Ultrasound-guided Thoracic Paravertebral Blockade

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Paravertebral block involves the use of local anaesthetic lateral to the vertebral column to produce ipsilateral anaesthesia and analgesia by blockade of the thoracic segmental nerves. The key advantages over intercostal blocks are broader coverage (can cover multiple dermatomes and include blockade of the posterior primary ramus) and the ability to insert a catheter – avoiding multiple needle insertions. In the lower lumbar region, this constitutes a psoas compartment block.

Single level injection with catheter insertion constitutes my usual approach for analgesia as part of a multimodal regimen for unilateral incisions in thoracic dermatomes, such as thoracotomy and nephrectomy. I have found it particularly useful for management of analgesia for fractured ribs in difficult cases. A bolus dose of 15ml 0.5% bupivacaine can cover a mean of 4 (1-11) thoracic dermatomes (1)

Single shot blocks performed at multiple spinal levels has been described as an anaesthetic technique for breast surgery. There are case reports and prospective studies of bilateral paravertebral blocks being used for obstetric analgesia, and even as an alternative to general anaesthesia for abdominal surgery (2)

Failure to establish paravertebral blockade when a landmark technique is used occurs in approximately 12% cases (1,3). Differing patterns of spread have been observed in contrast studies (4). It is likely that the use of ultrasound to accurately locate the paravertebral space and observing patterns of spread in real time may reduce the failure rate and improve local anaesthetic coverage.

Problems associated with epidural blockade, such as lower limb motor blockade, urinary retention, hypotension, and concerns about neuraxial nerve damage related to haematoma or abscess formation may explain the resurgence in use of the paravertebral block. Recent reports suggest improved long term outcomes, with reduced chronic pain (5) and cancer recurrence (6) after breast surgery, which is now the subject of prospective study. (7)

The blocks may be safely performed in the anaesthetised patient, improving patient acceptability and allowing flexibility with postoperative analgesic plans, for example when a laparoscopic cholecystectomy turns into an open procedure.

Anatomy

The thoracic paravertebral space is a wedge-shaped potential space, its depth greater medially when distended. It communicates with the cervical paravertebral space cephalad, but the psoas muscle probably limits direct communication with the lumbar paravertebral space caudally. Medially it is bound by the vertebral body, intervertebral
disc and intervertebral foramen. Its anterolateral border is the parietal pleura and it communicates with the intercostal space laterally, beyond the tip of the transverse process. The posterior border is formed by the transverse process and the superior costotransverse ligament, which forms the most important structure to be traversed by the needle. This ligament joins the inferior aspect of the transverse process above with the superior aspect of the neck of the rib below and may be appreciated by a ‘click’ on advancement of the needle.

The contents include fat and extrapleural fascia, the segmental nerve branching into anterior and posterior primary rami, the sympathetic chain and rami communicantes, and radicular vessels. The nerve at this point may consist of rootlets and is devoid of a sheath, allowing good local anaesthetic penetration. The nerve should lie deep to the transverse process, protecting it from the needle.

The endothoracic fascia, the deep fascia of the thorax, is a fibroelastic structure dividing the paravertebral space into anterior and posterior compartments. It is closely applied to the anterior vertebral body, and laterally it contains the sympathetic chain anterior to it, the segmental nerve posterior to it. Catheter placement relative to this layer may determine the different patterns of spread observed with this block.

**Fig. 1.** Anatomy of paravertebral space (8)
In the thoracic spine the superior aspect of the spinous process relates laterally to the transverse process of the vertebra below it, due to its steep downwards angulation. The tip of the transverse process is located ~2.5cm from the spinous process. This is the insertion point for the traditional approach to paravertebral blockade – the needle is inserted perpendicularly to skin until the transverse process tip is contacted, then ‘walked off’ into the paravertebral space.

**Sonoanatomy**

I usually start imaging with a linear probe at ~8MHz and change to a low frequency curved probe if imaging is inadequate. The curved probe provides a wider field of view which can help orientate the midline and pleura during transverse scanning, but at less resolution. The transverse process projects posteriorly, and the costotransverse articulation is on its anterior aspect, forming a step in bony depth and angle to allow identification of the transverse process tip with ultrasound. With a transverse probe orientation, the acoustic shadow of these bony margins becomes deeper at the point where the transverse process joins the rib. It is important to distinguish the pleura from the acoustic shadow of bone – pleura moves with inspiration and some penetration of ultrasound occurs. The pleura can be distinguished from bone more easily on saggital scanning – it is the deeper hyperechoic structure. Local anaesthetic injected into the paravertebral space should increase the depth between transverse process and parietal pleura. Identification of the radicular vessels using colour flow while scanning the paravertebral space is difficult because of the depth and size of the vessels, and the presence of acoustic shadow, but can inform the needle approach particularly in thinner subjects.
Fig 2. Note correlation of bone topography of posterior thorax in a spine model with the acoustic shadow of the transverse ultrasound image below.
Fig 3. Saggital paramedian scan at tip of transverse process. Cephalad to left of image. Note the rib shadow deep and cephalad to the transverse process in this example. Lateral angulation of probe helps imaging of the pleura as it reflects medially towards the mediastinum.

