Rectus sheath block results in greater cranial-caudal spread whereas transversus abdominis plane block results in greater lateral spread as assessed by computed tomography in dogs

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OBJECTIVE
To evaluate the in vivo spread of iodinated contrast following injections in the transversus abdominis plane (TAP) and rectus sheath in anesthetized dogs via computed tomography. Secondarily, the time of performing each block was compared.

ANIMALS
6 adult, purpose-bred Beagles.

METHODS
In a prospective crossover study, dogs were administered injections either in the rectus sheath or transversus abdominis fascial plane in the same manner as a rectus sheath block (RSB) or TAP block using dilute iodinated contrast. Computed tomography scans were performed immediately following injection (time [T]-0) and at 3, 9, 18, and 30 minutes postinjection. Data regarding the spread in the cranial-caudal and lateral directions and time to perform the injections were compared between the 2 techniques using paired or 2-sample t tests.

RESULTS
There was significantly greater spread in the cranial-caudal direction in the RSB group (62.9 ± 6.4 mm vs 54.8 ± 6.8 mm at T30; P = .009), whereas spread in the lateral direction was greater in the TAP group (37.3 ± 3.0 mm vs 48.6 ± 6.1 mm at T30; P < .0001). The RSB injection was performed in a more time-efficient manner than TAP injection (48.2 ± 3.2 seconds vs 82.3 ± 8.7 seconds; P = .03).

CONCLUSIONS
In living subjects, RSB injections resulted in greater cranial-caudal spread while TAP injections resulted in greater lateral spread. Rectus sheath block injections were performed in a more time efficient manner compared to a single point TAP injection in anesthetized dogs.

CLINICAL RELEVANCE
The RSB was performed in a more time-efficient manner and would likely result in greater coverage of the ventral midline. The TAP block would likely result in more significant regional anesthetic coverage of the lateral abdominal wall. Further studies are required to determine the degree of the clinical significance of these results.

Keywords: computed tomography, rectus sheath block, transversus abdominis plane block, ultrasound-guided regional anesthesia, fascial plane block

Abdominal surgical procedures, including elective ovariohysterectomy and exploratory laparotomy, are routinely performed in dogs. In order to provide multimodal analgesic coverage, systemic analgesics may be combined with regional anesthetic techniques. Fascial plane blocks are a regional anesthetic technique that rely on relatively large volumes of local anesthetic solution deposited in the plane between 2 fascial layers that contains multiple nerves compared to peripheral nerve blocks that discretely target individual nerves for blockade.† These locoregional anesthetic techniques are advantageous as they allow for a large area of analgesia with minimal

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injection points, often in a location relatively distant from the surgical site. Fascial plane blocks that are commonly employed to provide analgesia for abdominal surgery include the transversus abdominis plane (TAP) block and rectus sheath block (RSB).

The TAP block was first described in dogs in by Schroeder et al. and involves depositing local anesthetic in the fascial plane between the transversus abdominis and internal abdominal oblique muscles. This fascial plane contains the ventral roots of spinal nerves that ultimately penetrate the sheath containing the rectus abdominis muscle, branching to innervate cutaneous tissue, musculature, and peritoneum. Since the initial description of this technique, several studies have assessed the clinical efficacy of this block in dogs with varying success. In an effort to maximize regional anesthetic coverage of the abdominal body wall, modified approaches involving multiple injection points per hemiabdomen have also been described. The RSB in dogs has been described more recently by St James et al. and involves depositing local anesthetic solution in the fascial plane between the rectus abdominis muscle and internal rectus sheath. Like the TAP block, the RSB targets the ventral spinal nerves but targets these nerves more distally as they enter the internal rectus sheath. There is limited literature regarding the clinical efficacy of the RSB in dogs. One clinical study compared the analgesia provided by an incisonal block, TAP block, or RSB block in dogs undergoing ovariohysterectomy and concluded that all 3 techniques demonstrated acceptable analgesia.

Despite the ever-growing body of literature supporting the use of fascial plane blocks in human and veterinary patients, there is a paucity of evidence in veterinary medicine on the in vivo effects or spread. Many cadaveric studies in veterinary medicine exist for the TAP, with the spread of a local anesthetic solution having been characterized both by dissection and CT. The RSB is described less extensively in the veterinary literature, with only a handful of cadaveric dissection studies being published to date.

These cadaveric studies have limitations in their comparison to living patients as the spread of injectate in fresh or thawed cadavers may be impacted by tissue compression, lack of lymphatic or blood flow, respiratory patterns, temperature, and autolysis.

