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Original Article

The mid-point transverse process to pleura (MTP) block: a new end-point for thoracic paravertebral block*

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Summary

Current descriptions of thoracic paravertebral block techniques require the needle tip to be anterior to the superior costotransverse ligament. We hypothesised that an injection point midway between the posterior border of the transverse process and the pleura would result in spread to the paravertebral space. We completed bilateral injections of 5 ml methylene blue 0.2% midway between the posterior border of the transverse process and the pleura at T2, T4, T6, T8 and T10 in three unembalmed cadavers. The presence of methylene blue dye at the nerve root in the paravertebral space, the corresponding intercostal nerve and sympathetic chain at the level of injection, and at additional levels, was examined. We identified the superior costotransverse ligament, pleural displacement and spread to the erector spinae plane. We describe two case reports using this technique in patients. Our cadaver results and clinical cases demonstrate that, with the exception of cadaver 1, an injection point midway between the posterior border of the transverse process and pleura consistently achieved spread of dye at least to the paravertebral space at the level of injection, and frequently to adjacent levels. This may be a plausible explanation for the landmark technique's inability to reliably achieve a multilevel block. We describe a new ultrasound-guided technique for a single level paravertebral block.

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Introduction

Anaesthetists commonly describe the paravertebral space as wedge-shaped with clearly delineated boundaries. In contrast, anatomists do not typically use the term 'paravertebral space' when discussing paravertebral anatomy [1]. That disconnect appears to have been sustained to the present day, as the term remains absent from many modern anatomy textbooks [2, 3]. There has also been considerable variation in the description of the structure of the superior

costotransverse ligament (SCTL), an important posterior limitation of the space. Some of these descriptions question whether the SCTL could function as a bona fide limitation to the paravertebral space. As such, anatomists may be hesitant to describe this anatomical region as a clearly delineated 'space'.

Ultrasound-guided thoracic paravertebral block techniques [4] base the required end-point for effective needle-tip placement anterior (and deep) to the SCTL, on the assumption that the local anaesthetic must be injected into the paravertebral space to achieve a successful block. However, if the defined space is not a true anatomical compartment, this may open more superficial needle placement options that provide an effective block without the necessity to approach the pleura and the attendant risks. This concept is illustrated by several recently described thoracic paravertebral block variants, such as the erector spinae plane (ESP) block [5, 6], retrolaminar block [7] and the paraspinal block [8], all of which block thoracic spinal nerves using injections outside of the conventional paravertebral space.

We have previously reported pleural displacement during thoracic paravertebral block with the needle tip posterior to the SCTL, and, importantly, have achieved consistent clinical success with this site [9]. We use a parasagittal scan, with in-plane needle insertion caudad to cephalad (Fig. 1a). We initially scan over the ribs, then slide the probe medially in the parasagittal plane until we obtain an ultrasound image of the tips of the transverse processes. We aim to place our needle tip at the mid-point between the transverse process and pleura (Fig. 1b). We called this new technique the 'mid-point transverse process to pleura' (MTP) block. Based on our clinical observations, we hypothesised that an injection at the mid-point between the transverse process and pleura will result in a successful injectate spread to the paravertebral space.

Methods

Following institutional ethics board approval (Ottawa Health Science Network Research Ethics Board), we performed MTP blocks on unembalmed cadavers followed by dissection to examine the injectate spread.

