Ultrasound-guided thoracic paravertebral blocks: anatomy, approaches and techniques

Katharine Fleischmann, MD
Department of Anesthesia, Critical Care and Pain Medicine
Massachusetts General Hospital
Harvard Medical School
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Introduction:

Thoracic paravertebral blockade is a century old technique used for intra-operative and peri-operative pain control as well as acute and chronic non-operative pain. Although not used for many decades, this block has enjoyed a resurgence of interest over the past twenty years. Clinical benefits include the following: thoracic paravertebral blockade may be unilateral or bilateral, motor blockade is very rare, orthostatic hypotension is rare, there is little risk of urinary retention, the block may be performed as a single shot or by placement of an indwelling catheter, and a patient's opioid requirement may be decreased markedly. Many practitioners, however, remained hesitant to perform thoracic paravertebral blocks secondary to the associated risk of pneumothorax, reported to be 0.5%-2% in addition to the risk of dural puncture with some of the older medially directed landmark approaches.

The growth of ultrasound technology and, with it, our ability to visualize the pleura and other structures in and around the paravertebral space has fueled a tremendous increased interest in performing thoracic paravertebral blocks. These blocks may be used for acute pain control, as an adjunct to general anesthesia for peri-operative pain control and, in some practices, as the primary anesthetic. To date, no large multi-center trials have been done in an effort to show increased safety and efficacy of thoracic paravertebral blocks when performed using ultrasound technology. However, a number of smaller studies have suggested that this is true. Ultrasound technology has allowed us to broaden the depth of our knowledge of the anatomy of the paravertebral space in addition to enabling us to visualize the anatomic structures, the needle, and the spread of local anesthetic.

Anatomy:
(Fleischmann, ASRA, 5/17/12)

The thoracic paravertebral space is a wedge shaped space located next to the vertebral column where the spinal nerves emerge from the vertebral foramen. The anterolateral boundary is formed by the parietal pleura. The medial boundary is formed by the posterolateral aspect of the vertebral body, the intervertebral discs, the intervertebral foramen, the spinal nerves and connective tissues. The posterior boundary is formed by the superior costo-transverse ligament which extends from the inferior aspect of each transverse process to the superior aspect of the rib below. The superior costo-transverse ligament is continuous laterally with the internal intercostal membrane, which is the aponeurosis of the internal intercostal muscle and attaches medially to the upper and lower borders of the ribs. This space, although defined by its borders and the strength of the connecting tissues and structures, is contiguous with the intercostal space laterally and with the intervertebral foramen and epidural space medially. The cephalad limit of the thoracic paravertebral space remains unclear. The caudal limit of the space is generally accepted to be L1, at the origin of the Psoas Muscle.

Additionally, an important structure to mention, though of uncertain clinical significance, is the endothoracic fascia. The endothoracic fascia represents the deep investing fascia of the thorax and attaches to the ribs and medially to approximately the mid-point of the vertebral body. As such, it divides the paravertebral space into an anterior and a posterior compartment.

The contents of the thoracic paravertebral space include the intercostal nerves as they emerge from the vertebral foramen, the dorsal rami, the rami communicantes, the intercostal vessels, the sympathetic chain, and loose connective tissue and fatty tissue. The nerves remain, for the most part, unsheathed in the thoracic paravertebral space which allows for rapid uptake of local anesthetic.
Approaches and techniques:

A number of approaches and techniques have been described for performing ultrasound-guided thoracic paravertebral blocks. The ultrasound probe may be placed in a transverse position, a paramedian longitudinal position, or in an oblique plain. The ultrasound probe may be used to identify the structures, followed by a more traditional landmark guided approach to the thoracic paravertebral space. This is generally referred to as an "ultrasound-assisted" approach. "Ultrasound-guided" paravertebral blocks may be performed with the probe in any of the above mentioned positions. The needle may then be inserted in an in-plane or out-of-plane fashion. In addition, a catheter may be inserted using any of these approaches. A 5-12 MHz linear array probe is most commonly used, but a curved array ultrasound probe may be used as well. These blocks may be placed in the prone, lateral decubitus or seated position. Hence, the list of possible techniques available to place a thoracic paravertebral block is quite extensive. At the current time, no single technique has been shown to be more effective, easier to perform, or safer for the patient.