The primary objective of this study was to evaluate the in vivo spread of injectate following the TAP block and RSB in anesthetized dogs via CT. Additionally, a secondary objective was to assess the how efficiently each block can be performed. We hypothesized that the RSB would provide greater cranial-caudal spread along the abdominal body wall and would be performed in a more time-efficient manner than the TAP block.

**Methods**

**Animals**

Six adult, purpose-bred Beagles (3 females, 3 males) aged 12 months were used for this prospective, crossover study. This study was approved by the IACUC at the University of Wisconsin-Madison (V006664).

**Anesthesia and fascial plane injections**

Dogs were positioned in dorsal recumbency on the CT table. The hair over the dogs’ abdomens was removed by shaving, and baseline ultrasound images were obtained (HSL25x, 13 to 6 MHz; Sonosite SII; FUJIFILM Sonosite Inc). The abdomens were then scrubbed with a dilute chlorhexidine solution, and an ultrasound-guided RSB was performed using a single-point technique bilaterally as previously described. All locoregional techniques were performed by the same diplomate of the American College of Veterinary Anesthesia and Analgesia, experienced in ultrasound-guided regional anesthesia (CS). The probe was initially positioned to visualize the linea alba at a point 1-cm cranial to the umbilicus and then moved laterally to visualize the rectus abdominis muscle and associated rectus sheath. The injection was made so that the tip of the needle and associated injectate could be visualized in the plane between the internal rectus sheath and rectus abdominis muscle. Injections were made using an in-plane technique, with the probe oriented in the transverse plane, with respect to the animal’s long axis, using a 22-gauge, 2.5-inch nonchogenic spinal needle (Quincke Spinal Needle; BD) attached to a T-connector extension (18-cm MicroCLAVE; Zoetis Inc). The bilateral injection was timed, defined by the time from when the needle entered the skin on the first side until the injection was completed on the second side. Upon conclusion of the technique, the time was recorded in seconds and the CT scan initiated immediately (described below). Each hemi-abdomen was injected with a total volume of 0.5 mL/kg per hemiabdomen, for a total volume of 1.0 mL/kg of injectate solution containing a 3:1 ratio of saline (0.9% NaCl) and iohexol contrast (Omnipaque 240; General Electric).

Following a minimum 5-day washout period, the above protocol was repeated with a single lateral point TAP block performed bilaterally as previously described. The probe was initially positioned to visualize the linea alba at a point 1-cm cranial to the umbilicus and then moved laterally to visualize the rectus sheath muscle and, more laterally, transversus abdominis muscle. Injections were made using an in-plane technique, with the probe oriented in the transverse plane. The injection point was made at the point in which the plane between the internal abdominal oblique and transversus abdominis muscle could be most clearly identified on the ventrolateral aspect of the abdomen; injectate was deposited in the plane between the internal abdominal oblique and transversus abdominis muscle. In the same manner as the RSB injections, each hemi-abdomen was injected with a total volume of 0.5 mL/kg per hemiabdomen, for a total volume of 1.0 mL/kg of injectate solution, containing a 3:1 ratio of saline and iohexol contrast. The bilateral injection was timed, defined by the time from when the needle entered the skin to administer the block on the first side until
the block was completed on the second side. Upon conclusion of the technique, the time was recorded in seconds and the CT scan initiated immediately (described below).

Following the completion of CT scans, isoflurane was discontinued, and dogs were transported from the CT scanner back to the laboratory. Positive pressure ventilation was discontinued when spontaneous ventilation occurred. Dogs were then administered atipamezole (Antisedan; 0.05 mg/kg, IM; Zoetis), an α-2 adrenergic receptor antagonist formulated for the reversal of dexmedetomidine, in the epaxial muscles, and the trachea was extubated once an appropriate swallow reflex was regained. Dogs were monitored for 30 to 45 minutes following extubation for adverse effects and returned to the housing facility once they were fully alert and able to ambulate without assistance.