With the cadavers positioned prone, the T1–T12 thoracic spinal levels were sonographically identified using a high frequency HFL-50 15–6 MHz linear transducer (Sonosite M-Turbo, Bothell, WA, USA). Then, using a dynamic parasagittal scan as described with our MTP technique, we inserted the block needle (50 mm 22 G SonoTAP, Pajunk, Geisingen, Germany) in-plane to the transducer in a caudad to cephalad direction aiming towards the paravertebral space. Once the needle tip reached the mid-point between the transverse process and pleura, we injected a total volume of 5 ml study solution at T2, T4, T6, T8 and T10 bilaterally. The solution consisted of methylene blue 0.2% prepared by mixing methylene blue 1% diluted with bupivacaine 0.5% in a 1:4 ratio to achieve the desired concentration. Methylene blue was used as a

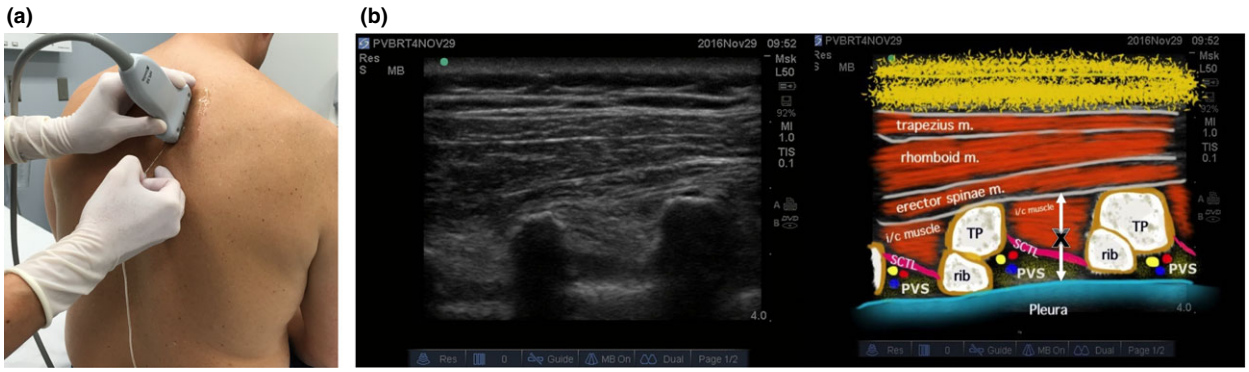

Figure 1 (a) Ultrasound transducer position and needle insertion site for mid-point transverse process to pleura (MTP) block technique. (b) Ultrasound image and schematic demonstrating the injection point for the MTP technique. SCTL, superior costotransverse ligament; PVS, paravertebral space; i/c muscle, intercostal muscle; m, muscle; TP, transverse process.

marker of the local anaesthetic spread. For each level injected, we also checked for the occurrence of anterior pleural displacement, documented the identification of the SCTL and examined the potential spread in the ESP.

Cadaveric dissection commenced immediately after injections. The anterior thoracic wall, heart and lungs were removed to visualise the posterior mediastinum. The parietal pleura was removed from the thoracic cavity. Each intercostal and paravertebral space was specifically examined for methylene blue spread. The outcomes sought at each level injected were methylene blue presence or staining of the (1) nerve root in the paravertebral space, (2) intercostal nerves distal to the paravertebral space and (3) sympathetic chain. Additional back dissection was also performed on two of the three cadavers. Due to time constraints, and the presence of a midline scar in the thoracic area of the first cadaver, we did not perform a back dissection on cadaver 1.

Results

For cadaver 1, a vertical midline scar in the mid to low thoracic area suggestive of previous back surgery was noted, and ultrasound images were less than ideal, with the SCTL not readily identifiable at the majority of levels. The nerve roots were stained blue in two out of five levels injected on the left, and three out of five injections on the right (Supporting Information Table S1). At dissection, the first rib on the left was found to be much higher than on the right, which led us to question if our injections on the left were actually performed at T3, T5, T7, T9 and T11 rather than the intended levels. If that were the case, the nerve roots as well as intercostals in four out of the five levels injected on the left were stained blue. Dye spread to the sympathetic chain was present at many levels (Table S1).

