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## Thoracic Paravertebral Block

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THORACIC paravertebral block (TPVB) is the technique of injecting local anesthetic adjacent to the thoracic vertebra close to where the spinal nerves emerge from the intervertebral foramina. This results in ipsilateral somatic and sympathetic nerve blockade in multiple contiguous thoracic dermatomes above and below the site of injection.<sup>1-3</sup> It is effective in treating acute<sup>2-8</sup> and chronic<sup>3,9,10</sup> pain of unilateral origin from the chest and abdomen. Bilateral use of TPVB has also been described.<sup>11-16</sup> Our understanding of the safety and efficacy of TPVB has improved significantly in the last two decades, prompting its use in children<sup>12,17-23</sup> and neonates<sup>20,22</sup> and for surgical anesthesia.<sup>11,14,16,24-26</sup>

### History

Hugo Sellheim of Leipzig (1871-1936) pioneered paravertebral block in 1905,<sup>27-29</sup> and used the technique to produce abdominal analgesia. Arthur Lawen refined Sellheim's technique in 1911 and called it "paravertebral conduction anesthesia."<sup>29</sup> Kappis developed the technique comparable to the one in present-day use<sup>27</sup> and in 1919, produced surgical anesthesia for abdominal surgery.<sup>30</sup> After its initial popularity, TPVB was neglected until 1979, when Eason and Wyatt<sup>3</sup> "revisited" TPVB and rekindled interest by describing a catheter technique. The last two decades have seen renewed interest in this form of afferent nerve blockade. Sabanathan, Richardson and Lönnqvist are three researchers who recently have contributed substantially to improving our understanding of this almost-forgotten technique.

### Anatomy

The thoracic paravertebral space (TPVS) is a wedge-shaped space<sup>31</sup> that lies on either side of the vertebral

column (fig. 1). It is wider on the left than on the right.<sup>32</sup> The parietal pleura forms the anterolateral boundary, while the base is formed by the posterolateral aspect of the vertebral body, the intervertebral disc, the intervertebral foramen and its contents.<sup>3,31</sup> The superior costovertebral ligament, which extends from the lower border of the transverse process above to the upper border of the transverse process below, forms the posterior wall of the TPVS. The apex of the space is continuous, with the intercostal space lateral to the tips of the transverse processes.<sup>3,31</sup> Interposed between the parietal pleura and the superior costovertebral ligament is a fibroelastic structure,<sup>33</sup> the endothoracic fascia<sup>34-38</sup> (figs. 1 and 2), which is the deep fascia of the thorax<sup>35,37,38</sup> and lines the inside of the thoracic cage.<sup>33,35-38</sup> In the paravertebral location, the endothoracic fascia is closely applied to the ribs<sup>31</sup> and fuses medially with the periosteum at the midpoint of the vertebral body.<sup>36</sup> An intervening layer of loose connective tissue, the "subserous fascia,"<sup>35-38</sup> is found between the parietal pleura and the endothoracic fascia. The endothoracic fascia thus divides the TPVS into two potential fascial compartments, the anterior "extrapleural paravertebral compartment" and the posterior "subendothoracic paravertebral compartment" (fig. 1).<sup>37,38</sup> The TPVS contains fatty tissue,<sup>31,33</sup> within which lies the intercostal (spinal) nerve, the dorsal ramus, the intercostal vessels, the rami communicantes, and, anteriorly, the sympathetic chain.<sup>3,31</sup> The spinal nerves in the TPVS are segmented into small bundles lying freely among the fat and devoid of a fascial sheath, which makes them exceptionally susceptible to local anesthetic block.<sup>39</sup> The intercostal nerve and vessels are located behind the endothoracic fascia,<sup>40,41</sup> while the sympathetic trunk is located anterior to it<sup>36,41</sup> in the TPVS (fig. 1).

