Epidural analgesia is still considered the gold standard for postoperative pain relief after many thoracoabdominal surgeries. In many patients, comorbidities and patient factors preclude the use of epidural analgesia, such as coagulopathy. Intravenous narcotics relieve pain at rest reasonably but fail to provide an acceptable level of pain relief with activities such as coughing and walking. Thus, there is a need for alternative analgesic techniques for this group of patients. Some new techniques have been described, such as the transversus abdominis plane block, and some older techniques have been rejuvenated, such as the paravertebral blocks.

Paravertebral blocks were initially described in the early twentieth century. Their use was reintroduced in 1979 by Eason and Wyatt. However, it is really over the past 15 years that paravertebral block has generated significant interest initially for the management of patients undergoing breast surgery and inguinal hernia repair. Today, evidence supports the concept that they are as effective as epidural blocks for perioperative pain management without many of the side effects of neuraxial techniques (Table 1).

The use of paravertebral block has been shown in a retrospective analysis to delay the recurrence of tumors and the development of metastases. These data are consistent with those demonstrating that the use of regional anesthesia (especially epidural) has similar effects on patients undergoing prostate cancer resection. The possible mechanisms involved not only the prevention of the stress response by the regional technique but also the possibility that the beneficial effects are the result of the associated opioid-sparing effects. Thus opioids have been shown to stimulate growth factors and diminish immunologic response.

PARAVERTEBRAL ANATOMY

The paravertebral space extends from the cervical spine to the sacrum. At each level, especially at the thoracic level, it is a space of triangular shape limited anteriorly by the parietal pleura, medially by the posterolateral aspect of the vertebra and the intervertebral foramen, laterally by the parietal pleura, and posteriorly by the...
costotransverse ligament (Figs. 1 and 2). The depth of the paravertebral space has been demonstrated to vary according to the level: more superficial at the cervical level and deeper at the lumbar level. Between T4 and T8, the depth of the paravertebral space is also dependent on body mass index, age, and gender and is more difficult to predict. In contrast, between T9 and T12, the depth of the paravertebral space is more predictable and mostly depends on the level at which the block is performed.

<table>
<thead>
<tr>
<th>Laterality</th>
<th>Epidural</th>
<th>Continuous Paravertebral Block</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypotension</td>
<td>Frequent</td>
<td>Infrequent</td>
</tr>
<tr>
<td>Postoperative Nausea and Vomiting</td>
<td>Frequent</td>
<td>No</td>
</tr>
<tr>
<td>Urinary Retention</td>
<td>Frequent</td>
<td>No</td>
</tr>
<tr>
<td>Pruritus</td>
<td>Frequent</td>
<td>No</td>
</tr>
<tr>
<td>Risk of Spinal Cord Injury</td>
<td>Low</td>
<td>Extremely Low</td>
</tr>
<tr>
<td>Risk of Respiratory Depression</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Preservation of Forced Vital Capacity After Thoracotomy</td>
<td>55% of preoperative</td>
<td>75% of preoperative</td>
</tr>
<tr>
<td>Degree of Neural Blockade</td>
<td>Partial (SEPs maintained)</td>
<td>Complete (SEPs ablated)</td>
</tr>
<tr>
<td>Motor Blockade Outside Surgical Dermatomes</td>
<td>Yes</td>
<td>Minimal</td>
</tr>
<tr>
<td>Severity of Bleeding Complications</td>
<td>High</td>
<td>Moderate</td>
</tr>
<tr>
<td>Thromboprophylaxis</td>
<td>Complicated</td>
<td>Simple</td>
</tr>
</tbody>
</table>

**Abbreviation:** SEP, somatosensory evoked potential.

*Data from Refs. 79–84*

---

Fig. 1. Anatomy of the paravertebral space.
INDICATIONS

For anesthesia, the indications are limited to mostly breast surgery, inguinal hernia repair, lithotripsy, and video-assisted thoracic surgery (VATS). For breast surgery, paravertebral blocks are performed at the level of T1 to T6, especially when the surgery is associated with an axillary dissection. For inguinal hernia repair, single blocks are performed at the level of T10 to L2.