For cadaver 2, injection was noted to be superficial to the SCTL in eight out of 10 levels (the SCTL was not clearly identified at the other two levels), pleural displacement was noted in seven out of 10 levels and erector spinae type spread was seen in nine out of 10 levels. Evidence of pleural displacement together with erector spinae block pattern of spread was seen in some levels (Supporting Information Video S1). The nerve roots were stained blue in all 10 levels, as well as on the right side of the T11 nerve root (Table S2 of the Supporting Information online, Fig. 2). The intercostal nerves were stained blue in all 10 levels, as well as five additional levels that were not injected. Dye spread to the sympathetic chain was variable.

For cadaver 3, injection was noted to be superficial to the SCTL in six out of 10 levels (the SCTL was not clearly identified in the other four levels), pleural displacement was noted in six out of 10 levels and erector spinae type spread was seen at five out of 10 levels injected (Supporting Information Video S2). The nerve roots from T1 to T10 were stained blue, with the exception of T9 on the right side (Supporting Information Table S3, Fig. 3). The intercostal nerves were stained blue in nine out of 10 injected levels, with an additional seven levels also stained blue. Dye spread to the sympathetic chain was variable.

Back dissections were carried out on cadavers 2 and 3. For cadaver 2, dye was present on the anterior and posterior surface of the erector spinae muscle from T2 to T12 bilaterally, as well as on the rhomboid, latissimus dorsi and trapezius muscles from T2 to T12 (with the exception of T9 on the right). For cadaver 3, the pattern of dye spread was generally similar to the pattern of spread observed for cadaver 2.

Case reports

Case 1

A 77-year-old, 57 kg woman with a past medical history of breast cancer, asthma and hiatus hernia, presented for right side mastectomy and sentinel lymph node biopsy. She had a history of left side mastectomy and sentinel lymph node biopsy four months prior, with paravertebral blocks and general anaesthesia.

After sedation with 1 mg midazolam, paravertebral blocks were performed at T2, T3 and T4 on the right using dynamic ultrasound with parasagittal scan, and in-plane, caudad to cephalad needle (22 G, 2 inch SonoTAP, Pajunk) insertion. Injection was performed at the mid-point between the posterior border of the transverse process and the pleura, with 10 ml ropivacaine 0.5% with adrenaline 1 in 400,000 injected in each level. Pleural displacement was observed at all three levels injected. Sensation to pin-prick was tested 20 min after the block, with decreased sensation noted

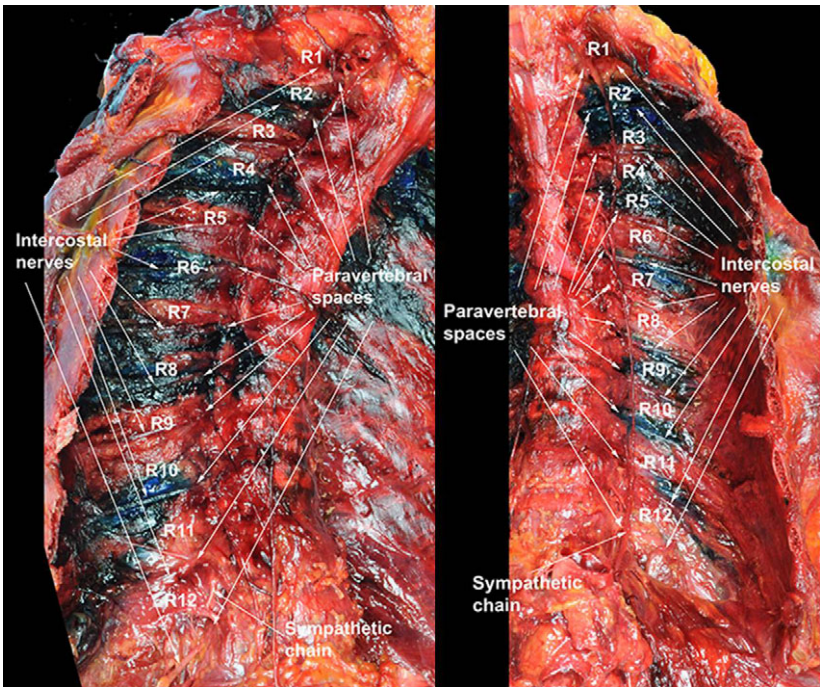

Figure 2 Dissection of cadaver 2 showing the paravertebral space, intercostal nerves and sympathetic chain.

