Paravertebral Blocks for Perioperative Analgesia in Thoracic Surgery Workshop

Authors: Brandi A Bottiger, MD
Department of Anesthesiology, Duke University
Durham, NC, USA
Brandi.bottiger@duke.edu

Gian Paparcuri, MD
Department of Anesthesiology, University of Miami
Miami, FL, USA
GPaparcuri@med.miami.edu

George W Kanellakos, MD, FRCPC
Department of Anesthesiology, Dalhousie University
Halifax, Nova Scotia, Canada
george.kanellakos@dal.ca

OBJECTIVES
1. Review the anatomy of the paravertebral space
2. Recognize the risks & benefits of paravertebral catheters
3. Identify key differences between paravertebral and epidural techniques
4. Review the perioperative management of patients with a single injection and continuous catheter techniques
5. Discuss insertion techniques, steps critical to a successful paravertebral block, and gain hands on experience with commonly used equipment
6. Understand the role of ultrasound in identifying the paravertebral space

Introduction
Paravertebral blocks (PVBs) administered correctly can successfully induce unilateral thoracic analgesia(1-7) for thoracoabdominal procedures including breast surgery, thoracic surgery, kidney surgery, inguinal hernia repair, open cholecystectomy, and rib fractures(8,9). For patients undergoing video-assisted thoracoscopic surgery (VATS), though patients are often spared a large thoracotomy incision, they are still subject to the development of chronic pain at an alarmingly high incidence(10,11). The goal of any regional or neuraxial technique is to minimize morbidity secondary to pain and improve outcomes.

PVBs administered via single injection or continuous catheter can produce analgesia with a reduced risk of hypotension and bradycardia in comparison to neuraxial techniques using local anesthetic (12,13). On average, the somatic and sympathetic block extends five and eight dermatomes, respectively. Absolute and relative contraindications are located in Table 1.
### Table 1: Absolute and relative contraindications to paravertebral blocks.

<table>
<thead>
<tr>
<th>Absolute Contraindications</th>
<th>Relative Contraindications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local infection or sepsis</td>
<td>Sternotomy</td>
</tr>
<tr>
<td>Patient refusal</td>
<td>Midline laparotomy</td>
</tr>
<tr>
<td>Local anesthetic allergy or toxicity</td>
<td>Severe respiratory disease</td>
</tr>
<tr>
<td>Tumor in the paravertebral space</td>
<td>Thoracic spine deformity</td>
</tr>
<tr>
<td></td>
<td>Ipsilateral diaphragmatic paresis</td>
</tr>
</tbody>
</table>

This block is not new(14) but had historically fallen out of favour(15) likely due to perceived inconsistency of adequate pain control. This perception is fueled by the numerous techniques that are all inappropriately labeled “paravertebral” or “intercostal” or “pleural”. An intercostal or pleural catheter placed posteriorly towards the midline is predictably unsuccessful(3) and has been mislabelled as a failed PVB. Local anesthetic administered in the intrapleural space has been shown to be inferior to local anesthetic in the extrapleural space(16).

However, there is now a refreshed interest in this technique. PVB and thoracic epidural analgesia for thoracotomy are listed as top recommendations from the Procedure-Specific Postoperative Pain Management (PROSPECT) working group both based on Grade A evidence.(17)

### Anatomy of Paravertebral Space

The paravertebral space can be difficult to understand. It is contained within the extrapleural space, or cavity. Confusingly, literature reviewing paravertebral techniques refers to the paravertebral space as extrapleural, intercostal (18,19), peridural(4) and interpleural(3).

The paravertebral space is a wedge-shaped potential space in the extrapleural cavity extending from T1 to T12. It contains intercostal nerves at the nerve root level, including ventral and dorsal rami and the thoracic sympathetic chain, as well as intercostal vessels and fat(20).

**Borders:**
- **Posteriorly:** the superior costotransverse ligament, heads of the ribs, thoracic vertebrae, and transverse process (TP)
- **Anteriolaterally:** parietal pleura.
- **Medially:** the vertebral column, intervertebral discs, and intervertebral foraminae

The boney borders of the paravertebral space (PVS) are shown in Figure 1(21). Figure 2(22) represents radiographic evidence of the paravertebral space.
Figure 1: Bony landmarks of the PV space. The paravertebral space lies immediately lateral to the thoracic vertebrae. A point 2.5 cm lateral to the spinous process identifies the insertion point of the needle. Paravertebral space (PVS); spinous process (SP); thoracic process (TP).