### Communications of the Thoracic Paravertebral Space

The TPVS is continuous with the intercostal space laterally,<sup>36,37,39,42-45</sup> the epidural space medially *via* the intervertebral foramen,<sup>31,42,45,46</sup> and the contralateral paravertebral space *via* the prevertebral<sup>34,37</sup> and epidural space.<sup>31</sup> The cranial extension of the TPVS is still not defined, but we have observed radiologic spread of

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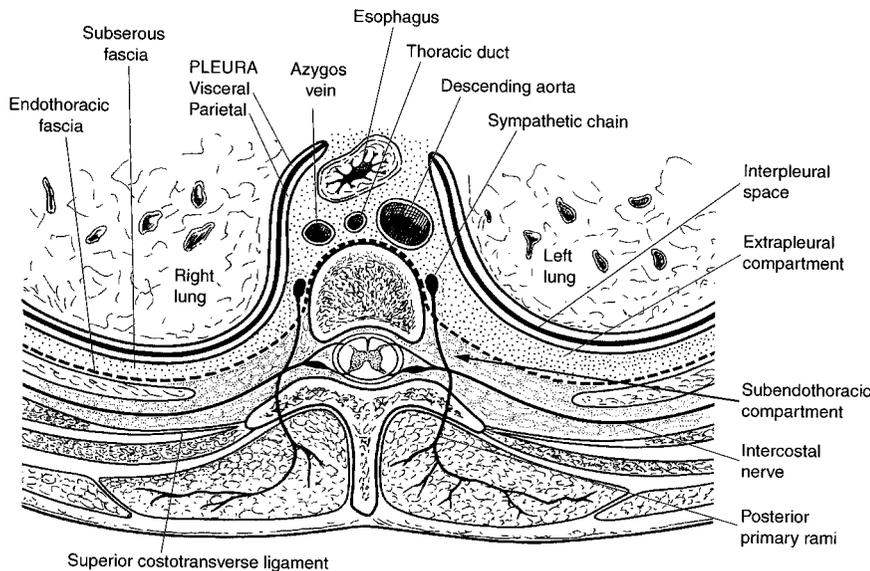


Fig. 1. Anatomy of the thoracic paravertebral space.

contrast medium into the cervical region after thoracic paravertebral injection. The origin of the psoas major muscle forms the caudal boundary,<sup>47</sup> and inferior (lumbar) spread through the TPVS is thought to be unlikely.<sup>47</sup> Ipsilateral thoracolumbar anesthesia,<sup>48</sup> radiologic spread of contrast below the diaphragm,<sup>45</sup> and thoracolumbar spread of colored dye in cadavers<sup>49</sup> have been described, and there is disagreement about the caudal limit of spread.<sup>1</sup> The endothoracic fascia is continuous inferiorly with the fascia transversalis of the abdomen dorsal to the diaphragm through the medial and lateral arcuate ligaments and the aortic hiatus.<sup>35,38</sup> An injection in the lower TPVS posterior to the endothoracic fascia<sup>50</sup> can spread inferiorly through the medial and lateral arcuate ligaments<sup>50,51</sup> to the retroperitoneal space behind the fascia transversalis, where the lumbar spinal nerves lie,<sup>50</sup> and is the anatomic basis of the technique of "extended unilateral anesthesia."<sup>51</sup>

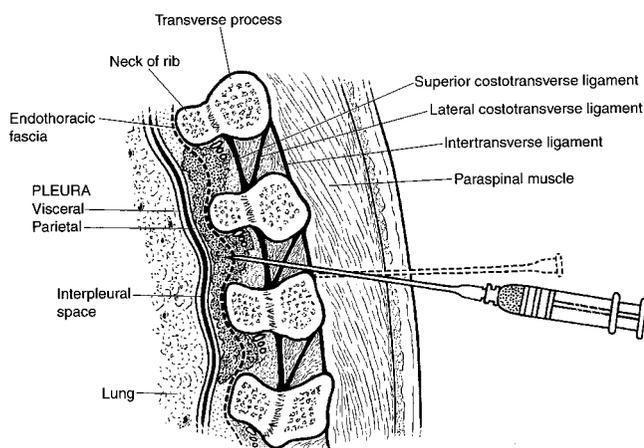


Fig. 2. Sagittal section through the thoracic paravertebral space showing a needle that has been advanced above the transverse process.