Computed tomography scans
The dogs remained in dorsal recumbency, and serial CT scans were performed. Computed tomography was performed with a 16-slice CT scanner (Lightspeed; General Electric). Images were obtained with 1.25-mm slice thickness, 0.562 pitch, 512 X 512 matrix, 200 mAs, and 120 kVp. The field of view and scan length were adjusted to include all relevant anatomy. In an initial pilot animal, scans were obtained immediately following contrast injection and then at 3, 6, 9, and 12 minutes following the injection. Subsequent animals were scanned immediately prior to contrast injection, immediately after, and then at 3, 9, 18, and 30 minutes after completion of the injection (time [T]–3, T9, T18, and T30). The extended interval between scans was to detect extent contrast dispersal. Images were obtained in detail using soft tissue and bone algorithms. Sagittal and dorsal reconstructions were created in a DICOM viewing software (Horos, version 3.3.6), and all measurements were performed in a DICOM viewing software (Phillips Intellispace, version 4.4). Images were subsequently evaluated by an anesthesiology resident who had been trained in cross-sectional image analysis within the imaging software for cranial-caudal spread, lateral spread from midline, and presence or absence of contrast within the correct anatomic location. Cranial-caudal spread measurements were made by identifying the first CT slice containing contrast and concluded when subsequent slices were contrast free. The lateral spread from midline was measured at the midpoint of the previously measured cranial-caudal spread and was completed via measurement tools within the imaging software.

Statistical analysis
Based upon previously published data on spread, a prestudy power analysis showed that 8 dogs would be required to achieve 80% power with an α of 0.05, assuming a large effect (G*Power, version 3.1; Heinrich-Heine-University Software, Universität Düsseldorf). However, the 6 subjects of the present study were obtained following the completion of data collection for an unrelated study; therefore, the decision was made to initially obtain data for 6 subjects rather than obtaining additional dogs. Data for cranial-caudal spread (millimeters), lateral spread from midline (millimeters), and time for block completion (seconds) were analyzed using commercially available software (Stata, version 17.0; StataCorp). The Shapiro-Wilk test was used to assess for normality. Paired t tests were used for paired parametric data, and 2-sample t tests were used for unpaired parametric data. Statistical significance was set at P < .05. The results are presented as mean ± SD for normally distributed data, and non-normally distributed data are presented as median (IQR) for data.

Results
Six dogs (weight, 9.63 kg ± 2 kg) completed both the RSB and TAP phases of the study. The induction, maintenance, and recovery phases of general anesthesia for all dogs were unremarkable, with no interventions beyond the manipulation of anesthetic depth required for the maintenance of physiologic parameters. There was no evidence of untoward effects from ultrasound-guided injections in any dog. All injections were made in the correct anatomic locations, with no intra-abdominal contrast noted in any of the CTs (Figures 1 and 2).

![Figure 1](image_url)

**Figure 1**—Images obtained via CT scan 30 minutes following rectus sheath injection of 0.5 mL/kg dilute iodinated contrast medium in a Beagle dog. **A**—Cross-sectional image. **B**—digital reconstruction of injectate spread. Note the spread of injectate contained within the rectus sheath, bilaterally present immediately lateral to midline.

Data regarding the spread of contrast may be found in Tables 1 and 2. Due to a timing error during the first CT in the RSB group, the terminal CT time point was shorter than other subjects, and, therefore, data from 1 dog was excluded from the spread analysis at all time points. Cranial-caudal spread was greater in the RSB group compared to the TAP group at the T0 and T30 time points (Table 1). The cranial-caudal spread was similar between groups at the T3, T9, and T18 time points. Lateral spread was greater in...
includes 5 dogs. Transversus abdominis plane data includes 6 dogs. Transversus abdominis plane injection of 0.5 mL/kg dilute iodinated contrast medium in a Beagle dog. A—Cross-sectional image. B—digital reconstruction of injectate spread. Note the more lateral spread of injectate contained within the plane superficial to the transversus abdominis muscle.

Table 1—Measurements of injectate spread visualized by CT in the cranial-caudal direction following rectus sheath block (RSB) and transversus abdominis plane (TAP) injections with dilute iodinated contrast medium.

<table>
<thead>
<tr>
<th>Cranial-caudal spread</th>
<th>RSB</th>
<th>TAP</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>T0 spread (mm)</td>
<td>44.6 ± 4.8</td>
<td>38.7 ± 6.7</td>
<td>.03</td>
</tr>
<tr>
<td>T3 spread (mm)</td>
<td>49 ± 6.1</td>
<td>43.3 ± 6.6</td>
<td>.05</td>
</tr>
<tr>
<td>T9 spread (mm)</td>
<td>53.3 ± 6.6</td>
<td>47.4 ± 7</td>
<td>.06</td>
</tr>
<tr>
<td>T18 spread (mm)</td>
<td>57 ± 7.1</td>
<td>51.0 ± 6.9</td>
<td>.06</td>
</tr>
<tr>
<td>T30 spread (mm)</td>
<td>62.9 ± 6.4</td>
<td>54.8 ± 6.8</td>
<td>.009</td>
</tr>
</tbody>
</table>

Data are presented as mean ± SD. Rectus sheath block data includes 6 dogs. Transversus abdominis plane data includes 6 dogs.

