Chapter 8

Analgesia for the Trunk: A Comparison of Epidural, Thoracic Paravertebral and Transversus Abdominis Plane Blocks

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Additional information is available at the end of the chapter

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1. Introduction

Major open upper and lower abdominal surgery, such as pancreaticoduodenectomy, abdominal aortic surgery, bowel resection, gastric bypass, gynecologic surgery and liver resection results in major morbidity for patients, including moderate to severe pain in the acute postoperative period.

Data on postoperative pain after surgery consistently shows moderate-to-severe pain in the first 24 hours after surgery with traditional systemic analgesic techniques, such as intravenous or intramuscular opioids, patient-controlled opioid analgesia, and multimodal analgesia with opioids combined with acetaminophen, NSAIDs, neuropathic agents, and ketamine [1, 2, 3]. In fact, moderate-to-severe pain can persist for 3 days after surgery [4]. In addition, specific multimodal analgesic techniques may be contraindicated depending on patient history, such as the use of NSAIDs in patients with renal dysfunction.

Pain following open abdominal surgery comprises both incisional pain and visceral pain. Interestingly, incisional pain may be reduced with the use of local anesthetics deposited around the incision site, and the use of wound catheters have been noted to reduce opioid consumption by about 30% [5]. However, the use of wound catheters does not allow for analgesia of the abdominal muscles beneath the incision nor the pain emanating from the viscera, which still results in substantial amounts of opioid consumption. Approximately 25-150 mg intravenous morphine equivalents are required to provide adequate analgesia in the first 24 to 48 hours after surgery [6, 7]. Even the use of systemic local anesthetics, such as intraoperative lidocaine infusions, has only been documented to improve pain scores by small increments in open abdominal surgery (4-10mm NRS) [8].

Despite opioid use, moderate-to-severe pain with coughing and mobilization continues to remain high in the first 72 hours after surgery, though with significant improvement after 24 hours. In addition, use of opioids may result in significant side effects such as hypoventilation, sedation, gastric dysmotility, and nausea and vomiting, which can worsen patient recovery [9, 10].

Regional anesthesia and analgesia can be used to significantly reduce postoperative pain scores and spare the use of systemic opioids. Regional anesthesia can be performed at the neuraxis (epidural), the nerve root (paravertebral), and the peripheral nerve (transversus abdominis plane) level. Local anesthetic deposition at these sites will selectively block nerve conduction and result in different analgesic and side effect profiles. This chapter will examine the role of each of these regional anesthetic techniques for postoperative analgesia, explain the procedure and offer pearls to improve the success of analgesia, discuss the benefits and potential complications of the use of each of these modalities, as well as review the literature and current evidence for their use in the postoperative period.

2. Thoracic Epidural Analgesia (TEA)

TEA is demonstrated to be a superior analgesic modality for major abdominal surgery. Unfortunately, it is not without risk of complications and side effects. More importantly, successful implementation of TEA requires additional technical skills and resources (equipment), appropriate education and training of physicians and support staff, as well as a well-defined framework for management (standing orders for infusion and management of side effects). Its role in postoperative care may even be more important in light of the evidence showing that it not only improves patient satisfaction due to excellent pain control, but also may have many other positive effects on postoperative outcomes (see below).

When approaching a patient undergoing major abdominal surgery, the actual procedure itself is but a small part of the process. A thorough discussion of indications and contraindications and counseling of the patient on possible complications and side effects should be performed. Once the decision is made to proceed with thoracic epidural analgesia, there are multiple decisions to be made to optimize analgesia, such as optimal level of thoracic epidural placement, patient positioning, amount and type of sedation, testing of epidural catheter for intravascular and intrathecal location, optimal bolus regimen, and optimal maintenance regimen. In addition, assessment of efficacy of the block and troubleshooting inadequate epidural blockade is crucial for improved patient pain relief and satisfaction.

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3. Dermatomes and innervation of the viscera

Pain associated with major abdominal surgery can be divided into somatic pain and visceral pain. Therefore, when performing epidural analgesia, both the abdominal wall innervation and the afferent visceral innervation, must be targeted to provide optimal analgesia.

The innervation of the abdominal wall has a segmental dermatomal distribution and is supplied by the anterior and lateral cutaneous branches of the ventral rami of the seventh to twelfth intercostal nerves (T7-12). To provide analgesia to the abdominal wall using the least amount of analgesics in the epidural space, the optimal location for epidural placement is a thoracic epidural placed at the level of the mid-thoracic spine (T7-9) for upper abdominal surgery and low thoracic spine (T10-12) for lower abdominal surgery.

Lumbar epidural placement for thoracic surgery, although possibly providing some analgesic benefit, will result in unnecessarily higher requirements for local anesthetic and opioid dosages in the epidural space with a resultant increase in the incidence of side effects such as lower extremity weakness (lower extremities receive their sensory and motor innervation from the lumbar and sacral roots), and urinary retention.

Visceral pain does contribute to a smaller, but still substantial, portion of postoperative surgical pain. It is usually short lived with the exception of pancreatic surgery and is much less intense then somatic pain. Unfortunately, innervation of the viscera is complex. Visceral afferent fibers travel alongside both sympathetic and parasympathetic efferent nerves of the autonomic nervous system. Therefore, epidural analgesia will unlikely completely cover all visceral afferent pain fibers for affected organs.

Visceral organ	Innervation
Stomach/pancreas	Celiac ganglia (T5-9)
Liver	Celiac ganglia (T5-9) Phrenic ganglia (C3-5) Vagus nerve (CN XI)
Small and large intestine	Celiac ganglia (T5-9) Superior mesenteric ganglia (T9-12) Inferior mesenteric ganglia (L1-2) Vagus nerve (CN XI)
Kidneys and ureters	Least and lesser thoracic nerves (T10-12) Vagus nerve (CN XI)
Pelvic viscera	T11-L4
Bladder	Pelvic splanchnic nerves (S2-4) Upper lumbar splanchnic nerves (L1-2)

Table 1. Visceral innervation

Because of the complicated innervation of the viscera and the relatively smaller number of afferent fibers as compared to cutaneous innervation, the decision on the optimal level to place the continuous epidural blockade is mainly determined by the location of the incision on the abdominal wall.

Failure to achieve optimal analgesia with an epidural technique may be caused by several reasons; one, incorrect determination of nerve root level that is responsible for the pain (an example being the placement of a lumbar epidural for surgery of the abdomen), and two, inability to place the catheter in the epidural space despite choosing the correct level of placement. The first reason is less crucial because epidural spread of injectate will allow some degree of forgiveness in placement of the epidural catheter a few levels from the desired level. Occasionally a predominantly unilateral epidural sensory distribution can occur due to anatomical issues (rare) or due to exit of the epidural catheter through the neuroforamina. Even despite optimal placement of the epidural catheter, analgesia could be suboptimal due to inappropriate dosing, pump failure or pharmacy delays. Because epidural dosing is somewhat empirical, frequent follow up is required for optimization, and top ups or patient-controlled epidural analgesia may be necessary to achieve improved pain control. Occasionally, epidural dosing is limited by the patient's inability to tolerate hypotension or other side effects. And finally, inadvertent dislodgment of catheter will result in failure of this analgesic modality.

4. Identifying the epidural space

Inability to identify the epidural space is a significant source of failure for TEA with major abdominal surgery. Compared to the lumbar epidural space, the thoracic epidural space, though more continuous, is variable in its width, roughly 7.5 mm in the upper thoracic region and 4.1 mm at T11-12 [11]. Approaches to placement of continuous TEA blocks consist of midline or paramedian approaches, both with drawbacks. The midline approach is performed with the needle entry point at the midline of the spinous processes, thus minimizing need for medial or lateral needle angulation. The paramedian approach is performed with a needle entry point lateral to midline and can be used to avoid bony contact with the spinous processes for ease of access to the epidural space.

The midline approach allows for minimal medial-to-lateral displacement of the needle. In young patients with minimal loss of disk height, and at the upper and lower thoracic region where the spinous processes are not as angulated, the midline approach is relatively simple to perform. Between T5 and T9, the spinous processes are more angulated, and midline approaches require greater cephalad angulation of the needle and greater needle depths to successfully identify the epidural space. If the needle entry point is not optimal, identification of the epidural space may be extremely difficult (Figure 1). In addition, the ligamentum flavum does not fuse midline in all patients, such that the feeling of resistance as the needle traverses this structure is not reliably noted, resulting in a more subtle change in resistance during the loss of resistance technique. Lirk and colleagues noted that the incidence of midline ligamen-

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tum flavum gaps is 2-5% at the level of T6 to T9, 17.9% at T9 to T10, and approximately 30% at T10 to T12 [12]. Successful midline approach depends on optimal patient position to "open up" the space between spinous processes, so it may be less suitable when positioning is limited (such as when TEA is performed postoperatively in a patient in severe pain). Also, steep needle angulations will require greater needle depths, even in less obese patients. Unlike the paramedian approach where depth is predictable once lamina is contacted, the midline approach requires experience to estimate the potential depth. Midline approaches in patients with rotation of the spine or a patient in a lateral decubitus position may be difficult for the novice as the needle trajectory may deviate away from the interspinous ligament, resulting in a false loss of resistance.