## Techniques of Thoracic Paravertebral Block

Several different techniques exist for TPVB. It can be performed with the patient in the sitting, lateral, or prone position. The sitting position allows easy identification of landmarks, and the patients are often more comfortable. The classical technique, which is most commonly used, involves eliciting loss of resistance.<sup>3</sup> At the appropriate dermatome under aseptic precautions, the needle (22-gauge, 8-10-cm short beveled spinal needle, or a Tuohy needle if a catheter is to be placed) is inserted 2.5-3 cm lateral to the most cephalad aspect of the spinous process and advanced perpendicular to the skin in all planes to contact the transverse process<sup>3</sup> of the vertebra below at a variable depth (2-4 cm) depending on the build of the individual. If bone is not encountered at this depth, it is possible that the needle tip is lying between adjacent transverse processes. It is imperative to locate the transverse process before advancing the needle any further to prevent inadvertent deep insertion and possible pleural puncture. This is accomplished by withdrawing the needle to the subcutaneous plane and redirecting it cephalad and caudad to the same depth until bone is encountered. If bone is still not encountered, the needle is advanced a further centimeter and the above process repeated until the transverse process is contacted. The needle is then walked above the transverse process (fig. 2) and gradually advanced until a loss of resistance<sup>3</sup> to air or saline, or a subtle "pop" is felt as the needle tip traverses the thin superior costotransverse ligament, usually within 1-1.5 cm from the superior edge of the transverse process.

After gentle aspiration, local anesthetic is injected in small aliquots or a catheter is inserted so that 1-3 cm of the distal end of the catheter lies within the TPVS. The same technique is used with modification in children,<sup>17,18,30,52,53</sup> and two simple equations help predict

the lateral distance for needle insertion and the skin-to-TPVS depth (both in millimeters):  $[10.2 + (0.12 \times \text{weight in kilograms})]$  and  $[21.2 + 0.53 \times (\text{weight in kilograms})]$ , respectively.<sup>53</sup> Various investigators also redirect their needle medially<sup>29</sup> to contact the vertebra, advance caudal to the transverse process,<sup>26,46,54</sup> or elicit paresthesia.<sup>10,54,55</sup> Medial redirection is not recommended because of the potential for epidural or intrathecal injection.

Unlike epidural space location, where a definite give is felt as the needle tip traverses the firm ligamentum flavum, TPVS location using loss of resistance is subjective and indefinite<sup>28,56</sup> and may not be appreciated as a definite give.<sup>23</sup> Difficulty is also commonly encountered during catheter insertion and may require manipulation of the needle<sup>3,23</sup> or injection of saline to create a saline-filled cavity before passing a catheter. Very easy passage of the catheter may indicate interpleural placement.<sup>43</sup>

The needle may be advanced by a fixed predetermined distance (1–2 cm)<sup>2,26</sup> once the needle is walked off the transverse process without eliciting loss of resistance.<sup>2,11,26</sup> This variation has been used very effectively with low risk of complication, including pneumothorax.<sup>2,11,26</sup> The use of a depth marker is recommended if a nongraduated needle is used to avoid pleural or pulmonary puncture. Fluoroscopy<sup>46</sup> and contrast chest radiography<sup>28,46,57</sup> are often used as supplementary methods to confirm the position of the needle or catheter. Contrast injected into the TPVS produces either a longitudinal or a cloud-like spread localized to the paravertebral region as depicted on frontal chest radiograph.<sup>57</sup> Radiologic images are not always readily identifiable,<sup>56</sup> and spread can vary in the same patient having repeated injections.<sup>46</sup>

A “pressure measurement technique” was recently advocated.<sup>56</sup> Pressure in the erector spinae muscle is higher during inspiration than during expiration.<sup>56</sup> Once the superior costotransverse ligament is traversed and the TPVS entered, there is a sudden lowering of pressure, and expiratory pressure then exceeds inspiratory pressure: “pressure inversion.”<sup>56</sup> These objective signs are described as an easy and reproducible method of locating the TPVS.<sup>56</sup> Negative pressure during both phases of respiration would indicate interpleural placement.<sup>58</sup>

A modification of the classical approach is the medial approach<sup>59</sup> in which the needle is inserted 1 cm from the midline and advanced perpendicularly to contact the lamina rather than the transverse process followed by lateral redirection to slip off the lamina into the TPVS.<sup>59,60</sup> Developed initially to avoid intrathecal injection by directing the needle away from the intervertebral foramen,<sup>59</sup> this approach has been associated with complications relating to dural puncture.<sup>60,61</sup> A recent variation of the medial approach is the “paravertebral-peridural block,”<sup>34</sup> in which the needle is inserted 3–4 cm

lateral to the midline and advanced at a 45° angle to the coronal plane with medial direction to contact the lamina. The needle is then redirected laterally by gradual increments in the angle of entry to the coronal plane until the needle is walked off the lamina into the TPVS.<sup>34</sup> Retrospective analyses using the paravertebral-peridural block technique report a high success rate and low incidence of complications.<sup>34</sup>