P values for each value are listed as the result of paired t tests, with significance set at P < .05.

Table 2—Measurements of injectate spread visualized by CT in the lateral direction following rectus sheath block (RSB) and transversus abdominis plane (TAP) injections with dilute iodinated contrast medium.

<table>
<thead>
<tr>
<th>Lateral spread</th>
<th>RSB</th>
<th>TAP</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>T0 spread (mm)</td>
<td>30.9 ± 3.7</td>
<td>37.9 ± 6.3</td>
<td>.005</td>
</tr>
<tr>
<td>T3 spread (mm)</td>
<td>32.5 ± 3.5</td>
<td>40.7 ± 5.9</td>
<td>.001</td>
</tr>
<tr>
<td>T9 spread (mm)</td>
<td>34.4 ± 3.2</td>
<td>43.6 ± 5.5</td>
<td>.0002</td>
</tr>
<tr>
<td>T18 spread (mm)</td>
<td>35.9 ± 3.0</td>
<td>46.3 ± 5.7</td>
<td>.0001</td>
</tr>
<tr>
<td>T30 spread (mm)</td>
<td>37 ± 3.0</td>
<td>48.6 ± 6.1</td>
<td>&lt; .0001</td>
</tr>
</tbody>
</table>

Data are presented as mean ± SD. Rectus sheath block data includes 5 dogs. Transversus abdominis plane data includes 6 dogs.

P values for each value are listed as the result of paired t tests, with significance set at P < .05.

The current study evaluated the in vivo spread of injectate following RSB and TAP injections in anesthetized dogs via CT and demonstrated that the RSB is associated with greater cranial-caudal spread and, thus, would likely provide greater regional anesthetic coverage along the abdominal midline compared to the TAP block when local anesthetic solution is used. However, as there was significantly greater lateral spread of injectate following TAP injection, this technique could prove more advantageous when regional anesthesia of the lateral abdominal wall is required.

The RSB was first described in humans in 1899 to facilitate surgery of the anterior abdominal wall in human adults but has more recently gained popularity in veterinary medicine as an ultrasound-guided regional anesthetic technique for midline abdominal procedures. The RSB targets regional anesthetic coverage of the terminal aspect of anterior, or ventral, branches of the spinal nerves as they enter the abdominal midline but not more laterally. Not only does the TAP block target a more lateral location, but the unique anatomic differences between these 2 targets may account for the greater cranial-caudal spread of injectate in the RSB group yet greater lateral spread with TAP injections in the current study. The rectus sheath in the dog is formed by the transversalis fascia and aponeurosis of the transversus abdominis. This compartment is more compact when compared to the fascial plane where the injectate is deposited in the TAP block, which is a larger, more distensible space. Injectate, therefore, is more likely to spread in the cranial-caudal direction within the rectus sheath as the lateral direction is more restricted, whereas the transversus abdominis fascial plane allows injectate to move freely in all directions. Indeed, a study assessing the dermatomal coverage of human subjects following TAP blocks suggested that regional anesthetic coverage may be inconsistent and located more laterally on the abdominal wall. Although this may suit surgical procedures involving lateral aspects of the abdomen, complete regional anesthetic coverage may be insufficient for ventral midline incisions, such as that of an exploratory laparotomy or ovariohysterectomy; RSB may be more suitable for these procedures.

One of the objectives of this study was to compare the length of time required to perform the injections between the 2 groups. The RSB was consistently performed in a more time-efficient manner compared to the TAP block. Several factors could account for this significant difference, including the time-effective manner compared to the TAP block (48.2 ± 3.2 seconds vs 82.3 ± 8.7 seconds; P = .03).
more straightforward anatomy associated with the RSB, the ease of imaging for the RSB compared to the TAP, and individual comfort with the blocks being performed. In the current study, all blocks were performed by a single anesthesiologist (CS) with extensive experience in regional anesthesia, which may have impacted these results. Furthermore, the institution where the study was performed routinely uses the RSB clinically, which may have impacted these results. Both injections were performed in a time-efficient manner and are 2 of the more straightforward ultrasound-guided regional anesthetic techniques to master. It is worth mentioning that the spleen was visually prominent in all dogs within the field of view of TAP injections but not noted in any of the RSB images. Careful avoidance of this deeper target was 1 reason why a modest increase in technique duration was observed with the TAP block. This also highlights the concern that iatrogenic splenic laceration could be a potential complication associated with the TAP block; training in regional anesthesia and skill in needle visualization are advised when performing this regional anesthetic technique.