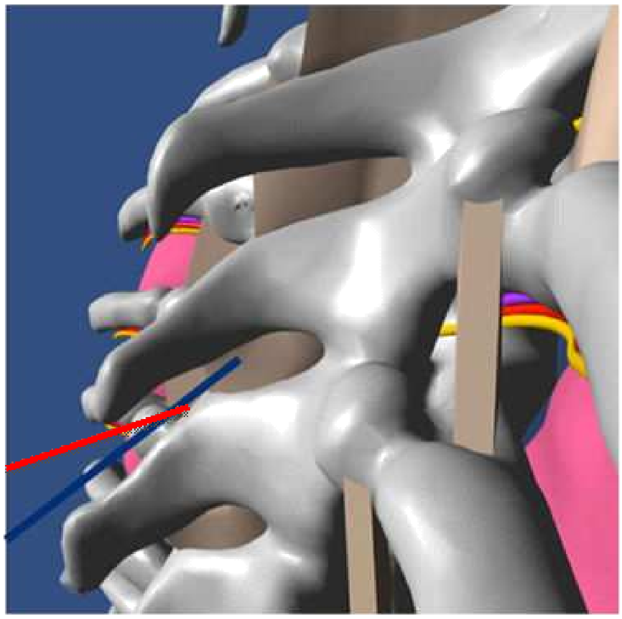

Figure 1. Two spinous processes with needle entry point at superior aspect (red line) and inferior aspect (blue line) of the space between spinous processes showing that the inferior aspect results in more successful placement midline

The paramedian approach allows for shallower needle depths, less cephalad needle angulation, and more consistency in the presence of the ligamentum flavum when compared to the midline approach. In addition, the lamina is utilized as a reliable deep marker for the identification of the epidural space. This approach is also less dependent on optimal patient positioning and is usually technically easier when done with the patient in the lateral decubitus position. However, determination of optimal medial angulation of the needle may be difficult and the thickness of ligamentum flavum decreases the further lateral the approach. Therefore, ideally, the needle tip should enter the epidural space as close to midline as possible. Traditionally, needle insertion occurs approximately 1 cm lateral to the spinous process, and how medial of an angle the needle is directed depends on the depth of the epidural space (Figure 2).

If medial angulation is too great, the needle may cross midline to the contralateral side, resulting in not only a false loss of resistance, but also complications such as pneumothorax. The extra manipulation along the transverse dimension adds a degree of difficulty to the

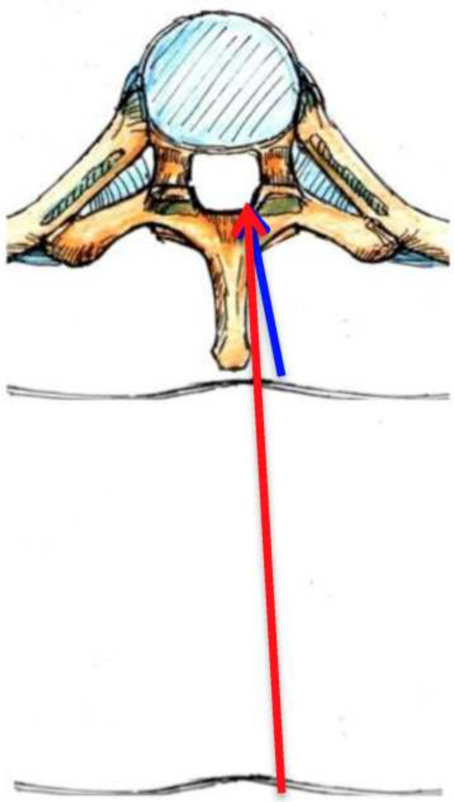

Figure 2. Obese patient and skinny patient and anticipated medial needle angulation

paramedian approach. An alternative approach to minimize the need for medial angulation is a paraspinous approach, where the needle entry point is only slightly lateral (~3mm) to the spinous process. In this technique, no or minimal medial angulation is required and the spinous process can be avoided along the needle trajectory (Figure 3).

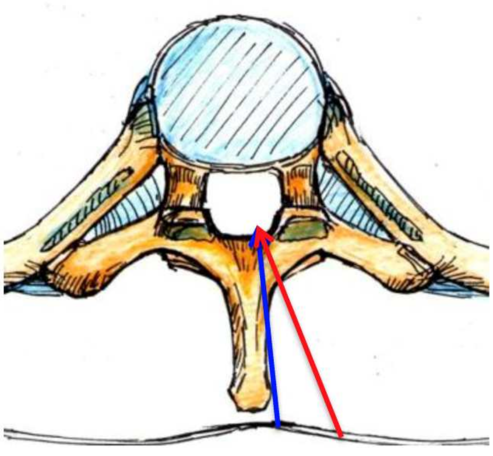

Figure 3. Paraspinous approach, blue line demonstrates the trajectory of the paraspinous process, red line demonstrates trajectory of a paramedian approach with more medial angulation of the needle

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5. Using live fluoroscopy, existing CT scan imaging and ultrasound to guide needle depth and entry point

Live fluoroscopy can be helpful in patients with difficult spine anatomy, but is impractical due to availability of equipment and concerns about radiation exposure.

The use of existing CT scan imaging to determine the depth of the epidural space can give the proceduralist a more informed expectation of depth of needle insertion, leading to higher success rates (Figure 4). Indeed, estimates of needle depth are more accurate when using a paramedian approach with a needle trajectory where the needle requires minimal angulation. The optimal needle insertion point on the skin occurs when a needle that is perpendicularly oriented in the parasagittal plane to the skin is advanced, the tip lies on the superior surface of the lamina, such that only a slight cephalad angulation is required to access the interlaminar space.

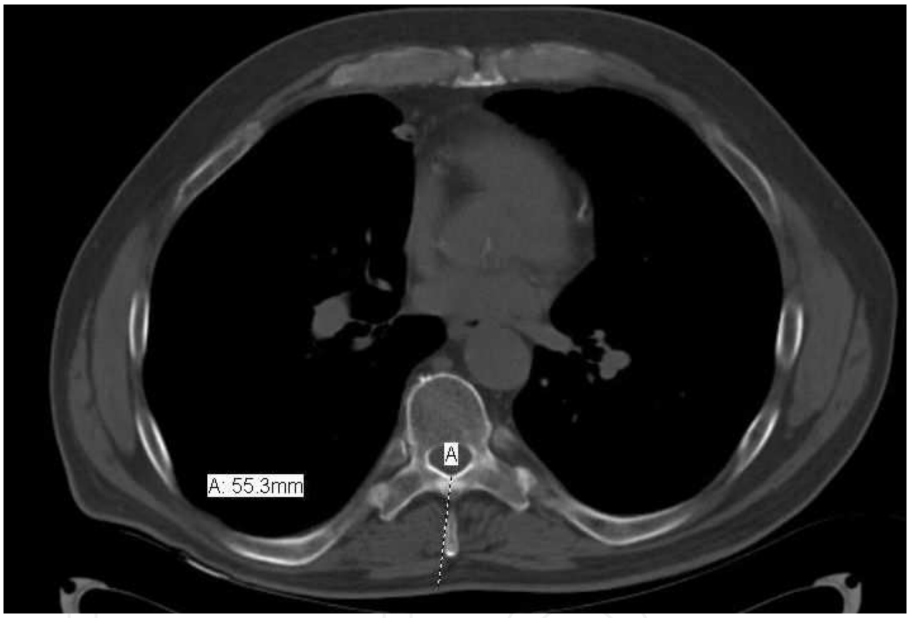

Figure 4. Measurement of depth of epidural space on CT scan

Another imaging modality that may assist with improved success of epidural space identification includes the use of ultrasound. When oriented in a transverse plane, the ultrasound may allow the proceduralist to determine midline accurately in patients whose landmarks are not palpable. The parasagittal view may be used to identify the correct level of insertion and the superior and inferior border of the lamina, to identify the optimal site of needle entry (Figure 5).

Alternatively the inferior border of the transverse process may be used as a second landmark to estimate a skin projection of the optimal spot on the lamina for initial needle placement for subsequent "walk off" into the epidural space. Ultrasound may also assist in determining the depth of the lamina and epidural space. However, care must be taken not to apply too much pressure to the ultrasound probe on the skin, leading to a falsely shallow estimated distance.