The most frequent indication for paravertebral blocks is perioperative management of pain. For surgeries associated with mild to moderate pain, such as limited inguinal hernia repair and minimally invasive cardiac surgery, single-injection paravertebral blocks are used. For minor abdominal surgery, such as laparoscopic cholecystectomy; radical prostatectomy; and hysterectomy, bilateral single paravertebral blocks are used. For major surgery, such as those associated with the placement of a chest tube; major abdominal surgery (colon resection, debulking, pancreatic resection); cardiac procedures; pelvic surgery (cystectomy, hysterectomy with node dissection); urologic procedures such as partial or complete nephrectomy; and open or laparoscopic surgery with a midline approach, a bilateral continuous paravertebral approach is recommended. In the case of a VATS or an open thoracotomy and a partial or complete nephrectomy, using a lateral approach and unilateral placement of a paravertebral catheter may be adequate. In this regard, it is important to recognize that most postoperative pain results from the surgical trauma and not from the skin incision. Therefore, even in the case of a laparoscopic approach, the use of a continuous paravertebral block is indicated. This point was recently illustrated by the limited benefits produced by the use of single paravertebral blocks in patients undergoing VATS. The level at which the paravertebral catheter is placed is presented in Table 2.

Continuous paravertebral block has also been effective in the management of pain in patients with multiple rib fractures. In this indication, they have also been demonstrated to improve pulmonary function, reduce the need for intubation, and

Fig. 2. Needle positioning.
decrease the associated mortality. Usually 1 paravertebral catheter is required for every 3 to 4 rib fractures beyond the first rib. Also one advantage of this technique is that it can be used in patients who receive enoxaparin for thromboprophylaxis. Thromboprophylaxis with enoxaparin is a contradiction for epidural. Paravertebral blocks are also indicated for acute and chronic pain\textsuperscript{10,53–62} and labor\textsuperscript{63–65}.

**TECHNIQUES**

**Classic Approach**

Over time, several techniques have been described that can be differentiated into either blind or ultrasound guided.

Irrespective of the technique and before the block is performed, the patient is properly positioned, in most cases in the sitting position, but, occasionally and especially in trauma patients, these blocks are performed in the lateral position. These blocks should be performed in an area with full monitoring and readily available resuscitation equipment. Baseline vital signs are obtained to ensure that the patient is stable hemodynamically. A combination of midazolam and fentanyl is titrated depending on the patient’s age; weight; prior history of pain and opioid use, anxiolytics, and alcohol; and hemodynamic stability. However, it should be recognized that with a carefully performed local anesthesia, it is possible to perform these blocks without any need for sedation. In elderly and very elderly patients in whom sedation is indicated, 0.5 mg of midazolam and 25 µg of fentanyl are often adequate. In young and healthy patients, 1 mg of midazolam and 50 µg of fentanyl is often used. This can be repeated according to the needs and condition of the patient. In most cases, no more than 2 mg of midazolam and 100 µg of fentanyl are required.

There are basically 3 ways to establish the level at which these blocks are performed:

1. C7
2. The lower border of the scapula (T7-T80)
3. The iliac crest (L4-L5).

Sometimes it is recommended to use 2 of these landmarks to confirm the exact level.
Originally, the identification of the paravertebral space was dependent on advancing the needle 1 to 2 cm after contacting the posterior surface of the transverse process. This is a technique we have used very successfully limiting our advancement to no more than 1 cm beyond the transverse process. Basically in this case, the superior border of the spinous process is identified. The site of introduction of the needle is 2.5 cm lateral from the spinous process. Before performing the block, the area is disinfected with chlorhexidine, and lidocaine 1% is injected locally using a 3.75-cm 25-gauge safety needle (B-Braun, Bethlehem, PA, USA). For single paravertebral block, a 22-gauge Tuohy needle (B-Braun, Bethlehem, PA, USA) is introduced perpendicularly to contact the posterior surface of the transverse process. When the transverse process is contacted, the distance between the skin and the transverse process is established; the needle is then withdrawn to the skin and reintroduced 1 cm beyond the transverse process at a 15° to 60° angle, allowing the positioning of the needle below the transverse process (Fig. 3). It is possible to experience a loss of resistance when the needle is pushed beyond the transverse process through the costotransverse ligament. If the block is performed in the upper thoracic level, the angle necessary to position the needle in the paravertebral space may have to be increased. If bone contact is established during the positioning of the needle, the needle should be withdrawn to the skin and reoriented using a greater angle. While placing a paravertebral catheter, it is not unusual that the location of the transverse process is established using a 25-gauge spinal needle (finder needle). This is followed by the placement of an 18-gauge Tuohy introducing needle in the paravertebral space.

Once the needle is positioned in the desired paravertebral space, 5 mL of either 1.0% (anesthesia) or 0.5% (analgesia) ropivacaine is slowly injected after negative aspiration for blood. If blood is aspirated, the needle is withdrawn and repositioned. When an introducer 18-gauge Tuohy needle is used, before injecting any local anesthetics in the paravertebral space, a drop technique can be used to verify that the tip of the needle is not intrapleural or in the lung. This is achieved by placing a drop of ropivacaine on the top of the needle, and the patient is asked to breathe deeply. If the ropivacaine drop follows the breathing pattern, this is considered as positive and the needle is repositioned. If the ropivacaine drop is not affected by the breathing pattern, it is considered that the needle is not intrathoracic. In this case, the needle is

Fig. 3. Performance of a paravertebral block. (A) Introduction of the needle perpendicular to the skin in search of the transverse process. (B) After contacting the transverse process, the needle is pulled to the skin and the fingers are placed 1 cm beyond the depth of the transverse process. (C) The needle is introduced at a 45° angle to be place in the paravertebral space below the transverse process.
connected to the tubing allowing the slow injection of 5 mL of 1.0% or 0.5% ropivacaine using a 10-mL syringe. If an introducer 18-gauge Tuohy needle is used and the needle is well positioned, the injection of ropivacaine should be easy (does not offer a lot of resistance). If the injection of ropivacaine offers resistance, the 18-gauge needle is withdrawn and repositioned. After the injection is completed, either the process is repeated at another level in the case of a single paravertebral block or the paravertebral 22-gauge catheter (B-Braun, Bethlehem, PA, USA) is introduced in the paravertebral space in the case of a continuous paravertebral block. Usually, the introduction of the catheter is easy. However, there are times, despite the injection of ropivacaine being easy, when it is not possible to push the catheter beyond the tip of the needle. In this case, the catheter is first withdrawn and then the needle is rotated 180° to reposition the bevel in the opposite direction. After the rotation of the needle is complete, the catheter is reintroduced. If despite this maneuver the catheter cannot be easily introduced, the introducing needle is withdrawn and repositioned and everything is repeated as previously described. The paravertebral catheter is usually positioned 3 to 4 cm beyond the tip of the needle. After the introducing Tuohy needle is withdrawn and the catheter is secured in place using benzoin and Steri-Strips (3M St. Paul, MN, USA), an additional 10 mL of 0.5% ropivacaine is slowly injected verifying negative aspiration for blood at least every 5 mL. If blood is aspirated, the injection is stopped and the catheter is repositioned.

The administration of 10 mL of local anesthetic leads to a spread of 3.5 ± 1.5 dermatomal segments. Although in more than 70% the spread occurs in the paravertebral space, in 10% a “cloud” distribution occurs and in 7% there is an intercostal spread (Fig. 4). The type of spread is not predictable by the quality of the block. Irrespective of the distribution, it is estimated that paravertebral block fails in 6% of patients. This success rate is much higher than that of thoracic epidural.