In the current study, CT scans were obtained immediately prior to contrast injection, at T0, and then at T3, T9, T18, and T30. This time period was selected as the total time of scan (30 minutes) closely mirrored the approximate period of time from preoperative block to surgical start time at the study institution; however, scans were performed at additional time periods to monitor the speed in which injectate spread occurred as well as gain knowledge that may optimize timing of fascial plane-based regional anesthetic techniques. In both study populations, the spread of injectate gradually increased over the duration of the study period, reaching its peak for the study period at the final time point (Tables 1 and 2). The spread of injectate was still increasing at the last time point in all dogs, meaning that additional scans may have shown further spread at additional time points.

Several limitations exist in this study. The most notable is that the regional anesthetic techniques in this study were performed with a solution that contained a 3:1 ratio of saline and iodinated contrast. This dilution was determined based on previous studies assessing the effects of contrast and local anesthetic on dye spread in dog cadavers in which a more concentrated solution of iodinated contrast decreased injectate spread in the dorsoventral direction; although cranial-caudal spread was not impacted in the previous study, the present study further diluted the contrast agent to avoid any potential effects on spread. The iodinated contrast is a hyperosmolar solution compared to the local anesthetics routinely used to perform these techniques clinically. The specific gravity and osmolality of the injectate used in the present study differs from that of local anesthetics used clinically and may have impacted spread. In future studies, creating an injectate that closely mimics the physiochemical profile of local anesthetics should be considered.

Fascial plane blocks, such as the RSB and TAP blocks, may have variable spread based on the volume of injectate and the approach and technique utilized to inject the fascial plane. In the present study, TAP blocks were performed as originally described by Schroeder et al using a single injection point in each hemiabdomen. More recently, several cadaveric studies have reported that performing the TAP block using multiple injection sites per hemiabdomen allows greater injectate spread compared to the original technique. In the current study, the decision was made to use the single-injection technique to provide a more standardized comparison to the single-point RSB. With both regional anesthetic techniques, it is likely that multiple injection points would have resulted in a greater injectate spread. Indeed, fascial plane blocks allow flexibility in technique that can be tailored to the surgical procedure and anesthetic plan. Injections may be spread among multiple points or techniques may be combined to provide more complete coverage of the abdominal wall.

Another limitation is the small sample size. A power analysis was performed based on similar studies, and, to achieve a power of 80% and a confidence level of 95%, a sample size of 8 subjects would give adequate power to detect a difference in spread. However, in the interest of reducing live subject numbers, the sample size of 6 was chosen to coordinate with an unrelated study. Although post hoc power analyses are often flawed, a post hoc power analysis revealed that sufficient power was achieved, and the normal and consistent distribution of the data led the authors to conclude that sacrificing additional live subjects was unnecessary.

As previously mentioned, at the last scanning time point the injectate dispersal was greatest in both the cranial-caudal and lateral orientations, suggesting continued spread. This suggests that injectate spread may be greater than reported, and future scans should be performed over a longer timeframe to determine maximal spread. However, the scanning protocol described subjected research dogs to significant radiation exposure from multiple scans. Given the continued injectate dispersal on the final scan, future studies of a heterogeneous population (such as client-owned dogs) of various sizes, conformations, or undergoing various surgical procedures could reduce patient radiation exposure by limiting scans to the time of injection and following the surgical procedure at a time point > 30 minutes following injection. This would also allow an investigation of the effects of tissue manipulation on contrast dispersal and absorption of the contrast from the local site over a longer period of time.

In conclusion, this study represents a novel assessment of injectate spread following injections in the rectus sheath and TAP in living subjects. The RSB injection resulted in greater cranial-caudal spread and was performed in a more time-efficient manner compared to a single-point TAP injection in anesthetized dogs. However, it is important to note that the difference in spread may represent additional coverage of, at best, a single dermatomal segment. Cadaveric studies of the RSB with equivalent
injectate volumes to the present study demonstrated that cranial-caudal spread of 70 to 125 mm created staining of 2 to 4 ventral branches of spinal nerves. Therefore, it is unlikely that the superior spread demonstrated in the present study would translate into coverage of more than 1 dermatomal segment. Additional injection points may be required to provide more extensive dermatomal coverage. Transversus abdominis plane injections did result in superior lateral spread compared to RSB injections. Although the impact of injectate content may have impacted the results, the observed spread should mirror that of clinical patients injected with local anesthetic solution, meaning that the RSB would likely result in a greater coverage of the ventral midline, whereas the TAP block would result in significant regional anesthetic coverage of the lateral abdominal wall. Further clinical studies are required to determine the degree of the clinical significance of these results.

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**Disclosures**

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