

Neurovascular entrapment seems to occur frequently with all circumcostal closure techniques. Nerve entrapment causes pain and discomfort after surgery. In phase 1, we demonstrated a high incidence of nerve entrapment using any circumcostal technique. The contribution of pain caused by nerve entrapment to the overall pain experienced is unknown, but given the results of our study it is seemingly appreciable. Dogs in the transcostal group were less painful than the circumcostal group dogs most likely because their intercostal nerves were not entrapped.

Rates of fentanyl administration recorded in our study are likely not a good variable to evaluate pain because of the subjectivity in determining infusion rate by the observer. However, it has been included because of its relevance when viewed concurrently with the PTS data. The transcostal group tolerated more incisional pressure with concurrently lower fentanyl infusion rates. Infusion rates were adjusted by subjective impression and objective variables (HR, RR) to mimic clinical patients. We used two observers both unaware of closure protocol for fentanyl infusion and PTS scoring to minimize confounding effects. Plasma fentanyl concentrations levels were not measured.

Assessment of pain in animals is difficult.10 Postoperative pain is influenced by severity of surgical trauma, mental state of the patient, and anesthetics used.4 No subjective measurement of pain is ideal, and many correlate poorly with objective measurements of pain such as HR, RR, and pain threshold tests.11,12 Also, observed behavior may not reflect an animal’s level of pain because of variations in domestication and socialization.11 Numerical rating scales apply numerical values to purposeful behaviors to more objectively interpret the subjective assessment of behaviors.11 A numerical rating scale was used in this study with objective criteria for pain to obtain a complete evaluation of an individual dog’s pain. Clinically, dogs in the 2 groups behaved similarly.

The most direct and objective measurement of pain is the pain threshold test.11 In animals, this test does not truly reflect the pain threshold but refers to the point at which the animal responds to the stimulation. It is unknown whether the animal perceives pain before, during, or after the response to the stimulus. Nevertheless, pain threshold tests when performed correctly are considered an excellent measure of pain severity in animals.11 In our study, dogs with transcostal sutures were able to maintain a higher PTS.

The limitations to our study were the short-term follow-up and low number of subjects. Subsequent studies should evaluate for rib fracture complications, suture erosion, and healing rates. Because of the low number of subjects and subsequent low power of this study, we cannot conclude that there is not a difference between the other variables evaluated.13

We concluded that circumcostal closure techniques are associated with a high incidence of intercostal nerve entrapment. Transcostal thoracotomy closure avoids intercostal nerve entrapment and appears to be less painful than the standard technique of circumcostal closure. Further clinical studies are warranted.

![Fig 3. Fentanyl constant infusion rates in μg/kg/h (± SE) for transcostal and circumcostal closure techniques. The transcostal closure required lower infusion rates of fentanyl (P=.001). The P-value for time was .018 and the P-value for time–treatment interactions was .778.](image-url)

**Table 2. Results (median + range) for Numeric Rating Scale**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Circumcostal</th>
<th>Transcostal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comfort level</td>
<td>0.67 ± 0.20</td>
<td>0.62 ± 0.16</td>
</tr>
<tr>
<td>Movement</td>
<td>0.31 ± 0.12</td>
<td>0.34 ± 0.11</td>
</tr>
<tr>
<td>Appearance</td>
<td>0.56 ± 0.20</td>
<td>0.72 ± 0.12</td>
</tr>
<tr>
<td>Unprovoked behavior</td>
<td>0.69 ± 0.20</td>
<td>0.75 ± 0.15</td>
</tr>
<tr>
<td>Provoked behavior</td>
<td>0.56 ± 0.22</td>
<td>0.81 ± 0.15</td>
</tr>
<tr>
<td>Vocalization</td>
<td>0.75 ± 0.17</td>
<td>0.68 ± 0.16</td>
</tr>
</tbody>
</table>
REFERENCES