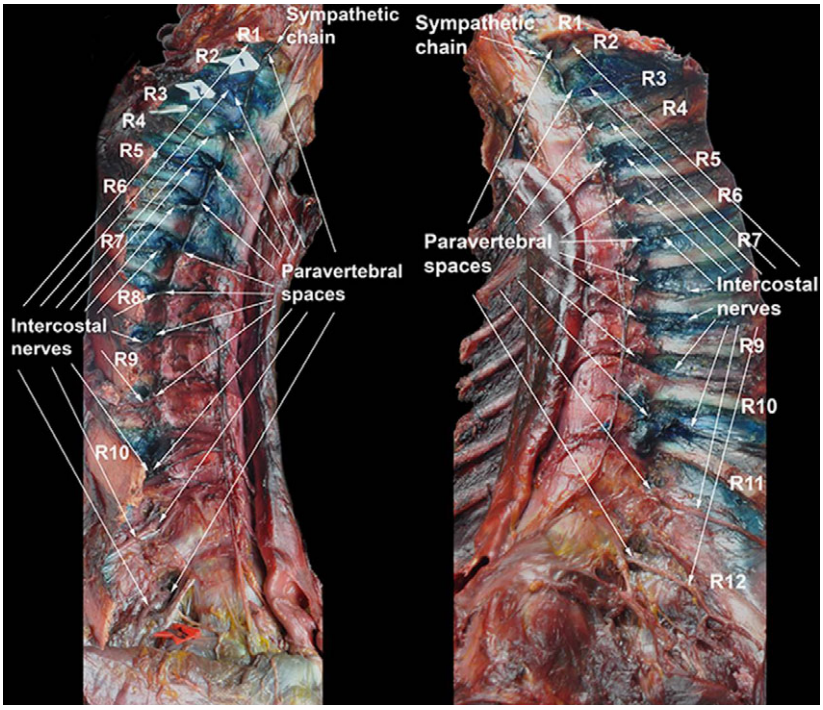

Figure 3 Dissection of cadaver 3 showing the paravertebral space, intercostal nerves and sympathetic chain.

in the T2–T5 dermatomes on the right side. Induction consisted of 100 μg of fentanyl, 120 mg propofol and 50 mg rocuronium to facilitate tracheal intubation. Anaesthesia was maintained with sevoflurane, at 0.6–0.8 age-corrected minimal alveolar concentration (MAC) throughout the surgery. This was increased to

1 MAC during sentinel node biopsy, and an additional 50 μg of fentanyl was given at this time, as the blood pressure had increased from 101/51 to 124/58. No additional opioids were given in the operating room. A surgical drain was placed, with the exit site at the T7/8 level.

The patient did not require any additional opioid in the recovery ward or the surgical day-care unit. She was given paracetamol 650 mg orally before same day discharge from hospital. Total time spent in recovery was 58 min. On arrival to recovery her pain score using a verbal analogue scale was 0/10. Before discharge from recovery there was 'slight discomfort' with a pain score of 1–2/10.

On postoperative telephone follow-up, the patient had taken 1 mg of oral hydromorphone at bedtime on the evening of surgery and the next two evenings in addition to paracetamol. The patient claimed to have less pain than with the surgery performed 4 months before.

Case 2

A 57-year-old, 73 kg woman with treated hypertension presented for left sided wide local excision, oncoplastic mammoplasty and sentinel lymph node biopsy.