Figure 2: Left: Bilateral PVB with X-ray contrast medium added to LA. Right: Bilateral PVB with X-ray contrast medium added to LA. Typical and optimal contrast medium distribution is shown with the addition of some spread around the intercostal spaces on the left.

Benefits and Risks of PVBs
The primary benefit of any pain management strategy involving a block is to minimize the amount of side effects arising from a narcotic based strategy. These well-known complications can lead to a prolonged hospitalization and include nausea, vomiting, ileus, pruritus, respiratory depression, postoperative pulmonary complications (particularly in thoracic or high abdominal incisions), over sedation.

Benefits of PVBs
A single injection is as effective as multiple injections; studies have demonstrated benefit in improved patient satisfaction(23). Studies have shown that a successful PVB covers 5 dermatomes of somatic analgesia and 3 additional dermatomes of sympathetic block, minimizing heart rate and blood pressure
changes(12,13) in response to surgical stimulus. In one study(12), hypertension was observed without a change in heart rate; authors speculated that unilateral vasodilation resulted in a compensatory increase in vascular resistance in the non-blocked areas.

PVBs are unique in that they successfully block the sympathetic chain in the paravertebral space, possibly leading to a reduced stress response. Multiple studies have shown that PVB is associated with lower serum cortisol and glucose concentrations, indicating a reduced neuroendocrine stress response to thoracic and abdominal surgery, when compared to epidural analgesia(1,18,24).

**Risks of PVB (See Table 2)**

1) **Pneumothorax**: Perhaps the most serious and often feared complication is pneumothorax, which has an incidence of approximately 1%(26). It is also important to note these side effects are predominantly a result of percutaneous insertions, similar to epidurals. Often in thoracic procedures, chest tubes are placed for postoperative care ultimately. Alternatively, open catheter placement by the surgical team substantially reduces these risks.

2) **Bleeding**: Current recommendations suggest that percutaneous insertions be avoided in anticoagulated patients and perioperative management of anticoagulants should follow the same ASRA guidelines for neuraxial techniques(27). There is a risk of accidental placement of PVBs in the epidural space, therefore the risk of epidural hematoma is theoretically possible.

3) **Toxicity** deserves special mention with PVBs, as the paravertebral space is highly vascular. Toxicity will initially present as confusion, perioral numbness, lightheadedness, and tinnitus; this is followed by seizure activity and cardiovascular instability. This is primarily observed with high infusion rates and concentrations of lidocaine and bupivacaine, particularly on postoperative day 1. Ropivacaine carries less risk of cardiac toxicity. Published studies demonstrate ropivacaine administered at high doses by long term epidural infusion does not result in toxic plasma levels(28,29) even after 120 hours(30).

4) **Intercostal blockade**: As with epidurals, blockade of the intercostal nerves in patients with preexisting pulmonary compromise diaphragmatic paralysis may result in respiratory decompensation.

<table>
<thead>
<tr>
<th>Epidural</th>
<th>Paravertebral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypotension</td>
<td>Intercostal or nerve root injury</td>
</tr>
<tr>
<td>Urinary retention</td>
<td>Inadvertent epidural or spinal</td>
</tr>
<tr>
<td>Pruritus</td>
<td>Infection</td>
</tr>
<tr>
<td>Nausea and vomiting</td>
<td>Pneumothorax</td>
</tr>
<tr>
<td>Respiratory depression</td>
<td>Incomplete block</td>
</tr>
<tr>
<td>Headache</td>
<td>Local anesthetic toxicity</td>
</tr>
<tr>
<td>Incomplete block</td>
<td></td>
</tr>
<tr>
<td>Infection</td>
<td></td>
</tr>
<tr>
<td>Spinal cord injury (hematoma)</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Side Effect Profile for Epidural(25) and Paravertebral Catheters

**Identify key differences between paravertebral and epidural techniques**

**Are epidural blocks superior to PVBs?**

Several studies support superiority of epidurals to PVBs (27, 29). However, these studies use low doses or low volumes of local anesthetic, have altered open surgical technique, or incorrect placement of catheters, which may have contributed to the poor outcome observed for PVBs. A 2012 prospective RCT
found that epidurals may provide enhanced analgesia over PVB when an opioid (hydromorphone) is added to epidural infusions (31), and PVBs are similar to epidurals in pain control when only local anesthetic infusion is used. Epidurals have been shown to have a failure rate ranging from 1% (32) to 12% (33). Modern day use of novel anticoagulants, especially low molecular weight heparins, has introduced uncertainty and complicated the care associated with epidurals.