Thoracic paravertebral catheters can also be safely, accurately, and easily placed under direct vision during thoracic surgery from within the chest.<sup>21,22,62</sup> The original description by Sabanathan *et al.*<sup>62</sup> involves reflecting the parietal pleura from the posterior wound margin on to the vertebral bodies to create an extrapleural paravertebral pocket into which a percutaneously inserted catheter is placed against the angles of the exposed ribs. This method has been refined to ensure accurate placement of the catheter in the TPVS by tunneling the tip through a small defect created by the surgeon in the extrapleural fascia,<sup>63</sup> rather than laying it adjacent to the vertebral bodies.<sup>62</sup> The anatomy of the extrapleural fascia is not clear,<sup>63</sup> and the endothoracic fascia may have been referred to as the extrapleural fascia. This method, which requires an open chest, has been combined very effectively with preincisional percutaneous thoracic paravertebral injection to provide both intraoperative and postoperative analgesia after thoracic surgery.<sup>7,64</sup> Video-assisted placement of a paravertebral catheter under direct vision during thoracoscopic surgery has also been described.<sup>15</sup>

## Mechanism and Spread of Anesthesia

A thoracic paravertebral injection may remain localized to the level injected,<sup>65</sup> or it may spread to the contiguous levels above and below,<sup>37,42,45</sup> the intercostal space laterally,<sup>42,45,46</sup> the epidural space medially,<sup>31,45,46</sup> or a combination of the above to affect ipsilateral somatic<sup>1,2,5,48,66</sup> and sympathetic nerves,<sup>1,66</sup> including the posterior primary ramus<sup>3</sup> in multiple contiguous thoracic dermatomes. There are no published data that compare the effects of volume or dose of local anesthetic on the dermatomal distribution of TPVB. Eason and Wyatt<sup>3</sup> found that at least four intercostal spaces could be covered by a single 15-ml injection of 0.375% bupivacaine. More recently, 15 ml of bupivacaine 0.5% injected into the TPVS has been shown to produce mean unilateral somatic block over 5 (range, 1–9) dermatomes and sympathetic block over 8 (range, 6–10) dermatomes.<sup>1</sup> Similarly, 1.5 mg/kg bupivacaine 0.5% produced sensory loss at the level of injection with a mean superior spread of 1.4 (range, 0–4) dermatomes and a mean inferior spread of 2.8 (range, 0–7) dermatomes.<sup>48</sup> In children, 0.25 ml/kg (SD, 0.12) of contrast medium injected into the TPVS produces radiologic spread over 5.7 segments (SD, 1.6).<sup>57</sup> Thoracic paraverte-

**Table 1. Advantages of Thoracic Paravertebral Block**

| Technical  | Clinical  |
|--|---|
| Simple and easy to learn   | Single injection produces multidermatomal ipsilateral somatic and sympathetic nerve block |
| Safer and easier than thoracic epidural  | Reliably blocks the posterior primary ramus   |
| Palpation of rib not necessary and scapula does not interfere with block                 | Abolishes cortical responses to thoracic dermatomal stimulation                           |
| Safe to perform in sedated and ventilated patients                                       | Inhibits stress and pressor response to surgical stimuli                                  |
| Catheter placement under direct vision during thoracic surgery is safe and accurate      | Maintains hemodynamic stability   |
| Chest drain loss of local anesthetic is four times lower than that of interpleural block | Reduces opioid requirements   |
|  | Low incidence of complication   |
|  | Preserves bladder sensation   |
|  | Preserves lower limb motor power  |
|  | Promotes early mobilization   |
|  | No additional nursing vigilance required  |

bral anesthesia does not appear to be gravity-dependent, but there is a tendency for preferential caudal spread of somatic<sup>1,2,5,48</sup> and sympathetic blockade.<sup>1</sup>

There is controversy about epidural spread and its contribution to the extension of TPVB. Radioopaque contrast medium infused postoperatively through an extrapleural paravertebral catheter placed intraoperatively under direct vision remains confined to the paravertebral space.<sup>8,67</sup> In contrast, varying degrees of epidural spread has been shown to occur after 70% of percutaneous paravertebral injections,<sup>46</sup> which is mostly unilateral,<sup>46</sup> and the volume involved is considered too small to produce clinically significant epidural block.<sup>68</sup> Cadaveric dissection also confirms that only a small proportion of the injectate enters the epidural space<sup>42</sup> and remains confined to the side of injection. The vertebral attachment of the endothoracic fascia attenuates prevertebral spread<sup>36,40</sup> and may also influence epidural spread or mass movement of drug after an extrapleural paravertebral compartment injection. Clinically, sensory anesthesia is predominantly ipsilateral and greater after epidural spread than after only paravertebral spread.<sup>46</sup> Current evidence therefore suggests that ipsilateral epidural spread of discrete amounts of local anesthetic occurs after thoracic paravertebral injection, which contributes to the extension of a TPVB.