Paravertebral blocks were performed at T2, T3, T4 on the left using the same technique described in case 1, but this time with an 18G Tuohy Needle (SonoTAP Tuohy Pajunk) and 10 ml bupivacaine 0.25% with adrenaline 1 in 400,000 at each level. Pleural displacement was only visualised at T3, with ESP spread being more evident at T2 and T4. Intravenous fentanyl at a dose of 50 μg was used for analgesia during block insertion. Sensation to pin-prick was tested postoperatively in the PACU, with decreased sensation noted in the T2–T5 dermatomes on the left side. General anaesthesia was induced with 100 μg fentanyl and 120 mg propofol. A size-four i-Gel® (Intersurgical, Berkshire, UK) was inserted, and her lungs were ventilated using intermittent positive pressure ventilation. Anaesthesia was maintained with sevoflurane, at 0.6–0.9 age-corrected MAC throughout the surgery. There was no change in baseline heart rate or blood pressure on commencement of sentinel node biopsy. No further opioids were given in the operating room, PACU or the surgical daycare unit. She was given paracetamol 1 g orally four times a day, ibuprofen 400 mg three times a day and dihydrocodeine 30 mg four times a day (as per usual protocol) before same-day discharge. Total time spent in recovery was 45 min. On arrival in recovery, her pain score was 0/10 and remained so until discharge.

At postoperative telephone follow-up 24 h later, the patient had taken three doses of regular paracetamol 1 g, three doses of ibuprofen 400 mg and one dose of dihydrocodeine 30 mg. Her pain score was 2/10.

Discussion

Our cadaver results and case descriptions demonstrate that, with the exception of cadaver 1, an injection point midway between the posterior border of the transverse process and pleura consistently achieved spread of dye to, at least, the paravertebral space at the level of injection, and frequently to adjacent levels. There are several potential hypotheses to explain our cadaver and clinical findings. The presence of a gap between the medial and lateral portions of the SCTL has previously been reported [10]. Fenestrations in the SCTL are apparent in a previous study of in-situ images of the thoracic paravertebral space [11]. In addition, a study on the quantitative morphology of the lateral ligaments of the spine [12] described that the SCTL 'blended laterally with the internal intercostal membrane, while the medial border formed a free edge'. They also classified the SCTL as either tendon-like (consisting of continuous dense fibres), woven (consisting of bundles of fibres interwoven with adipose-like tissue) or membranous (consisting of thin membrane-like structures that blended into the internal intercostal membrane) in nature, with an incidence of 71% tendon-like, 25% woven and 4% membranous.

The SCTL runs in an oblique fashion in two directions (posterior to anterior, and posterolateral to anteromedial) from the anterior and inferior surface of the transverse process above, to the upper border of the neck of the rib below. The mid-point from the posterior border of the transverse process to the pleura is thus most likely to be posterior to the SCTL (Fig. 1b). The SCTL has a thickness of approximately 1 mm [12], and it is evident that it is not completely continuous. It is possible that an injection posterior to

the SCTL will result in solution passing through gaps and fenestrations in the SCTL, and reaching the nerve root in the paravertebral space. In fact, we do not know if the end-point for injection with the landmark technique lies posterior or anterior to the SCTL. The location of injection relative to the SCTL may be an explanation for the multilevel spread with the landmark technique, that could not be predicted, as seen in previous studies [13], with injections anterior to SCTL resulting in a multilevel spread, and injections posterior to SCTL resulting in a single level or limited multilevel spread.

A high-fidelity phantom model examining the ability of the landmark technique to place the needle tip in the paravertebral space [14] has shown a success rate of 28%, and a pleural puncture rate of 12%. The authors postulated that higher success rates in clinical studies may be attributed to the diffusion of a local anaesthetic over time into the paravertebral space or minor anatomical variations not seen with their model.