Are PVBs superior to epidurals?
Many studies support PVBs as at least equal to or more efficacious than epidurals (1-7,34). Specifically, a meta-analysis (4) and an extensive “best evidence review” (6), compared paravertebral to epidural continuous infusions for post-thoracotomy pain control. Results support equivalent pain control with less observed side effects. In this meta-analysis, the catheter insertion techniques involved both percutaneous and open insertion. Percutaneous insertions inherently have a higher rate of incomplete or failed block, however their inclusion in the study did not lower the overall success rate. Rather, they found PVB failed less often than epidurals.

The paravertebral approach seems to achieve a more effective ipsilateral block of the afferent pain pathway as evidenced by Richardson (35) in a study of intercostal somatosensory evoked potential abolition using paravertebral blockade. This effect on nociceptive tracts might provide excellent pain relief and greater inhibition of the surgical stress response. These findings have not been shown with more central forms of analgesia such as thoracic epidural (36) and might play a key role facilitating postoperative recovery of pulmonary function (1,6).

It is important to note that in many of these studies, additional pain modalities were employed in the paravertebral groups, ranging from PCA morphine to IM ketorolac.

Perioperative management of PVBs
Dosing a PVB
There is no established “best dose” of local anesthetic used for PVBs (37), and a variety of local anesthetic solutions and concentrations have been used. For each planned dermatome to be blocked, the literature supports 2mL of local anesthetic injected (12,13). This results in an average single injection volume of 10 mL to block 5 dermatome levels. The goal is to attempt to maximize pain relief while being cognizant of toxicity. Bupivacaine and ropivacaine dosing regimens vary widely between institutions making comparisons very difficult.

Recommendations from one study (28) advocate a minimum bupivacaine concentration of 0.25% or equivalent ropivacaine concentration of 0.3%, with higher initial concentration required in the first 24 hours to achieve adequate pain control. Richardson and Sabanathan have done extensive work in this area and routinely use 0.5% bupivacaine at 0.1 mL/kg/hr. Launcelott has utilized multiple concentrations of local anesthetic regimens using lidocaine, bupivacaine or ropivacaine, with 0.375% bupivacaine being found optimal (38). In a continuous catheter, we typically use 0.2-0.3% ropivacaine at 6-12 mL/hr. Whatever dosing strategy is chosen, most successful regimens include one that begins with boluses and/or initiation of infusion intraoperatively that continues postoperatively without interruption.

Multimodal analgesia for postoperative pain management:
To increase the chance of successful pain control, multimodal analgesic regimens have been well described and should be included in the perioperative management (18,39,40) whenever possible. The
following medications and dosing have been used as adjuncts perioperatively for additional pain control if the patient is appropriate. When choosing adjunct medications, special attention must be made to patient comorbidities including cardiac, pulmonary, renal, and hepatic dysfunction. In addition to these, narcotic prn doses or PCAs can be used, if necessary.

Gabapentin 200 – 600 mg PO or pregabalin 75-150 mg
Acetaminophen 975 mg PO or 1000 mg IV (if no oral acetaminophen given; 24 hour maximum 4 g)
Celecoxib 200 mg PO OR Ketorolac 15-30 mg IV (if no celecoxib PO)
Ketamine 200-500 mcg/kg/hr (41)

**Technique**
The success rate of PVBs is highly dependent on the insertion technique and practice.

**Blind percutaneous insertion**
The failure rate of blind techniques is 10%(26). Advances in regional anesthesia including nerve stimulators and ultrasound have reduced the use of blind techniques, reducing the failure rate to 6%(42,43). The classic percutaneous insertion technique(44) is similar to epidural insertion. The anatomy of the paravertebral space seen on ultrasound requires significant practice to recognize. A significant benefit of the percutaneous technique over thoracic epidurals is the acceptance of placement while the patient is anesthetized(45).

**Steps to achieving PVB via percutaneous insertion:**
1) Identify and contact the transverse process, approximately 2.5 cm lateral to the midline of the spine.
2) Insert needle over or under the boney landmark no more than 1 cm. Loss of resistance is felt immediately after puncturing the superior costotransverse ligament in PVB.
3) Deliver local anesthetic and/or insert a catheter. The skin to paravertebral distance is, on average, 5.5 cm(46). Appropriate catheter position is depicted in **Figure 3**(15).
4) Appropriate dermatome coverage may require higher volumes of local anesthetic, and if a continuous catheter technique is chosen, may require multiple catheters.