**Loss-of-Resistance Techniques**

It is possible to localize the paravertebral space using the same loss-of-resistance technique as the one used to identify the epidural space. This can only be achieved when using an 18- or a lower-gauge Tuohy needle. In this case, a couple of options are available.

**Classic technique**

It is the same approach that is used to identify the epidural space. A Tuohy needle mounted to a loss-of-resistance syringe filled with saline is advanced until resistance is lost.

**Pressure transducer approach**

The 18-gauge Tuohy needle is connected to a pressure transducer via pressure tubing. When the needle penetrates the paravertebral space, the pressure registered by the transducer suddenly decreases. If the needle is introduced too far, it is possible to reach the pleura and/or epidural space. This technique does not allow to distinguish among the 3 possible locations unless the needle is carefully advanced.

**Neurostimulation Technique**

The paravertebral space is located using an insulated 18-gauge Tuohy needle (continuous paravertebral technique) or a 22-gauge needle (single paravertebral block) connected to a nerve stimulator delivering a current of 2.5 to 5.0 mA with a pulse duration of 0.1 milliseconds and a frequency of 2 Hz. When the insulated needle is at the proximity of the nerve bundle, a motor response is elicited (contraction of the intercostals or the abdominal muscle). This can result in an intercostal muscle contraction with
an intensity directly related to the distance between the needle and the intercostals nerve. The position of the needle is considered optimal when the muscle response is maintained with a current less than 0.5 mA.

ULTRASOUND-GUIDED APPROACH

After determining the thoracic or lumbar level at which the block has to be performed, a parallel line 2.5 cm lateral to the spinous process, a low-frequency probe connected to an ultrasound machine, in our case an S-Nerve (Sonosite, Bothell, WA, USA), is applied parallel to the spinous process.\textsuperscript{59–71} Scanning the area allows the identification of the transverse process, the costotransverse intercostalis ligament, the pleura, and the lung dynamically. This is facilitated by asking the patient to breathe deeply during the scanning. Using an in-plane approach, a needle is introduced between 2

Fig. 4. Spread of the 10 mL of the contrast product demonstrating a paravertebral spread along the thoracic spine (as indicated by the arrows).
corresponding transverse processes and positioned past the costotransverse inter-
costals ligament and posterior to the parietal pleura. After negative aspiration for
blood, 5 mL of local anesthetic is slowly injected. The injection of local anesthetic
can be visualized, and the correct position of the needle is confirmed by seeing the
local anesthetic volume pushing the pleura anteriorly. The anatomic landmarks are
presented in Figs. 1 and 2.

**Lateral Approach to the Paravertebral Space**

**Blind approach**
The placement of a paravertebral catheter can be achieved using an intercostal
approach (see Fig. 3). Depending on the segments to be blocked, the corresponding
intercostal space is identified. The site of introduction of the needle is 8 cm from the
corresponding spinous process. A 5-cm 18-gauge introducer Tuohy needle is intro-
duced into the corresponding intercostal space initially to contact the rib. When the
contact is established, the needle is reoriented 60° medially and at a 45° angle, pushed
1 cm within the intercostals space in the direction of the corresponding spinous
process. After negative aspiration for blood, 5 mL of 0.5% ropivacaine is slowly
injected to open the space. This is followed by the introduction of the catheter medially
toward the corresponding paravertebral space. With such an approach it is expected
that the catheter is positioned in the paravertebral space by traveling medially in the
corresponding intercostal space. This approach offers the advantage of allowing
access to the paravertebral space using a more superficial approach than the classic
approach. This may be of some advantage to be safer, especially in patients with
coagulopathy.