Below I will review some of the more widely discussed and performed techniques for placing a thoracic paravertebral block. Given that the rebirth of this old procedure under ultrasound guidance is a relatively recent development, I expect a continuing rapid growth in our knowledge and understanding of this block in the next few years. Perhaps at some time there will be a general consensus regarding both the approach to the paravertebral space and the technique used.

Ultrasound-assisted thoracic paravertebral block:

Ultrasound technology may be used as a guide prior to performing a thoracic paravertebral block using any approach or technique. A pre-procedure anatomic scan is conducted. A 5-12MHz linear array probe is placed over a spinous process in the mid-line in a longitudinal fashion. The probe is then moved laterally to visualize the transverse process, the point at which the transverse process and the rib intersects, the superior costotransverse ligament and the pleura with lung tissue visualized anteriorly. This scan is often conducted more easily in a lateral to medial fashion. The point at which the transverse process and the rib intersects represents the lateral aspect of the paravertebral space, and it is generally approximately 2.5-3 cm from the mid-line (figure 3 and figure 3a). One may
also turn the probe in a lateral transverse fashion and visualize the transverse process, the shimmering pleura which dips medially and the lung tissue anterior to the pleura (figure 4 and figure 4a). It is important to differentiate between the pleura and the rib with the probe placed in a transverse fashion. The rib is more superficial with dropout seen beneath it using ultrasound. The pleura is deeper, "shimmers" and moves with respiration, and lung tissue can be seen beneath it (anterior) using ultrasound. Anatomic scanning should take place prior to the performance of any ultrasound assisted or "real time" ultrasound guided thoracic paravertebral block, and the planned insertion site should be marked.

When performing an ultrasound assisted block, the practitioner measures the depth of the transverse process, the depth of the superior costotransverse ligament, and the depth of the pleura. An angle correction for insertion depth may be calculated mathematically or, more frequently, is estimated. The ultrasound probe is then put aside and the thoracic paravertebral block is performed using a traditional landmark technique, keeping in mind the specific depth measurements.

Figure 3:
Ultrasound probe placement for paramedian sagittal US guided scan
(adapted from www.nysora.com image)

Figure 3a:
US image of paramedian sagittal scan
Ultrasound guided thoracic paravertebral block:

Ultrasound guided thoracic paravertebral blocks can be performed in many different ways. Below, I will review several of the most commonly used approaches to the thoracic paravertebral space using ultrasound guidance. Cardiovascular monitors including NIBP, pulse oximetry, and EKG should always be used. After an initial anatomic scan to confirm the thoracic levels, appearance and depth of the structures, the procedural site should be marked. The patient's back is then prepped and draped in sterile fashion. A 5-12 MHz linear array ultrasound transducer is placed in a sterile sheath. A sterile area is set up for the necessary equipment for either a single injection or placement of a catheter. A single injection will cover 4-5 dermatomes and is adequate for many procedures such as a mastectomy. Some practitioners prefer to perform a thoracic paravertebral block at two or three levels. The most commonly used agents are Bupivicaine 0.5% and Ropivicaine 0.5% with epinephrine 1:200,000-1:400,000.

Paramedian sagittal thoracic paravertebral block:

The paramedian sagittal thoracic nerve block may be performed in plane and out of plane. An out of plane block may be placed in a parallel fashion with the probe in a longitudinal paramedian position or with the probe in an transverse position. An in plane paramedian sagittal block is placed with the probe in a vertical position approximately 2.5-3 cm lateral to the midline.

When performing an in plane block, the midpoint of the transducer is placed in a longitudinal paramedian plane between two transverse processes. Both transverse processes should be visualized, with the superior costotransverse ligament and the pleura visible in between (figure 5 and 5a). An 18-20 gauge blunt tipped block needle or a Tuohy needle is introduced in a cephalad direction. The tip of the needle is advanced under direct visualization until it pierces the superior costotransverse ligament. If the superior costotransverse ligament is not easily seen, the needle is advanced until it is directly above the pleura. Due to the steep angle with which the block needle enters the tissue, the needle is often difficult to visualize. For this reason some practitioners choose to inject small aliquots of normal saline intermittently as they advance the needle to confirm the position of the tip. When the needle tip is located immediately above the pleura, the needle is aspirated to confirm the absence of blood or air. After this, 10-20 cc of local anesthetic is injected in 3-4 cc increments. Spread of local anesthetic with depression of the pleura will be
clearly visualized. The extent of local anesthetic spread should be evaluated by moving the ultrasound probe superiorly and inferiorly.