Patients are positioned prone, lateral decubitus or sitting up, similar to thoracic epidural placement, with their necks flexed forward, chin to the chest, shoulders relaxed forward, and the back arched posteriorly (kyphotic posture). It is imperative to identify and mark the spinous process corresponding to the thoracic dermatomes to be blocked, the transverse process of the immediately caudal vertebra is located 2.5 cm laterally. Location of the transverse process and measurement of its distance from the skin, therefore limiting the depth of needle insertion, minimizes the risk of pneumothorax.

**An open insertion technique**
Open, intraoperative placement after the surgical procedure is described step by step by Sabanathan(47). Open insertion by the surgical team has been demonstrated to have a reduced risk of failed block when compared with percutaneous techniques.

1) The parietal pleura is raised from the posterior chest wall up to the vertebral bodies from two intercostal spaces above and below the thoracotomy incision, exposing the paravertebral space.
2) A small defect is made in the extrapleural fascia into the paravertebral space using Lahey’s forceps.
3) A percutaneously inserted cannula is passed through the defect into the paravertebral space under direct vision and advanced 2 to 3 cm to lie against the costovertebral joints.

4) The pleura is reattached, if possible, and the paravertebral space is infused for 5 days with 0.5% bupivacaine at a rate of 0.1 mL/kg body weight per hour with an on-line bacterial filter.

![Figure 3: Optimal position of a paravertebral catheter](Published by Richardson and Lonnqvist, 1998)(15)

**Ultrasound Guided Technique:**

The wedge shape of the paravertebral space is suitable for ultrasound scanning. Real time image guided blocks have been used safely to both identify landmarks and place local anesthetic under direct visualization. This is helpful not only in normal patients, but especially in patients with significant anatomic abnormalities such as scoliosis. Blocks should be performed in monitored areas dedicated for preoperative blocks or in the operative room, with access to emergency airway equipment and medications. Blocks may be performed awake, under light sedation, or under a general anesthetic in pediatric cases. Patients are positioned typically sitting, with similar considerations to the percutaneous technique.

After landmarks are well established a linear array probe at 5 – 10 MHz is placed in a sterile sheath and used for real time guidance. If imaging is inadequate, a curved, lower frequency probe will display a wider field at lower resolution. The parietal pleura, the spinous process and the costotransverse articulation should be identified on US. Asking the patient to breathe deeply during the scanning facilitates echosonographic visualization of the pleura. The needle can be inserted using an in-plane (needle at the side of the probe) or out-of-plane (in the center of the probe) technique. Correct injection of local anesthetic increases the depth between the transverse process and the pleura by “tissue dissection”. The observance of local anesthetic spread in the paravertebral space also reduces the failure rate.

**Sagittal (paramedian longitudinal) approach:**

In the traditional approach, scanning vertically from midline to lateral, the spinous and transverse processes, the superior costotransverse ligament and the underlying parietal pleura are identified. The ligament is visualized as an arrangement of linear echogenic bands running in between transverse processes (Figure 4).
After local anesthesia is delivered, an 18 gauge Tuohy needle is introduced in-plane at the lower border of the transducer in a cephalad direction. In order to visualize the needle is important to match the angle of the needle insertion with the angle of the ultrasound beam. The paravertebral space is accessed between transverse processes, puncturing the costotransverse ligament avoiding inducing discomfort by contacting bony structures.

**Transverse (in line) approach:**
Following identification of sonographic landmarks (Figure 5) the needle insertion point is 2 cm lateral to the transverse process tip. The needle approach is from lateral to medial through the intercostal muscles.

**Keys to success:**
1) The insertion technique and experience are key in block success. If a continuous catheter is chosen, location of the catheter is critical.
2) Local anesthetic must be deposited as close to the vertebral column as possible. If the injection is too lateral, it fails to spread cephalad-caudad adequately and becomes similar to an intercostal block.

3) Both concentration and total volume placed in a single injection or through a continuous catheter will impact pain control.

4) The success of a PVB is also dependent on a complete multimodal therapy regimen that offers excellent pain relief while minimizing narcotic use.

5) Familiarity with ultrasound may improve identification and visualization of structures

References


38. Launcelott G. Personal communication. EMAIL: glauncel@gmail.com, 2010.