**Ultrasound-guided technique**
The corresponding intercostal space is scanned by applying a 10- to 15-MHz probe 8
cm laterally from the spine to allow the identification of the ribs and pleura.69,72 The
identification of the pleura can be facilitated by asking the patient to breathe deeply
and visualizing the movement of the lung. The probe is then rotated over the long
axis of the rib and tilted to help identify the external intercostal muscle and internal
intercostal membrane (Figs. 5 and 6). Lidocaine 1% is injected superficially at the
site of introduction of the needle. The 18-gauge introducer Tuohy needle is introduced

![Fig. 5. Ultrasound approach to the paravertebral space. (A) Placement of the low-frequency probe and the needle. (B) Ultrasound image. CTL, costothoracic ligament; LA, local anesthetics; N, needle; P, pleura; T, transverse process.](image-url)
in plane and directed medially to position the tip of the needle between the internal intercostals membrane and the parietal pleura. After negative aspiration for blood, 5 mL of 5% ropivacaine is injected slowly. A 22-gauge catheter is introduced into the intercostal space and positioned 8 cm from the site of introduction of the needle. The introducer needle is removed and the catheter is secured in place using Steri-Strips. The catheter is protected by transparent dressing. After it is secured in place at the level of the corresponding surgery, an additional 10 mL of 0.5% ropivacaine is injected slowly after confirming negative aspiration for blood. This completes the block and also assures the patency of the paravertebral catheter.

LOCAL ANESTHETIC MIXTURES AND MODE OF ADMINISTRATION

Bupivacaine, ropivacaine, and lidocaine have been the local anesthetics of choice to perform paravertebral blocks. Although most practitioners do not recommend the use of additive, some recommend the addition of epinephrine, fentanyl, and clonidine to prolong the duration of the block. For single paravertebral blocks, the use of 0.50% (anesthesia) or 0.25% (analgesia) bupivacaine or 1.0% (anesthesia) or 0.5% (analgesia) ropivacaine has been advocated. In the case of continuous paravertebral blocks, 0.1 mL/kg of 0.5% bupivacaine and 1.0% lidocaine have been originally reported. At present, we favor the use of 0.2% ropivacaine, 0.06% bupivacaine, and 0.25% lidocaine starting at 7 mL/h per paravertebral catheter with a 3-mL bolus available per hour. This can be increased to 10 mL/h if necessary.

The effectiveness of this technique is significantly improved when the paravertebral block is part of a multimodal approach to pain management, including the use of ketamine 0.1 mg/kg intravenously followed by an infusion of 5 to 10 mg/h started in the recovery room. This can be combined with antiinflammatory drugs, such as ketorolac tromethamine (Toradol), 7.5 to 10 mg given intravenously every 6 hours for 48 hours, if there is no preexisting coagulopathy, allergy to nonsteroidal antiinflammatory drugs, or renal insufficiency. Such an approach can reduce the opioid requirements and opioid-related adverse events by 70% to 80%.

Fig. 6. Probe positioning (A) and ultrasound image (B) identifying the external intercostal muscle and internal intercostal membrane.
COMPLICATIONS

It is established that the use of paravertebral blocks are safer than epidural and that complications with this technique are infrequent.\textsuperscript{74,75} The most frequently reported complications are discussed.

\textit{Pneumothorax and Pleural Puncture}

Pleural puncture has been reported to occur around 1\%, which may be reduced by the use of ultrasound guidance to perform these blocks. Pneumothorax is the most dreaded complication in the ambulatory setting and is estimated to occur at a frequency of around 0.5\%. It is also reported that the performance of bilateral paravertebral blocks increases the potential for this complication by 8-fold. In the past few years that we have performed this block (over 30,000), we have had a total of 3 cases presenting with pneumothorax, with only 1 patient requiring the placement of a chest tube. The risk for pneumothorax exists in blocks performed between T1 and T8, and it is unlikely to occur in paravertebral blocks performed between T10 and L3.