Bilateral symmetrical anesthesia<sup>11,46,69-72</sup> is described and may be caused by extensive epidural spread<sup>46</sup> or inadvertent intrathecal injection into the dural sleeve,<sup>61</sup> and may occur more commonly with the median injection technique<sup>59,61</sup> or the use of large volumes of injectate (> 25 ml)<sup>70</sup> Segmental contralateral anesthesia<sup>2,57</sup> adjacent to the site of injection occurs in 1.1% of paravertebral injections<sup>68</sup> and may be caused by either prevertebral spread<sup>34,37,57,73</sup> or epidural spread<sup>31,65</sup> to the contralateral TPVS. Bilateral sympathetic blockade may occur in the absence of bilateral sensory blockade<sup>34</sup> caused by prevertebral spread<sup>34,37,73</sup> to the contralateral sympathetic chain, which is more anteriorly placed in the TPVS and also more sensitive to local anesthetic agents. This may be one explanation for bilateral Horner syndrome reported after unilateral TPVB.<sup>46</sup> Ipsilateral

lumbar spinal nerves are also occasionally involved,<sup>1,48</sup> and this may be caused by an extended subendothoracic fascial spread to the retroperitoneal space (vide supra)<sup>49-51</sup> or epidural spread.

There are no published data comparing the distribution of anesthesia after a single-site *versus* a multiple-site percutaneous thoracic paravertebral injection. Current evidence suggests that a single-site injection of 0.375–0.5% bupivacaine, 15–20 ml or 0.3 ml/kg.<sup>1,3,72</sup> is as effective as a multiple-site injection of 0.5% bupivacaine, 3–4 ml per site,<sup>11,14,16,26</sup> in producing unilateral anesthesia over four to five thoracic dermatomes. The effect of increasing the volume of local anesthetic injected into a single site is not known but may predispose to bilateral sensory blockade.<sup>70</sup> Therefore, if a wide unilateral thoracic block (*i.e.*,  $\geq 5$  dermatomes) is desired, it may be preferable to inject at multiple contiguous sites<sup>11,14,26</sup> or at two separate sites several dermatomes apart.<sup>3</sup> This may be one of the reasons why TPVB is not commonly used.

## Indications

Thoracic paravertebral block offers several technical and clinical advantages (table 1) and is indicated for anesthesia and analgesia when the afferent pain input is predominantly unilateral from the chest and abdomen. Reported indications are listed in table 2. Bilateral TPVB has also been used perioperatively during thoracic,<sup>12,15</sup> major abdominal vascular,<sup>13</sup> and breast<sup>11,16</sup> surgeries.

## Contraindications

Infection at the site of needle insertion, empyema, allergy to local anesthetic drugs, and tumor occupying the TPVS are some of the few contraindications. A coagulopathy, bleeding disorder or therapeutic anticoagulation are considered as relative contraindications for TPVB.<sup>28</sup> One must exercise caution in patients with kyphoscoliosis and patients who have had previous thoracotomy. Chest deformity in the former may predispose

**Table 2. Reported Indications for Thoracic Paravertebral Block**

|   |
|---|
| Postoperative analgesia                                       |
| Thoracic surgery  |
| Breast surgery  |
| Cholecystectomy   |
| Renal and ureteric surgery                                    |
| Herniorrhaphy   |
| Appendectomy  |
| Video-assisted thoracoscopic surgery                          |
| Minimally invasive cardiac surgery                            |
| Surgical anesthesia   |
| Breast surgery  |
| Herniorrhaphy   |
| Chest wound exploration in a single lung transplant recipient |
| Acute postherpetic neuralgia                                  |
| Chronic pain management: benign and malignant neuralgia       |
| Miscellaneous   |
| Fractured ribs  |
| Therapeutic control of hyperhidrosis                          |
| Liver capsule pain after blunt abdominal trauma               |

to thecal or pleural puncture, whereas obliteration of the TPVS by scar tissue and adhesion of the lung to the chest wall<sup>74</sup> in the latter may predispose to pleural and pulmonary puncture. TPVB can be used in patients undergoing pleurectomy as long as the parietal pleura over the TPVS medial to the angle of the rib is left intact.<sup>15,75</sup>