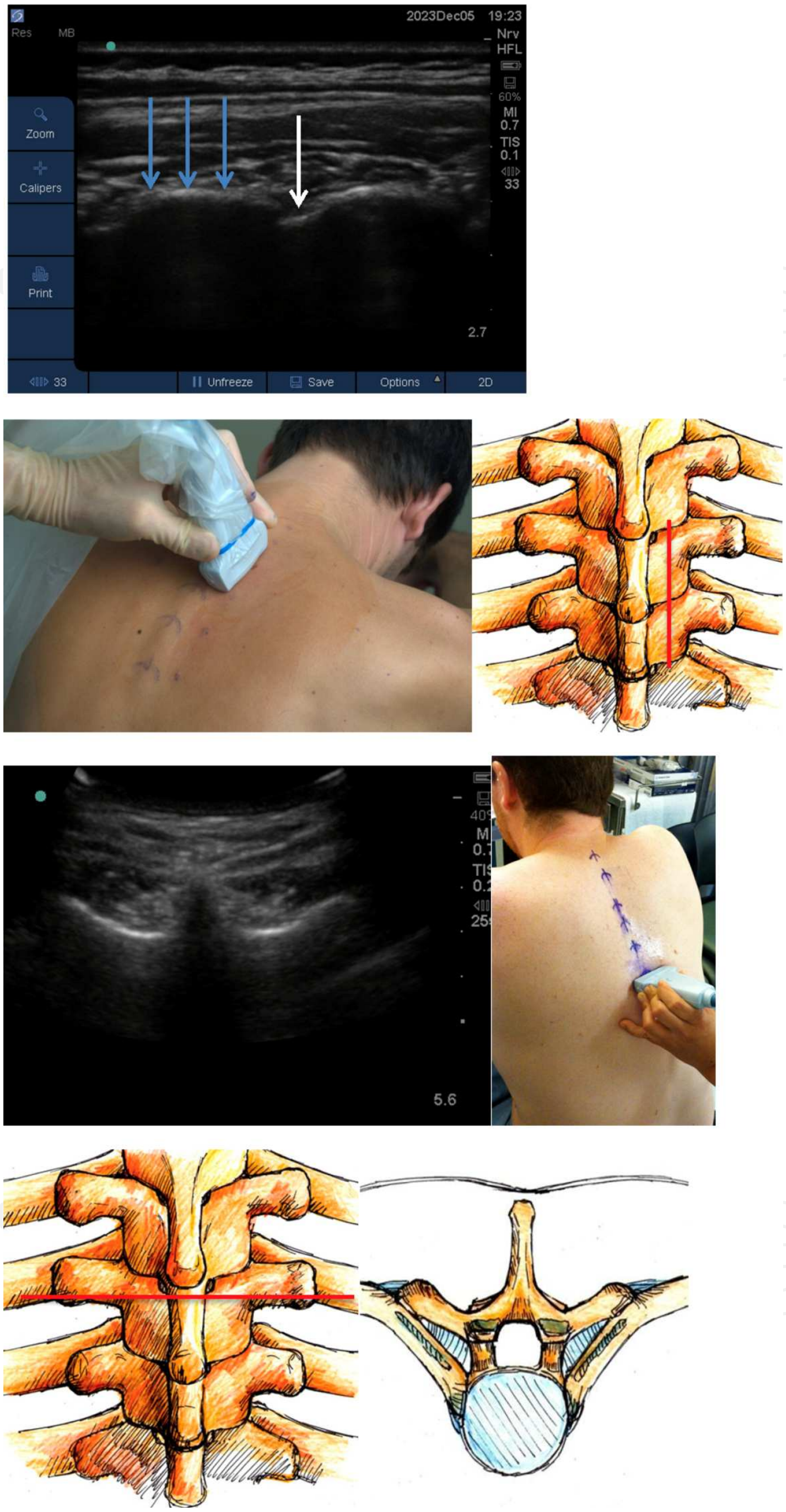

Figure 5. Ultrasound images of the spinous process, lamina and transverse processes; a. parasagittal view of the lamina, blue arrows indicate lamina, white arrow indicates interlaminar space, b. diagram showing the orientation of ultrasound probe for parasagittal view of the lamina line), c. transverse view of the spinous process, lamina, and transverse processes, d. diagram showing the orientation of the ultrasound probe for the transverse view of the spine (red line)

Ultrasound may also help to determine the largest interspace for ease of access. Although ultrasound imaging may assist with determining optimal location to proceed with epidural catheter placement, live ultrasound-guided needle placement is not widely used in clinical practice due to the need for an extra set of hands to stabilize the probe and concerns regarding the unknown effect of inadvertent transference of ultrasound gel into epidural space.

6. Indications and contraindications

Indications for use of TEA include major open abdominal surgery in which moderate-to-severe pain is expected to last more than 24 hours. This can include open procedures such as abdominal aortic aneurysm repair, Whipple procedures, bowel surgery, large ventral hernia repair, cholecystectomy, major gynecologic surgery, nephrectomy, and cystectomy. Surgeries such as pheochromocytoma resection, in which catecholamine surges may result in life-threatening blood pressure and heart rate swings may also benefit from the use of TEA to blunt the catecholamine release to surgical stimulation. Hepatectomy results in significant pain. However, the use of epidural anesthesia should be balanced against the need to reduce bleeding at the surgical site using measures such as volume restriction. Although most patients with hepatic surgery tend to be hypercoagulable postoperatively, large liver resections may result in a reduced ability to produce vitamin K dependent factors for coagulation and subsequent potential for excessive risk of catastrophic bleeding in the spinal canal with possible spinal cord compression.

There is a subset of patients that particularly benefit from the use of TEA. Patients with pulmonary comorbidities and patients with obstructive sleep apnea may benefit from the opioid sparing effects of TEA and the decreased risk of respiratory depression. In patients with chronic pain or who consume high dose opioids and are tolerant to opioids, TEA may allow for more effective analgesia.

Contraindications to TEA have been traditionally labeled as absolute and relative. Absolute contraindications to TEA include placement of neuraxial block at the peak effect of a potent anticoagulant or when the patient is at risk of bleeding due to other reasons such as profound thrombocytopenia or hemophilia, patient refusal, and localized infection along the trajectory of the needle. Frequently, the medical decision to perform a TEA is not as straightforward, and the risk-to-benefit ratio must be determined to provide the patient with a more thorough informed consent.

Relative contraindications to TEA include placing the epidural in patients who are febrile or immunosuppressed or in patients who have a true local anesthetic allergy, metastatic lesions to the spine, intracranial hypertension, planned postoperative anticoagulation, severe hypovolemia, aortic stenosis, neurologic disorders such as multiple sclerosis, or in patients at risk of masking unrelated complications (patients with multiple traumatic injuries who require frequent neurologic assessment of the lower extremity or patients at risk for anterior spinal cord syndrome after open thoracoabdominal aneurysm repair). With regards to the febrile patient, more concerning is whether elevated temperatures are a result of bacteremia and if traumatic needle placements may introduce pathogens directly into the subarachnoid space and place the patient at risk for meningitis. Observational studies of lumbar punctures in febrile patients have not demonstrated increased risk of meningitis, though expert opinion recommends caution with neuraxial procedures in patients with bacteremia.

Despite thorough preoperative planning and weighing of the benefits and risks of TEA, difficult scenarios may still arise. For example, an epidural that is placed preoperatively in a patient with no contraindication for neuraxial blockade who develops an intraoperative myocardial infarction and requires an anti-platelet agent or thrombin inhibitor after placement of a coronary stent presents a difficult situation in which clinical judgment as to the optimal postoperative management of the epidural catheter is tested.

7. Benefits and effectiveness

Thoracic epidural anesthesia and analgesia can result in significantly lower pain scores at rest and with movement during major open abdominal aortic surgery [13]. This degree of analgesia was found to last until postoperative day 3. The benefits of TEA extend beyond patient comfort and analgesia. The authors also noted a decreased incidence of myocardial infarction, acute respiratory failure and continued need for postoperative mechanical ventilation, gastrointestinal complications and renal complications.

Blockade of the cardiac sympathetic fibers arising from T1 to T5 has been demonstrated to reduce heart rate, mean arterial pressure and myocardial contractility. This reduction in cardiac work results in decreased myocardial oxygen consumption. Coronary insufficiency, demonstrated by electrocardiography, echocardiography, and angiography, is reduced by TEA [14].

Interestingly, although blockade of sympathetic fibers may result in predominant parasympathetic tone and lead to increased bronchomotor activity of the lungs, asthmatic episodes have decreased with use of TEA. This is speculated to be due to reduced afferent input. In addition, the use of epidural analgesia spares the amount of opioids required to achieve adequate analgesia, reducing opioid-related side effects, most notably sedation and respiratory depression.

The stress response to major surgical insult has been shown to be reduced by predominantly blocking the efferent and afferent pathways to the adrenal medulla. A thoracic epidural blockade of T6 to L1 results in a blunted catecholamine response and decreased cortisol levels [14].

Improved gut motility with the use of TEA has been documented to reduce postoperative ileus in bowel surgery by approximately 12 hours [15]. This improved gut motility may be attributed to the reduced sympathetic tone and sparing of the parasympathetic tone (vagus nerve) in the gastrointestinal tract as well as reduction in postoperative opioids, which have been known to cause gastric dysmotility. In addition, blockade of the splanchnic nerves T6-L1 may reduce vascular resistance, allowing for pooling of blood in the gut [14]. If systemic blood pressures are maintained, this can result in improved perfusion of the bowel mucosa.

New exciting data about the possible reduction of cancer recurrence with intraoperative dosing and postoperative maintenance of thoracic epidural catheters after different types of oncologic surgery is appearing in the literature. However, at this time, most human data is retrospective in nature.

8. Side effects

The side effects of continuous epidural infusion are mostly specific to the medications used. Most commonly, local anesthetic and opioids are delivered through the epidural space, and their combined use allows for improved analgesia with less doses of each.