\textit{Bleeding}

Hematoma following a paravertebral block has been reported to be around 2.4\% and a risk of vascular puncture around 5\%. Usually the hematoma is limited in magnitude. In performing continuous paravertebral blocks for thoracic surgery, we have observed bleeding of 50 mL or less in the chest in 1 patient. In this case, the aspiration of the blood revealed a vascular injury. When performing (Fig. 7) paravertebral blocks, it is possible to produce vascular injuries illustrated by the ability to aspirate blood via the needle during the procedure. Such an event is rare and certainly not associated with any major symptoms of development of significant hematoma.

\textit{Epidural or Intrathecal Spread}

This complication has been estimated to occur between 1\% and 70\%.\textsuperscript{76,77} There are 3 factors that contribute to this. The first factor is the approach used with the needle. The investigators who reported up to 70\% spread included those using an ultrasound-guided technique approach over the paravertebral space with a lateral to medial

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{fig7.png}
\caption{Limited intrapleural bleed from a vascular puncture during the performance of a paravertebral block. (A) Blood in the chest cavity and (B) vascular puncture pointed out by the arrow.}
\end{figure}
needle direction, whereas those who reported infrequent epidural or intrathecal spread used a perpendicular approach parallel to the spinous process. Second, the volume of local anesthetics injected contributed to epidural spread. Most epidural spread occurred with volumes of 15 mL or higher. In the case of single paravertebral blocks, injecting 5 mL of the local anesthetic solution at multiple levels not only minimizes the risk for epidural spread but also provides a more extensive block. In the case of a continuous block, the initial injection of 5 mL of local anesthetic followed by injection of 10 mL of local anesthetic through a multiorifice catheter also provided the optimum condition to avoid these side effects. In most cases, epidural spread is not associated with any significant clinical consequences except for transient hypotension and bilateral lower limb weakness. The problem is more catastrophic when the needle is positioned intrathecally and is followed by an intrathecal injection of larger volume of the local anesthetic. When this occurs at a high thoracic level (T4 or higher), most of these patients required intubation and artificial ventilation until the effects of the injections dissipate. Third, practitioner inexperience and spinal deformity increase the risk of intrathecal administration of local anesthetics. This risk factor is greatly reduced when the block is performed using an ultrasound-guided technique. Irrespective of the cause, injecting the local anesthetic slowly and fractionated represents an excellent technique to minimize the amount of local anesthetics injected intrathecally.

**Infection**

Infection is a very rare complication. In our experience, we have not observed any abscess or systemic infection following the performance of a paravertebral block. In rare occasions, we have observed a local infection/inflammation that did not require any treatment. The occurrence of this complication significantly correlates with the duration of the continuous block left in situ, similar to epidural analgesia.

**Nerve Injuries**

As with any nerve block, performing paravertebral blocks can lead to occasional nerve injuries. Except for cervical and lumbar paravertebral blocks, injuries involved the sensory nerves and not motor nerves; therefore, the associated clinical symptoms included radiculopathy and pain similar to herpes zoster infection. The pain responds well to medications such as gabapentin (Neurontin) and pregabalin.

**Hypotension**

Hypotension has been reported in 4% of cases. This is a much less frequent complication than those reported when epidural is performed (30%). Hypotension could be attributed to the sympathetic blockade, epidural spread, or effect of local anesthetics on the vascular tone.

**Spinal Headache**

Spinal headache occurs very infrequently. Spinal headaches have been reported after the performance of paravertebral blocks. The most likely mechanism is trauma to the dural sleeve of the nerve in the paravertebral space during the performance of a paravertebral block that would lead to a leak of spinal fluid. In our experience, we recorded 2 cases of spinal headache.

**SUMMARY**

Paravertebral block is one of the regional anesthesia techniques that has raised the most interest recently. The ongoing prospective studies on their role in delaying the
recurrence of cancer and development of metastases will allow us to determine the role that this block can play in regional anesthesia.

REFERENCES