We suggest that injections posterior to the SCTL may reach the paravertebral space via several mechanisms, including: medial to the SCTL through the gap between SCTL and vertebral bodies; through fenestrations in the SCTL; lateral to the SCTL through the internal intercostal membrane; and via spread deep to the erector spinae muscles, through the intercostal muscles and into the intercostal space (Fig. 4). Pleural displacement may not be necessary for paravertebral spread, as evident with the ESP [5, 6], retrolaminar [7] and paraspinal [8] blocks. In many cases we achieved paravertebral spread without pleural displacement, as has previously been reported [15].

Our needle-tip location midway between the posterior border of the transverse process and the pleura does not rely on identifying the SCTL. If the SCTL is not readily apparent, a successful paravertebral block can still be achieved by injection in this location. This is potentially safer than aiming to place the needle tip within a few millimetres of the pleura, especially when ultrasound imaging is less than ideal.

A limitation of our cadaveric investigation is that a cadaver may not exhibit the same integrity of tissue and permeability to diffusion as a living patient. Also, factors such as temperature may affect diffusion, and we were unable to control for this.

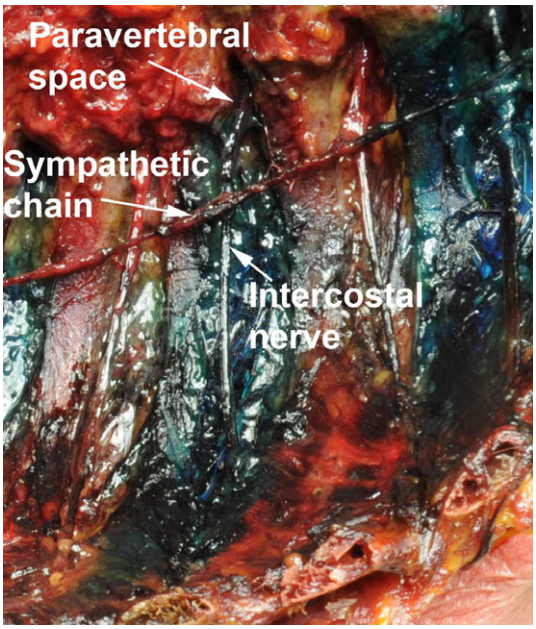

Figure 4 Close-up image of intercostal nerve with methylene blue dye posterior to the nerve.

We have described a new technique for thoracic paravertebral block with parasagittal scan, in-plane needle advancement, and injection at the midway point between the transverse process and pleura. Our results challenge the traditional teaching that the SCTL must be traversed in order to achieve a successful ultrasound-guided thoracic paravertebral block. The MTP block does not require the SCTL to be identified, and is further from the pleura than currently described techniques, thus may be more acceptable to those learning ultrasound-guided thoracic paravertebral block. The MTP block could result in a lower incidence of pleural puncture as the needle remains distant from the pleura, potentially also reducing the risk of injury to the nerve and vessels that lie superior to, and well beyond, the needle tip. There has been a long-held dogma that the SCTL needs to be traversed by the needle tip in order to achieve a successful paravertebral block. Until the use of ultrasound, it has not been possible to verify that the needle tip is actually in the paravertebral space.

Our cadaver and clinical work suggest that the SCTL may not be a barrier to diffusion and that the paravertebral space is not a discrete anatomical compartment. In addition to the retrolaminar technique [7], the ESP block [5, 6] and the paraspinal/intercostal

[8] techniques recently described, our work is further evidence that a paravertebral block can be achieved with an injection outside the paravertebral space. Future work is needed to elucidate the differences between these recently described paravertebral block variants.

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Written consent was obtained from the patients for the cases described. No external funding or competing interests declared.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Video S1. MTP injection demonstrating pleural displacement together with erector spinae plane block pattern of spread.

Video S2. MTP injection demonstrating erector spinae plane block pattern of spread.

Table S1. Spread of methylene blue seen in cadaver 1 at dissection.

Table S2. Spread of methylene blue seen in cadaver 2 at dissection.

Table S3. Spread of methylene blue seen in cadaver 3 at dissection.