Local anesthetic in the epidural compartment results in a sympathectomy. Vasodilation, especially of the splanchnic circulation, results in a relative reduction in preload as the intravascular volume is redistributed, resulting in hypotension. This effect is especially noticeable in patients who undergo bowel preps in anticipation of surgery of the gastrointestinal tract, who are already intravascularly depleted prior to epidural placement. In addition, dense concentrations of local anesthetic will also result not only in blockade of pain but in sensory and motor changes. Although sensory changes may be even desired, motor changes may detrimentally affect the patient. Low thoracic epidurals have the ability to anesthetize the muscles of the lower extremity. Proximal motor function, such as hip flexion, can be affected if epidural spread reaches the upper lumbar roots. Midthoracic epidural catheter placements with low volume infusions of local anesthetic will mostly affect intercostal and abdominal muscles. The motor effects on these muscles have not appreciatively affected the patient's ability to cough.

Respiratory depression and sedation can also occur [16]. Two types of respiratory depression, early and late, each with a different mechanism have been described. The most feared complication is delayed respiratory depression that may occur 12-24 hours after epidural administration of hydrophilic opioids (morphine) due to rostral migration of the drug into the cerebral spinal fluid, which can be especially concerning if patient's ventilation status is not closely monitored. With use of more lipophilic opioids such as sufentanil in the epidural space, plasma concentrations may increase shortly after bolus administration of the drug and reach levels high enough to cause systemic effects with early respiratory depression [17, 18]. Overall, respiratory depression with use of opioid medications is higher with the intravenous as opposed to the epidural route of administration.

Urinary retention appears to be related more to local anesthetic and less to opioid use. Post-void residuals were noted to be more affected by epidural bupivacaine as opposed to epidural fentanyl, even at the thoracic epidural level [19]. Despite this effect, the absence of a bladder catheterization in a patient with an epidural infusion of low concentration local anesthetic and opioid has not resulted in an increased need for repeat catheterization of the bladder. In addition, the early removal of bladder catheters has resulted in a decreased incidence of urinary tract infections [20].

	Opioids	**Local Anesthetics**
Respiratory	Depression	Usually no depression
Cardiovascular	No reduction in Blood Pressure	Postural hypotension Reduced heart rate w/ high block
Sedation	Yes	Mild/absent
Nausea/Vomiting	Yes	Uncommon
Pruritus	Yes	No
Motor	No effect	Block
Sensation	No effect	Block
Urinary retention	Yes	Yes
GI	Decreased motility	Increased motility

Table 2. Comparison of side effects of epidural opioid and local anesthetics

9. Epidural management

To provide safe care to the patient that will undergo TEA, the procedure is preferably performed 30-60 minutes prior to surgery with the patient optimally positioned in the sitting position and ASA monitors attached in a dedicated block area. Supplemental oxygen is provided and judicious sedation is given to allow for patient feedback and block assessment immediately after the procedure. Aseptic technique using sterile gown, gloves and mask as well as chloraprep skin disinfecting and draping is preferable to reduce the risk of infection. The use of soft-tipped epidural catheters is preferable to reduce the potential perforation of epidural veins and resistance to advancement when a false loss of resistance occurs. There is unlikely a clinical difference in the use of single or multiple orifice catheters. Advancement of the catheter to approximately 5 cm past the needle tip will allow for adequate, but not excessive length of the catheter and avoid the potential for knotting. Meticulous attention to taping with use of adhesives such as mastizol is important to prevent premature dislodgement of the catheter. Special tapes are available that have reduced the incidence of catheter migration (Sorbaview, Centurion Medical Products, Michigan).

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After confirming lack of intravascular and subarachnoid placement of the catheter, dosing of the catheter with local anesthetics such as ropivacaine 0.5 or 0.75% could be used in 3-5 ml increments to achieve a band of anesthesia in the area of surgery. Smaller boluses (3 mL) or shorter acting agents (lidocaine) can be used when the risk of immediate hypotension (frail patient after bowel preparation) or risk for significant intraoperative bleeding is high. (Usually, a 3-5 ml test dose of lidocaine is enough to confirm epidural position and may result in 3-8 dermatomal levels of spread. Occasionally, intravenous fluid boluses or use of ephedrine (including subcutaneous or intramuscular injection) may be needed to maintain stable hemodynamics. Before the time of induction in the operating room, injection of 100 micrograms of fentanyl into the epidural space will provide analgesia without further effects on hemodynamics. The onset of epidural fentanyl is 10 minutes, and despite the fact that fentanyl is lipophilic, a large dose results in significant CSF concentrations. Additionally, the use of vasoconstrictors in the epidural space increases the fraction of fentanyl in the neuraxial space and provides segmental analgesia for several hours. Determining the patient response to the initial test dose and boluses allows the clinician to better anticipate the effects and determine the optimal postoperative epidural prescription. At the author's institution, the standard infusion is ropivacaine 0.2% at a basal rate of 6 to 8 ml per hour with a PCEA bolus of 4 ml every 30 minutes. All patients have standing orders for intravenous opioids as rescue analgesics. Infusions are immediately initiated at induction with top ups of ropivacaine 0.5% 30 minutes prior to emergence from anesthesia. Dedicated members of an Acute Pain Service assess the patients immediately after surgery for presence or absence of epidural analgesia and the need for further dosing of the epidural catheter. These assessments are performed by physicians who also review the patient's volume status and the need for additional fluids or vasopressors.

For the same volume and dose of local anesthetic, the effect is greater with the use of TEA than with lumbar epidural and definitely more than with thoracic paravertebral analgesia. Even a 3 ml test dose of lidocaine 1.5% with epinephrine 1:200, 000 can result in a 3-4 dermatome effect, as demonstrated by loss of the patient's ability to detect cold. The volume of local anesthetic infusion depends on the extent of the surgery. Bolus dosing leads to greater spread of volume in the epidural space as compared with basal infusion. Manual bolus usually results in better spread than bolus dosing through the pump due to higher injection pressures.

The optimal drug regimen in the epidural space would provide optimal analgesia and minimize the risks associated with the medications used. Due to the reduced risk of cardiovascular toxicity with improved sensory-motor differentiation, ropivacaine 0.2-0.3% is the preferred local anesthetic at the author's institution. Use of shorter duration local anesthetics may allow for faster titration of epidural effect, but may result in tachyphylaxis and rapid offset when discontinued and requires close nurse monitoring to reduce gaps in analgesia during bag changes. Bupivacaine is a good alternative, but results in greater motor blockade and makes assessment of whether lower extremity weakness is due to excess local anesthetic or epidural hematoma more difficult. Bupivacaine is less costly and can be safer when used only for infusions at low concentrations to avoid potentially catastrophic local anesthetic systemic toxicity (LAST).

Opioids may be used to reduce the local anesthetic dose required to provide analgesia. Higher concentrations of opioids may result in noticeable sedation and respiratory depression in patients and should be used with caution in elderly patients and patients with obstructive sleep apnea or other pulmonary comorbidities. Morphine, hydromorphone, fentanyl and sufentanil are all reasonable alternatives for epidural analgesia. The addition of systemic opioids or other sedatives in addition to the use of neuraxial opioids has resulted in significant respiratory depression and sedation and is discouraged for opioid naïve patients.

Unfortunately, there is no data for the ideal prescription or medication combination. Different institutions use different local anesthetics and opioids in different combinations at different concentrations. In general, the total dose is more important than the concentration. (Tables 3, 4, 5) The addition of epinephrine (usual concentration 2 mcg/ml) in the infusion decreases systemic absorption of drugs delivered epidurally and increases the transfer of the drugs to the subarachnoid space with improved analgesia.

Opioid	Bolus Dose	Onset	Peak	Duration	Infusion Dose	Lipid Solubility
Morphine	1-6mg	20-30mins	30-60mins	10-24hrs	0.1-0.75mg/hr	1
Hydromorphone	1-2mg	10-20mins	20-30mins	5-15hrs	0.1-0.5mg/hr	1.5
Fentanyl	25-100mcg	5-10mins	10-20mins	1-5hrs	25-100mcg/hr	800
Sufentanil	10-50mcg	5-10mins	10-15mins	1-5hrs	10-50mcg/hr	1800

Table 3. Epidural Opioids

Morphine
PO – 30mg
IM – 10mg
Epidural – 2-3mg
Intrathecal – 0.2-0.3mg

Table 4. Equianalgesic dose of morphine based on route of administration

Drug	Bolus dose	Lockout interval (min)	Background infusion
Morphine	0.2 mg	10 min	+/- 0.4 mg/hr
Hydromorphone	0.15-0.3 mg	15-30 min	
Fentanyl	15-50 mcg	5-15 min	+/- 50-100 mcg/hr
Sufentanil	4 mcg	6 min	+/- 8 mcg/hr

Table 5. Opioid analgesic prescription for TEA

Unfortunately, with the increased productivity and time constraints of a busy hospital setting, it is not uncommon to use standard manufacturer-prepared bags with predetermined mixtures of local anesthetics and opioids to provide easy and uninterrupted flow of drugs for continuous epidural analgesia. The use of standardized prescriptions also helps to minimize drug errors.

In the author's institution, the preference is to have only local anesthetic in the epidural infusion as a standard infusion with the delivery of opioids intravenously as a rescue analgesic. This allows for the flexibility by all services to provide for parenteral opioids without cumulative opioid effects from the epidural, and allows for satisfactory alternative analgesia should the TEA not provide complete coverage. In addition, in the opioid naïve patient, should the patient develop intolerable side effects from opioids, the time to symptom resolution after discontinuation of intravenous opioids is much shorter than with neuraxial opioids. Not uncommonly, patients achieve excellent analgesia with local anesthetics as the sole epidural medication with the addition of non-opioid adjuncts such as acetaminophen or non-steroidal anti-inflammatory agents. Most benefits of TEA are usually from the use of epidural local anesthetics and not opioids. Occasionally, patients, such as those with chronic pain, will need both epidural and intravenous opioids for optimal analgesia.