When performing an out of plane paramedian sagittal block the probe may be placed as described above. In this case the needle is placed at the side of the probe. The needle is advanced with small aliquots of normal saline injected to evaluate the position of the tip by "tissue dissection". When the superior costotransverse ligament is pierced and after careful aspiration, the pleura will be depressed by the injection of normal saline. This is followed by injection of 10-20 cc local anesthetic injected in 3-4cc increments. When a catheter is placed using this technique it is generally threaded approximately 2-3 cm beyond the tip of the needle.

Figure 5:
Block needle insertion site for a paramedian sagittal in plane block
(adapted from www.nysora.com image)

In plane paramedian insertion site
More commonly, an out of plane paramedian thoracic paravertebral block is performed by placing the transducer in a transverse position (figure 6 and 6a) with the transverse process visualized medially and the pleura dipping toward the transverse process. The needle is inserted at the midpoint of the transducer in a cephalad direction. It is advanced slowly until the tip of the needle comes into view. Often small aliquots of normal saline will be injected to confirm positioning as described above. When the needle tip is visualized next to the transverse process and just above the pleura, local anesthetic is injected in 3-4 cc increments to a total volume of 10-20cc. Depression of the pleura is always observed with proper placement of the needle.

**In plane transverse intercostal thoracic paravertebral block:**

The in plane transverse intercostal technique is another frequently used approach to performing a thoracic paravertebral block. The ultrasound transducer is placed in a transverse position (figure 6) and the probe is moved superiorly and inferiorly to confirm the correct position. The transverse process is visualized medially with the pleura dipping under the inferolateral aspect. The internal intercostal membrane, which is contiguous with the superior costotransverse ligament, is generally seen as a thin radio-opaque line extending from the transverse process, creating a wedge shaped pocket which represents the thoracic paravertebral space. Using this approach an 18-20 gauge Touhy or blunt tipped block needle is advanced in plane from the midpoint of the lateral aspect of the ultrasound probe (figure 7 and figure 7a). The needle is generally more easily visualized with this approach as the angle of reflectance is not as acute as with the longitudinal parasaggital technique. If the needle is difficult to see when clearly in plane, tissue dissection with small aliquots of normal saline or local anesthetic may be used as described earlier to assist with confirmation of needle placement. However, visualization of the needle tip is of the utmost importance using this medially directed technique. When the needle pierces the internal intercostal membrane, and after careful aspiration to demonstrate the absence of air or blood, 10-20 cc local anesthetic is
deposited in 3-4 cc increments. Depression of the pleura is clearly visualized. The probe is then turned longitudinally, and the spread of local anesthetic superiorly and inferiorly may be evaluated.

Figure 7: In plane transverse intercostal block
Figure 7a: US image of in plane IC approach

Needle insertion site

A similar, more lateral approach has been described for placement of a paravertebral catheter. A 17 gauge Tuohy needle is advanced in the same manner described above. The endpoint is, however, the space between the internal and innermost intercostal muscles. Local anesthetic is injected, depression of the pleura is observed, and a catheter is threaded 7 cm beyond the tip. A local anesthetic infusion is then started at 10cc per hour. This may represent a medial intercostal block with the catheter tip in the intercostal space rather than the true paravertebral space.

Recently, an in plane oblique approach to the thoracic paravertebral space has been described. As described above, the transverse process is located medially with the pleura and internal intercostal membrane seen lateral to it. However, the probe is placed at a 30-45% oblique angle to the spine. Visualization may be improved by this maneuver and catheter placement may be easier at this angle. However, the risk of entering a vertebral foramen may also be increased with this technique. To date, this is not known.

Summary:

There are numerous approaches to performing paravertebral blocks, both in plane and out of plane. They may all be done in a seated, lateral decubitus or prone position. Both single injection techniques and catheters may be placed and the decision to do one or the other must be based on desired duration of the block, nature of the planned surgical procedure, and estimated length of hospital stay. Each block has associated risks and benefits. At the current time no single approach or technique has been proven to be safer, easier, or more effective than the others.

References and further reading:


11. www.usra.ca

12. www.nysora.com