**Needle approaches to the paravertebral space**

A number of US-guided approaches to the paravertebral space have been advocated, and no particular approach has been shown superior (8). Proximity to the neuraxis and lung require a good orientation to the anatomy and steep angles of insertion may make needle visibility difficult. Orientation to the transverse and spinous processes during needle insertion is greatly helped by creating surface markings during your survey scan.

**Ultrasound-assisted traditional approach**

I would recommend this approach for beginners to ultrasound or paravertebral block, in obese patients, or if there is subcutaneous emphysema making imaging difficult. The traditional approach has a good success rate and low risk of complications (3). A survey scan defines the location and depth of the transverse process tip for marking, and the depth to lung. When measuring distance, only light probe pressure should be used. Proceed with paravertebral blockade in the traditional way, ensuring the angle of needle insertion matches the angle of the ultrasound beam during the survey. I use a 16G
Tuohy needle for this approach with the curved surface facing the pleura once the needle is angulated. Once the transverse process is contacted, walk off cephalad (or caudad) to a predetermined distance (10-15mm depending on size of patient/survey scan). Walking the needle cephalad is said to have a higher risk of pneumothorax and a second bone contact onto juxtaposed rib may confuse the approach (see Fig. 3), but is my preferred approach to avoid the nerve root which lies caudad to the transverse process. A “click” may be encountered traversing the superior costotransverse ligament, or loss of resistance can be sought to assist with the endpoint, but these are not always easily appreciated. I deliver a bolus of local anaesthetic to distend the space before placing the catheter. The advantage of this approach is its simplicity and not having to contend with needle visibility. The disadvantages are that displacement of the pleura from local anaesthetic injection is not observed, and resistance to feeding the catheter into the space (due to the steep angle of approach) is common. Catheter displacement within 48 hours may result. The steep angle of insertion also potentially increases the risk of pneumothorax.

Transverse In-plane approach
This appears to be the preferred approach by other authors (and myself) for both single shot blocks and catheter insertion. Identification of the key landmarks is as described above.

When performing a survey scan, mark the tip of the transverse process and spinous process. It is usually possible to visualize the transverse process and pleura without the rib obscuring it - position the tip of the transverse process in the middle of the image and then rotate the probe slightly. The heel of the hand holding the probe should be resting firmly against the patient to hold this position. The needle insertion point should be at least 2cm lateral to the tip of the transverse process to allow an insertion angle suitable for needle visualization. A sonographic Tuohy needle also helps (such as Pajunk Tuohy Sono). The needle approach is between these structures and injection is performed under vision (by an assistant with extension tubing) to observe pleural displacement, confirming correct position (Fig. 5).

Care should be taken not to advance the needle more than 1cm once it is in the acoustic shadow of the transverse process, as it is pointing in the direction of the intervertebral foramen. It is also possible the catheter fed beyond the needle may enter the neuraxis, although this has not been reported in the published case series(9).

An alternative approach is to slide the probe above or below the transverse process and insert needle tangential to the pleura which is no longer obscured by bone, bevel up, moving the probe intermittently to reference the bony landmarks and ensure injection is deep to the plane of the transverse process. This approach would be less likely to point directly at the intervertebral foramen (personal communication, M Karmakar), and allows better visualization of the needle tip, but requires greater dexterity with probe handling and interpretation of the anatomy.
Fig. 4 Transverse in plane approach. Probe has been rotated from the image obtained in Figure 2 to visualize pleura rather than rib. Needle tip is just deep to transverse process and is obscured by its acoustic shadow. Note local anaesthetic (LA) distending the lateral paravertebral and intercostal space.

Saggital In-plane approach
Positioning the probe in a sagittal orientation 2-3cm lateral to the midline to obtain an image as in Figure 3, clearly distinguishes bone and pleura. Angulating the probe slightly laterally may improve visibility of the pleura which reflects anteriorly toward the mediastinum at this site (see Fig 1). Between the transverse processes are the superior costotransverse and intertransverse ligaments and, deep to these, the paravertebral space. The difficulty I find with this approach is the angle of insertion becomes relatively steep to map a course between the bony landmarks and finish close to pleura, making needle visibility difficult (Fig 6). This may be helped by flexing the patient as much as possible, making the block slightly shallower and the bones further apart, and using a sonographic needle. The advantages are spread can be observed in the adjacent acoustic windows and catheter insertion is not pointing toward the neuraxis.
Conclusion
Paravertebral blockade is experiencing a resurgence in interest and use. As regional anaesthetists become more experienced with the use of ultrasound, its application to guide routine paravertebral insertion is inevitable. Although this is challenging, it can be achieved. Further study is required to define the optimal approach and demonstrate improved outcomes with ultrasound guidance.

References & Reading

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