10. Discontinuation and step down analgesia

The optimal duration of epidural analgesia should include the period of time that expected pain would be moderate to severe in intensity. The avoidance of intravenous opioids may allow for earlier return of bowel function and reduce their negative effects, such as sedation and respiratory depression. Therefore, use of epidural analgesia until at least the third postoperative day, or until return of bowel function, allows optimization of this analgesia modality. Weaning trials should be attempted prior to removal to avoid premature discontinuation of the epidural. The severity of postoperative pain has many variables such as extent of surgery and the patient's tolerance of pain.

Analgesic adjuncts such as acetaminophen, non-steroidal anti-inflammatory drugs, and systemic opioids may be considered in addition to epidural analgesia. These medications can and should be considered on an individual basis depending on patient comorbidities such as pulmonary or renal dysfunction.

Patients with chronic pain who are on pre-existent opioid therapy require continuation of systemic opioids. In addition, pain outside of the distribution of the epidural spread, such as headache and low back pain, will not be improved by thoracic epidural analgesia, and systemic analgesics would be needed for patient comfort. The use of NMDA antagonists such as ketamine, anti-spasmodic agents, and benzodiazepines can be considered for the patient, but their use may lead to further central effects and worsening sedation.

Epidural management should be tailored to the individual patient to provide effective analgesia. Routine and frequent follow-up and adjustments of medications, concentrations, and volumes improve satisfaction with analgesia and is key to providing effective analgesia. In addition, consistent follow-up allows for early detection and management of complications.

11. Complications

Complications of TEA include post-dural puncture headache (PDPH) with inadvertent dural puncture. The rate of dural puncture is operator dependent. The incidence of PDPH after an inadvertent dural puncture with a large bore epidural needle is nearly 70-80% with the incidence of chronic headaches 28% [21]. Regardless, patients demonstrating signs of PDPH will have difficulties with ambulation and rehabilitation.

Unrecognized intrathecal catheter placement may result in high spinals. Neurologic injury from thoracic epidural placement is predominantly attributed to neuraxial hematoma or infection (meningitis or epidural abscess) although spinal cord ischemia, direct needle trauma or chemical toxicity also occur [22].

Because the increase in incidence of neuraxial hematomas after the introduction of the low-molecular weight heparin enoxaparin in the United States in 1993, guidelines on the placement of neuraxial blocks in the anticoagulated patient were introduced and updated periodically. These guidelines are based on existing cases of neuraxial hematomas and aid the physicians in determining the optimal time from anticoagulant dose to epidural placement and removal. Patients with higher susceptibility to neuraxial hematoma includes the elderly female patient, possibly from the increased incidence of spinal stenosis and reduced tolerance to similar volumes of blood near the spinal column. However, the incidence of neuraxial hematoma in a patient without abnormal hemostasis is low [23].

Major surgery negatively impacts postoperative immune status. Therefore, infectious risks such as localized infection and epidural abscess from epidural catheterization occur. While epidemiologic studies are few, a study in Denmark estimated the incidence of epidural abscess to be 1:1930 epidural catheters [24]. Adherence to aseptic technique and routine assessment of catheter site is imperative to avoid this complication.

12. Thoracic paravertebral analgesia

12.1. Anatomy

The paravertebral space is a potential space that, when filled with fluid (e.g. local anesthetic), becomes wedge-shaped. It is bordered by: anteriorly, the parietal pleura; medially, the posterolateral vertebral body, the vertebral disc, and the vertebral foramen and spinal nerve; posteriorly, the superior costotransverse ligament (SCTL); laterally, the posterior intercostal membrane and the intercostal space; superiorly/inferiorly, the heads and necks of the ribs. The SCTL runs obliquely from the transverse process superiorly to the rib below inferiorly. It is slightly more superficial superiorly and is slightly denser laterally (Figure 6).

The paravertebral spaces of the cervical and thoracic regions communicate, but there is unpredictable spread of local anesthetic. Large-volume (15-20 ml) boluses of local anesthetics will usually spread 1 or 2 levels cephalad and caudad but may remain within the level injected [25]. MRI study of the paravertebral spread of 20 ml of 1% mepivacaine with contrast demonstrated fairly consistent spread of contrast dye 1 level cephalad and 3 levels caudad to the

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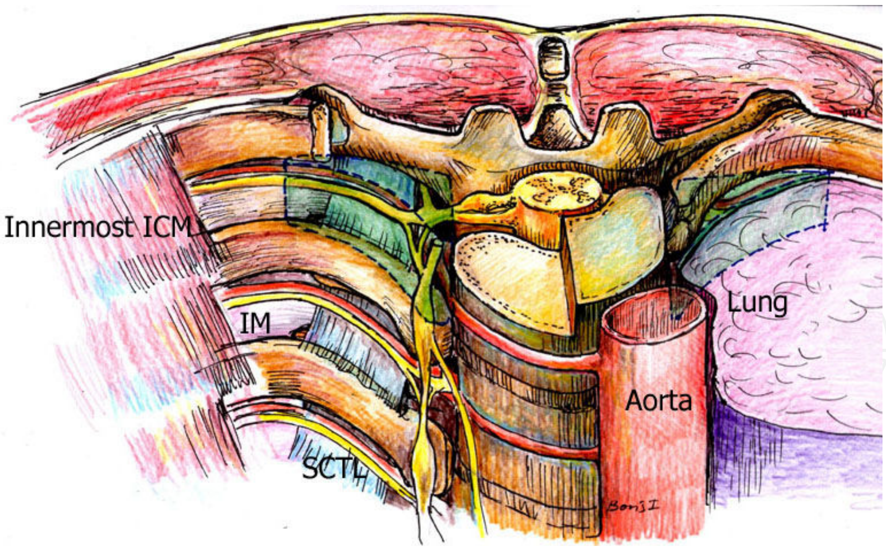


Figure 6. The median distance from skin to paravertebral space is 5.5 cm, with greater depth in the upper (T1-3) and lower (T9-12) thoracic regions (WR). Body habitus significantly influences the depth to this space, which can be measured using ultrasound.

level of injection. However, the number of sensory dermatomes affected by this block was highly variable [26]. If more than 4 levels of spread are desired, multiple injections should be performed to improve analgesic distribution of local anesthetic. For major abdominal surgery, bilateral paravertebral catheters should be used.

12.2. Technique

Multiple techniques may be used to identify the paravertebral space. Loss of resistance, nerve stimulation, and ultrasound may be used individually or in combination.

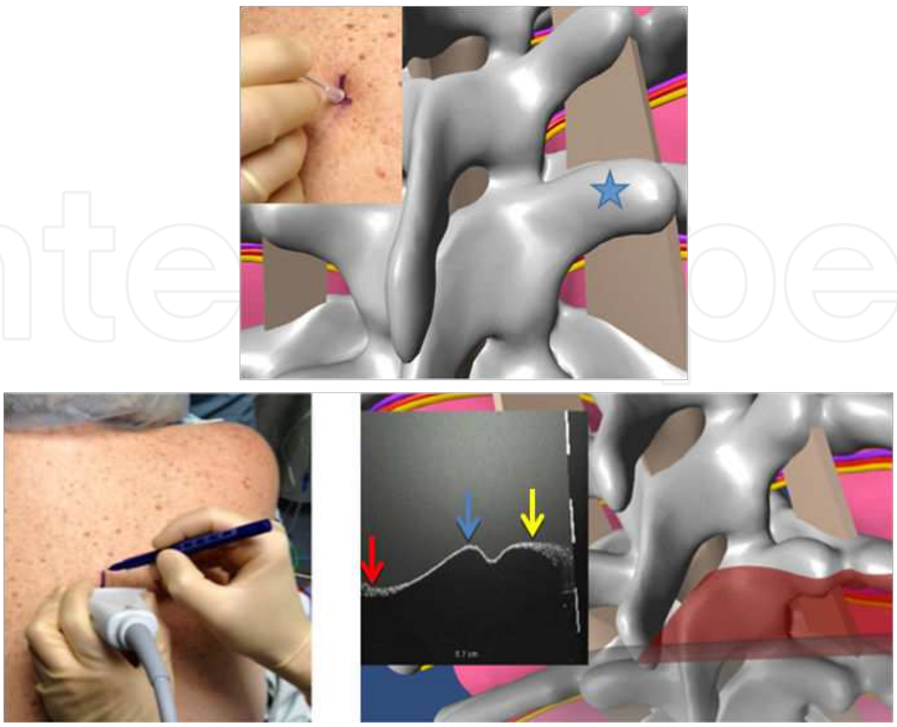
12.3. Identification of point of insertion

12.3.1. Palpation

The patient is ideally positioned seated with the neck and back flexed and the shoulders relaxed. Alternatively, the patient may be positioned lateral decubitus. The spinous processes of the thoracic vertebrae are level with the transverse process (TP) of the next lower vertebra. After palpation of the spinous process, the needle entry point should be made 2.5 cm lateral to the superior aspect of the spinous process. (As an example, a T7 paravertebral block is desired, then the needle entry point would be 2.5 cm lateral to the superior aspect of the T6 spinous process.) Landmark identification does not require any special equipment, however, there is considerable interpatient and intrapatient variability in the location of the TP relative to the spinous process. For example, the upper thoracic TPs are longer and have a more cephalad angulation. Needle insertion too medial can result in contact with the lamina, and too lateral insertion would put the needle in contact with the rib or pleura. Where TPs are angled more cephalad, standard landmark identification can result in needle placement between TPs, increasing the risk of pneumothorax.

12.3.2. Ultrasound (Figure 7)

Ultrasound can assist with accurate identification of the level to be blocked and assessment of depth from skin to the transverse process and to pleura. A linear, high-frequency probe can be used for thin patients and curvilinear, low frequency probes may be needed for larger patients. Once the level of entry is identified, the probe is placed in a transverse orientation such that the tip of the spinous process, lamina, transverse process and ribs are identified. The lateral aspect of the TP is centered on the screen and the skin is marked, representing the lateral entry point. Care should be taken not to tilt the probe excessively cephalad or caudad. The probe should be completely perpendicular to the skin with equal pressure on both ends of the probe. The probe is then placed in a parasaggital orientation approximately 5cm from midline and slid medially, looking for the transition from rib to TP, which should be where the lateral mark is made. The TP is more superficial than the rib and will be seen as a "step-up" on the screen. Ribs are also more rounded, and the TP have a square contour. The ultrasound is positioned such that the inferior aspect of the TP is centered. Again, the US probe must be perpendicular to the skin with equal pressure applied to both ends of the ultrasound probe. The skin is then marked where the center of the probe lies (at the inferior edge of the TP). This mark represents the vertical entry point for the needle. Release of excessive pressure from the probe allows for accurate determination of depth of TP and pleura from skin. Extension of the marks for lateral and vertical entry points should create an intersected point for optimal needle entry. The block may then proceed as described below using either loss of resistance or nerve stimulation as endpoints. Ultrasound can be especially useful in obese patients without palpable landmarks but image quality decreases with increasing depth to TPV space. Ultrasound used as a "rescue" technique can be limited if loss of resistance (LOR) to air is used from prior attempts due to image distortion from subcutaneous air.



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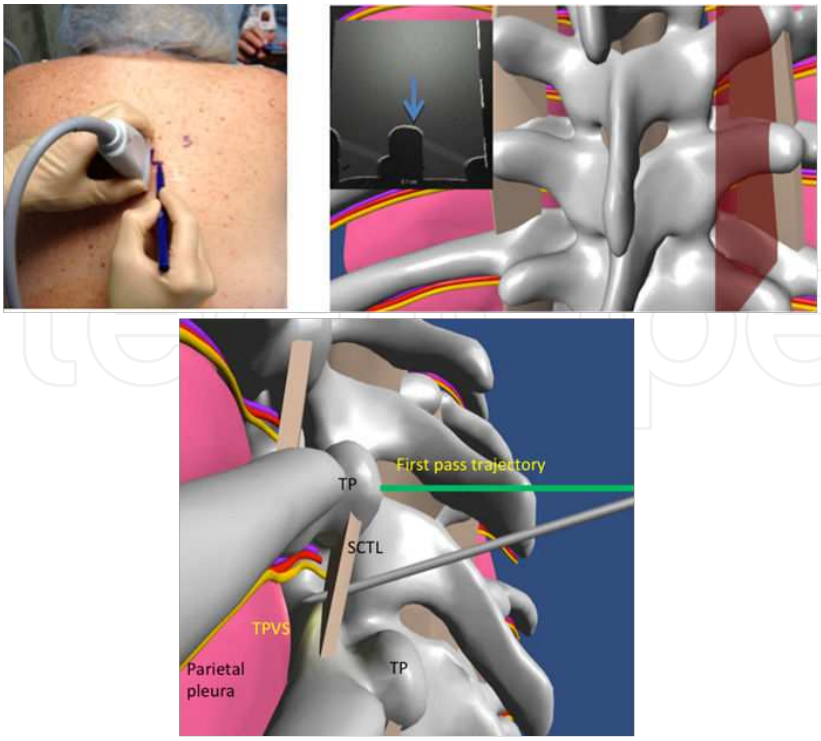

Figure 7. Ultrasound identification of transverse process: a. The star represents the desired entry point of the needle, which is directly over the transverse process, b. Initially, a transverse probe orientation allows the proceduralist to identify the most lateral aspect of the TP and where it contacts rib. Lamina (red arrow), lateral aspect of TP (blue arrow) and rib (yellow arrow) are shown. In the simulated image of the spine, the red shade represents the slice of tissue that is on the ultrasound image, c. Next, a parasaggital probe orientation allows visualization of the transverse processes. The inferior aspect of the TP is placed at the center of the length of the probe in anticipation of walking the needle caudad to the TP. Blue arrow designates desired point needle tip contact with bone. On ultrasound image, left is cephalad, right is caudad. In the simulated image of the spine, the red shade represents the slice of tissue that is seen on the ultrasound image. d. Placement of the initial needle tip on inferior aspect of the TP allows minimal needle angulation caudad to access TPV space.

13. Paravertebral space endpoints

13.1. Loss of resistance

The needle is advanced through the skin in the parasagittal plane until bone is contacted. Maintaining the needle in a strictly parasagittal direction decreases the risk of neuraxial complications, which are increased with medial angulation of the needle, and pneumothorax, which are more likely to occur with lateral needle angulation. With use of surface landmarks and palpation (instead of US) to identify surface landmarks, needle depth from skin to TP is not measured. This distance, however, may be anticipated, although estimates of needle depth may be less accurate if the proceduralist has had less experience. However, if bone (TP) is not contacted at an expected and appropriate depth, the needle is withdrawn and angled slightly cephalad, and if not, caudad, until contact with bone is made. In general, in the average 70kg patient, bone contact should occur at a depth of 2-4 cm. The authors, however, encourage the use of ultrasound to determine depth of TP and pleura to assist the proceduralist in more accurate estimations of TP, thoracic paravertebral space, and pleura to minimize both failures and excessively deep needle placements (pneumothorax). As the paravertebral space is approximately 1 cm deep to the TP, the needle is then grasped 1 cm from the skin, withdrawn to the subcutaneous tissue, and angled caudally. With a LOR syringe attached, the needle is advanced until LOR is attained, being careful not to advance beyond the depth marked by finger-grasp. Once the paravertebral space is entered and following negative aspiration of air, blood or cerebral spinal fluid, local anesthetic with epinephrine is injected and/or a catheter is threaded into the paravertebral space.

13.2. Nerve stimulator

Alternatively, nerve stimulation can be used as an endpoint. With a nerve stimulator set at 2 Hz frequency, 0.3 msec pulse duration and an amplitude of 3-5 mA, a stimulating needle is advanced as with the LOR technique. Paraspinal muscle contractions are frequently observed superficial to the TPV as the needle is advanced. These twitches are no longer observed once the needle advances through the superior costotransverse ligament into the paravertebral space. At this point intercostal muscle or abdominal muscle contractions can be observed, or palpated in the obese patient. In a fully awake or lightly sedated patient, a thumping sensation may be reported by the patient. The electrical current is then decreased to 0.8mA with small needle manipulations if necessary to retain desired muscle contraction. Local anesthetic is then injected or a catheter is inserted through the needle, but needle manipulation to maintain motor stimulation with a stimulating catheter is not necessary and may lead to increased risk of pleural puncture.

13.3. Ultrasound

For ultrasound assisted block placement, ultrasound may be used after LOR or nerve stimulation (NS) to confirm correct needle/catheter placement by observing anterior displacement of the parietal pleura as local anesthetic is injected. Ultrasound can also be used to confirm absence of pneumothorax after the procedure.

Ultrasound-guided placement, which means constant visualization of the needle during placement into the paravertebral space, requires greater skill and experience with ultrasound (Figure 8). There are two main orientations for holding the ultrasound probe, parasagittal and axial, as well as two approaches with the needle, in-plane and out-of-plane. The preferred technique at the authors' institution is a parasagittal probe orientation with the inferior and lateral aspect of the transverse process centered on the screen. Using an out-of-plane technique, the needle is advanced perpendicular to the skin about 2-3 mm from the probe with minimal medial angulation. Tissue deflection can be seen as the needle is advanced. The depth of the TP on the US screen is noted and the needle is advanced no further 5mm from the anticipated depth of TP, eliciting contact with bone. Then the US probe is placed down and the needle is walked off in a caudad direction as above. Alternatively, an oblique parasaggital view can be obtained (Figure 8) with the cephalad aspect of the probe just slightly medial and the caudad aspect of the probe slightly lateral. An in-plane approach can be utilized. However, needle visualization can be tricky, and this in-plane approach is recommended for more advanced proceduralists. In addition, the in-plane technique is more suitable for non-obese patients as image resolution at greater depths may be suboptimal.

14. Indications/Contraindications

Thoracic paravertebral analgesia may be used as an alternative to epidural analgesia for all surgery of the trunk. Unilateral thoracic paravertebral blocks may be performed for thoracotomy and breast surgery while bilateral thoracic paravertebral blocks can be performed for open abdominal surgery. Bilateral thoracic paravertebral blocks for hepatectomy allow for analgesia with a reduced incidence of sympathectomy. Bilateral thoracic paravertebral blocks can also be used as a backup plan for patients who are at a higher risk for epidural hematoma (anticoagulated patient) or for patients in which the epidural space cannot be identified. However, to achieve nearly the same analgesic distribution as epidural analgesia, a higher volume and more bolus dosing is usually required.

Contraindications to the use of thoracic paravertebral analgesia are similar to those of epidural analgesia, but with a lower (but not zero) risk of inadvertent dural puncture and epidural hematoma. Patient refusal and infection along the trajectory of the needle tract remain absolute contraindications.

Contraindication	Rationale
Severe coagulopathy	While the paravertebral space is distensible, it is not easily compressed if bleeding does occur
Systemic infection	Risk of introducing infection into the paravertebral space, especially when not or inadequately treated prior to anticipated TPV placement
Tumor along anticipated needle trajectory	Risk of tumor "seeding"
Previous ipsilateral thoracic surgery	Risk of altered tissue planes due to scarring, especially if use loss of resistance technique is planned

Table 6. Relative contraindications

15. Benefits/Efficacy

There is growing use of bilateral paravertebral nerve blocks as an alternative to neuraxial techniques for analgesia in patients in whom neuraxial catheters are contraindicated or difficult.

Due to the lower risk of hypotension compared to epidural from a decreased sympathectomy, continuous paravetebral blocks may be preferable when hemodynamic instability is antici-

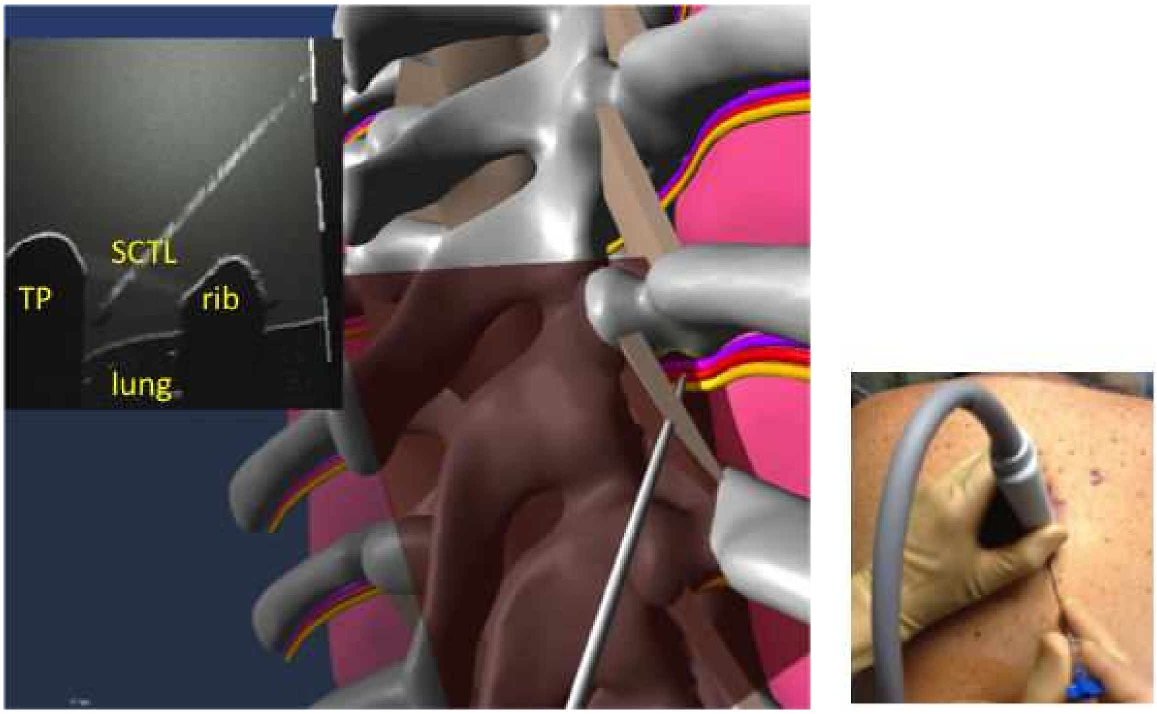

Figure 8. Live needle guidance for TPV block is an advanced technique and should be done only in individuals experienced in needle guidance under ultrasound. An oblique parasaggital view of the paravertebral space may improve visualization of the paravertebral space and pleura as well as an optimal needle trajectory.

pated (high surgical blood loss, hepatectomy). Bilateral thoracic paravertebral catheters can provide nearly similar pain control compared to thoracic epidural with decreased need for colloid infusion and vasoactive medications [27].

In patients undergoing total abdominal hysterectomy, both PVC and TAP catheters were found to be effective at reducing post-operative opioid requirements leading to reduction in opioid-induced side effects such as PONV, compared to control patients receiving opioids. Also, both patients with continuous TPV and TAP blocks had reduced pain scores and increased satisfaction compared to control patients [28].

In a meta-analysis of patients undergoing thoracotomy, PVC was found to significantly decrease pain scores and also to decrease pulmonary complications. The number-needed-to-treat to prevent one pulmonary complication was 4.2 ± 0.08. There was no benefit of epidural pain control versus systemic opioid analgesia with regards to pulmonary complications. Pain control with paravertebral catheters and epidural catheters was found to be comparable [29].

At the author's institution, although continuous bilateral TPV provides excellent analgesia in a subset of patients, higher volumes and bolus dosing of TPV catheters is required to achieve adequate spread of local anesthetic. Still, the analgesia does not appear as consistent as with TEA and the addition of subarachnoid morphine has been routinely used to improve analgesia. However, with high injection pressures from bolus dosing of TPV, epidural spread can be noted with TPV and improved analgesia is observed. Despite this fact, patients still appear to

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have higher requirements for systemic analgesics with bilateral continuous TPV as compared to TEA.

16. Side effects and complications

Side effects of thoracic paravertebral are less observed compared to TEA. A sympathectomy is not observed as frequently, although motor and sensory blocks are limited in their distribution. In addition, because only local anesthetics are infused in TPV blocks, no opioid-related complications are noted, such as pruritus, urinary retention, sedation, respiratory depression or nausea and vomiting other than the opioid-related side effects of requiring intravenous opioids as an adjunct to TPV analgesia.

Complications of TPV analgesia include failure of the block, both due to inability to place catheter correctly in TPV space or due to suboptimal spread of local anesthetic. Vascular punctures and intravascular placement may occur, but the consequences of bleeding are not as catastrophic as bleeding in the epidural space. Isolated puncture of parietal pleura may result in pneumothorax, either from the needle or from catheter advancement, but usually is Insignificand and does not require treatment. However, puncture of the visceral pleura and subsequent use of positive pressure mechanical ventilation may result in a tension pneumothorax with hemodynamic and respiratory compromise that will increase the need for chest tube placement. Visceral injury can be detected by aspiration of air through the needle or through the catheter.

A benefit of paravertebral nerve block is unilateral block. However, epidural and contralateral spread may occur with high volume dosing and pressurized dosing (such as with bolus injection). In a study halted early because of high rate of epidural spread, half (5/10) of patients who received high-pressure (>20 psi) lumbar paravertebral injection had evidence of neuraxial spread with a level at or above T11 although none (0/10) of the patients who received low-pressure (<15 psi) injection did. Additionally, 6/10 patients in the high-pressure group had bilateral femoral nerve sensory block and none in the low-pressure group had bilateral block [30]. While the study is performed in lumbar paravertebral blocks, these results can be extrapolated to thoracic paravertebral blocks. At the author's institution, greater reductions in blood pressure have been noted with bolus dosing as compared to basal infusions alone.

As demonstrated in the diagram (Figure 9), inadvertent dural puncture is possible since the dural sleeve may extend beyond the neuraxial space, resulting in total spinal anesthesia. The use of small gauge needles is not recommended because CSF leakage with dural puncture may not be easily detected or aspirated. The same is true for puncture of a blood vessel. Intravascular needle placement is less detectable and not easily aspirated. The inability to detect an intrathecal or intravascular needle placement can potentially lead to catastrophic complications with local anesthetic dosing. Use of sharp needles is also discouraged since resistance as the needle traverses the ligaments is less notable and identification of the thoracic paravertebral space more subtle. Medial angulation of the needle should be avoided so that you do not introduce a catheter into the neuraxial space, resulting in a transforaminal epidural catheter. Despite strict parasaggital needle manipulation, extension of a dural sleeve or a Tarlov cyst can still result in intrathecal needle or catheter placement and observation for CSF flow through the needle and test dose is recommended.

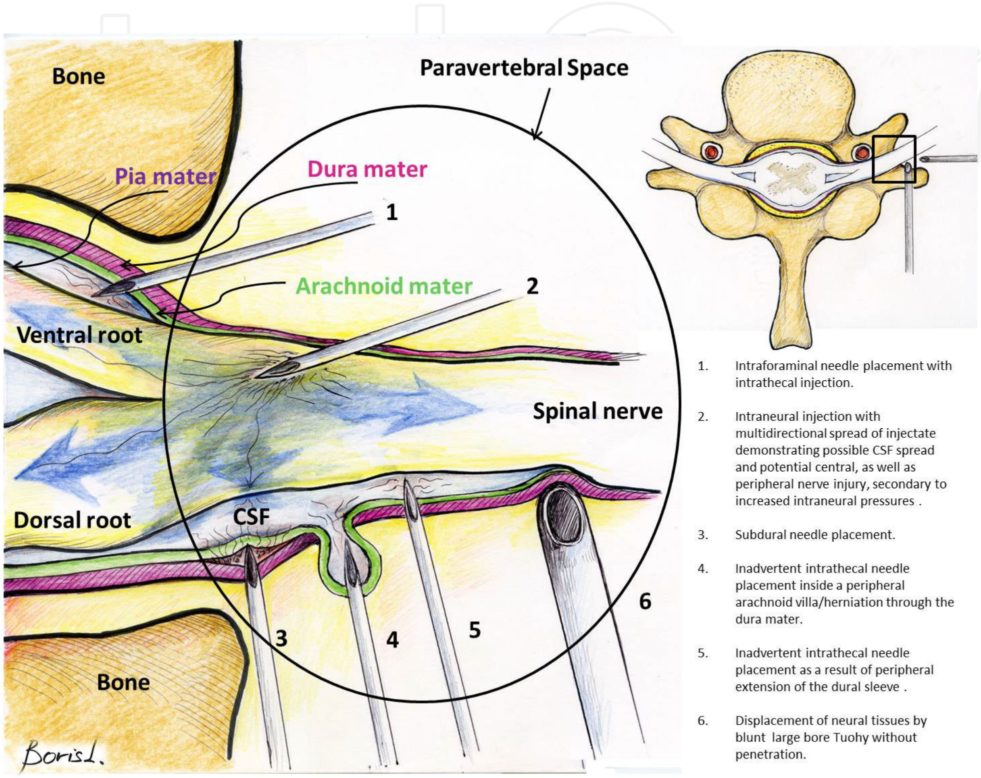

Figure 9. A possible mechanism for catastrophic outcomes from paravertebral block is inadvertent dural puncture. The above diagram demonstrates the potential extension of the dural sleeve in the cervical spine. This diagram can also be extrapolated to the thoracic spine. Catastrophic total spinal anesthesia has occurred with attempted thoracic paravertebral block placements.

17. Transversus Abdominis Plane (TAP) block

The Transversus Abdomins Plane (TAP) block was initially introduced by Rafi in 2001 [31]. Rafi described an anterior approach to the lumbar triangle of Petit in which he used a "pop" technique to reach the plane between the internal oblique and transversus abdominis muscles. Injection and spread of local anesthetic within this neurovascular plane can reach the anterior divisions of the thoracolumbar nerves, T6-L1, providing analgesia to the abdominal wall. With the traditional approach, however, sensory testing and cadaver studies have shown that dermatomes of T11-12 are most readily blocked, with spread to T9 and L1 much less often and usually requiring larger volumes of local anesthetic [32]. A block at this level provides analgesia of the abdominal wall in surgery of the lower abdomen, such as cesarean section, hysterectomy, inguinal hernia repair, and appendectomy.

Hebbard initially introduced standard posterior US-guided TAP block where local anesthetic was deposited between the internal oblique and transversus abdominis muscle above the iliac crest for analgesia of the lower abdomen. Then, in 2008, Hebbard introduced the oblique subcostal TAP block, in which local anesthetic is deposited along the costal margin between the transversus abdominis and rectus abdominis muscle medially, and the transversus abdominis and internal oblique muscle laterally, thus providing analgesia of the abdominal wall above the umbilicus [33].

It is important to emphasize that TAP blocks target peripheral nerves, and their effect is limited to blockade of afferent sensory nerves of the abdominal wall and not viscerally derived pain [34]. Therefore, the role of TAP blocks in major abdominal surgery is limited and should be used as an alternative if neuraxial or paravertebral analgesia is contraindicated or difficult.

17.1. Benefits and indications

When compared to neuraxial blockade, TAP blocks do not result in a sympathectomy and resultant hypotension. Sensory and motor blockade is limited to the abdominal wall musculature and lower extremity weakness is rare, only occurring with the TAP block performed at the level of the iliac crest and not the subcostal TAP approach. Lower extremity weakness is likely due to spread of local anesthetic to the femoral nerve. Side effects such as urinary retention, pruritus, nausea and vomiting, and sedation do not occur with TAP blocks.

In addition, TAP blocks provide an alternative to epidurals for patients receiving potent anticoagulation due to the minimal risk of epidural hematoma. Placement under general anesthesia is not considered unsafe because the target for local anesthetic infiltration is along a muscle plane and not a nerve root or outside the spinal cord. Furthermore, the procedure may be performed with the patient in the supine position.

Single injection TAP blocks have an analgesic duration of no greater than 24 hours despite use of long-acting local anesthetics such as bupivacaine or ropivacaine. The use of continuous TAP blocks will result in prolonged duration of analgesia. However, continuous TAP blocks, as compared to continuous neuraxial or paravertebral analgesia, will result in catheters that are located near the surgical site and may be dislodged or interfere with surgical field when placed prior to surgery.

17.2. Risks and complications

Although generally considered safe, potential adverse effects of TAP blocks include intraperitoneal injection, neural or muscle ischemia, and femoral nerve palsy. Failed block analgesia can stem from incomplete local anesthetic spread within the TAP plane, or a superior block on one side compared to the other in bilateral TAP blocks. Liver trauma is possible, particularly when employing a subcostal approach. Most of these adverse outcomes are relatively minor and self-limited when compared to that of epidurals.

Ultrasound guidance has gained acceptance as a standard over the traditional landmark “double pop” technique. One study looking at needle placement by blind TAP block showed correct needle placement in 23.6% of attempts, and incorrect needle placement included 18% in the peritoneum. The risk of visceral injury has led most proceduralists to employ the use of ultrasound and abandon the landmark approach alone [35]. Furthermore, ultrasound guidance has proven beneficial for ease of block performance because the Triangle of Petit can be difficult to identify, particularly in obese and peripartum patients [36].

Another risk of TAP blocks is systemic local anesthetic toxicity. As this block requires injection of local anesthetic within an intermuscular plane, a larger volume is required for wider dermatomal spread. The usual dose in adults is 15-30 mL of local anesthetic, which is doubled when bilateral injections are used. In particular, pediatric patients and post-caesarean section patients would be more susceptible to this systemic toxicity [37].

17.3. Clinical pearls

The lateral decubitus position for TAP blocks of the lower abdomen, especially in obese patients, will allow displacement of fat and excess soft tissue anteriorly and improved ease of access to the space (Figure 10). Two-inch silk tape can be used to deflect breast tissue cephalad and tissue surrounding the hip caudally. A pillow placed underneath the dependent side further opens the space between the 12th rib and iliac crest. An added benefit is that by placing the entry point on the side and tunneling posteriorly, the catheter can in most, but not all instances, be located away from the surgical field. In the cases of chevron and long subcostal incisions, this may not be possible. The use of multiple ports along the catheter may afford some benefit because analgesia is dependent on the spread of local anesthetic to all terminal nerves innervating the abdominal wall. For incisions crossing midline, bilateral catheters will be needed.

Subcostal catheters for upper abdominal surgery placed along the subcostal margin anteriorly will anesthetize the sensory nerves of the upper abdominal wall [38]. These catheters can be performed in the supine position in a medial-to-lateral direction along the costal margin. The proceduralist stands on the contralateral side with the ultrasound machine on the ipsilateral side. This allows ease of in-plane needle placement and catheter advancement. The drawback of this approach is that the catheter entry points (or the catheter itself) may be located in the surgical field. Therefore, catheter placement may be done under direct visualization or ultrasound guidance by the surgeon prior to fascial closure or at the conclusion of surgery prior to emergence.

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Figure 10. Lateral position for TAP blocks allow tissue deflection away from site of block placement.

Figure 11. Subcostal TAP block single injection performed. Due to the spread of nerves of the upper abdominal wall, when single injections are performed, usually the needle is reintroduced multiple times along the subcostal margin in order to achieve optimal spread of LA.

Local anesthetic infusions can be initiated at higher rates (8 ml per hour per catheter). As with TPV block, large boluses may be necessary to improve spread of local anesthetic. Systemic absorption is notable with this block [39] and use of epinephrine with local anesthetic may reduce absorption and increase duration of analgesia. Total dose in milligrams of local anesthesia should be assessed periodically and patients observed for signs of LAST.

18. Utility of TAP blocks

Overall, TAP blocks are most often considered as part of a multimodal analgesia approach to major abdominal surgery. There is some evidence that TAP blocks are opioid-sparing or delay the use of opioids, making them helpful as adjuncts to systemic analgesics. However, they should not be considered as first-line when superior analgesic modalities such as thoracic epidural or thoracic paravertebral blockade are available.

19. Conclusion

Regional anesthesia provides an superior analgesic modality. Thoracic epidural analgesia, thoracic paravertebral analgesia and continuous transversus abdominis plane blocks have all been utilized as part of a multimodal analgesic approach with success. TEA provides the most complete analgesia, but may be limited due to its side effect profile. TPV and TAP blocks may be less effective, but still substantial analgesic modalities. In order to provide optimal analgesia, knowledge of the benefits and limitations of each is imperative.

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