### Drugs Used and Dosage

There are no published data that describe an optimal dose or concentration of local anesthetic for either single-shot injection or continuous thoracic paravertebral infusion. For a multiple level TPVB, 3–4 ml of bupivacaine 0.5%<sup>11,14,26</sup> or ropivacaine 0.5%<sup>25</sup> with epinephrine (2.5  $\mu\text{g}/\text{ml}$ ) is injected at each segment. On the other hand, for a single-level thoracic paravertebral injection and continuous thoracic paravertebral infusion, bupivacaine<sup>1,3,18,20,22,48,76–79</sup> and lidocaine<sup>8,52,80</sup> with or without epinephrine are used, and the commonly reported dosage schedules in adults and children are outlined in table 3.

### Pharmacokinetics

In adults, the commonly used bolus dose of 20 ml 0.5% bupivacaine results in a mean (SEM) maximum concentration of 1.45 (0.32)  $\mu\text{g}/\text{ml}$  in a median time of 25 min (range, 10–60 min).<sup>76</sup> Peak arterial plasma concentration and time to peak concentration were compared in 20 patients undergoing thoracotomy after bupivacaine 0.25% (1 mg/kg) with or without epinephrine (5  $\mu\text{g}/\text{ml}$ ).<sup>77</sup> The time to peak concentration was 5 min (range, 5–20 min) in both groups, and there were small differences in peak plasma concentrations that were not statistically significant.<sup>77</sup> After continuous infusion of bupivacaine 0.5% at 0.1 ml  $\cdot$  kg<sup>-1</sup>  $\cdot$  h<sup>-1</sup> for 120 h, there was a gradual

increase to a mean (SEM) peak total bupivacaine concentration of 4.92 (0.7)  $\mu\text{g}/\text{ml}$  at 48 h (range, 5–96 h), after which there was a small but insignificant decrease in concentration.<sup>76</sup> There were no clinical signs of toxicity, and bupivacaine levels as high as 7.48  $\mu\text{g}/\text{ml}$  were measured in one patient.<sup>76</sup> Other investigators have also reported progressive accumulation of bupivacaine in plasma during continuous thoracic paravertebral infusion without clinical signs of toxicity,<sup>78,79,81</sup> although bupivacaine levels have often exceeded the threshold for central nervous system toxicity (2–4.5  $\mu\text{g}/\text{ml}$ ).<sup>80</sup> This may account for the few reported cases of postoperative confusion that resolved after temporary cessation of the infusion.<sup>82</sup>

In children with a median age of 5.3 weeks, a loading dose of 1.25 mg/kg of bupivacaine 0.25% resulted in mean (SD) maximum serum bupivacaine concentration of 1.03 (0.56)  $\mu\text{g}/\text{ml}$  in a median time of 10 min (range, 10–60 min).<sup>22</sup> Lidocaine 1% with epinephrine (5  $\mu\text{g}/\text{ml}$ ) as a 0.5-ml/kg loading dose in children aged 1 month to 12 yr resulted in peak plasma concentrations ranging between 1.7 and 3.0  $\mu\text{g}/\text{ml}$  within 15–30 min after injection.<sup>52</sup> A continuous infusion of bupivacaine (0.25% at 0.5 mg  $\cdot$  kg<sup>-1</sup>  $\cdot$  h<sup>-1</sup>) in small infants resulted in a mean (SD) maximum serum bupivacaine concentration of 2.0 (0.63)  $\mu\text{g}/\text{ml}$  in 24 h with no clinical toxicity.<sup>22</sup> There was wide variation in bupivacaine concentrations (range, 0.80–3.14  $\mu\text{g}/\text{ml}$ ) between individual infants.<sup>22</sup> In a follow-up study of even smaller infants (median age, 1.5 weeks) given half the dose of bupivacaine (0.125%, 0.25 mg  $\cdot$  kg<sup>-1</sup>  $\cdot$  h<sup>-1</sup>) with epinephrine (2.5  $\mu\text{g}/\text{ml}$ ) as a continuous infusion, the mean (SD) serum bupivacaine concentration at 48 h was 1.60 (0.67)  $\mu\text{g}/\text{ml}$ , and no patient showed clinical signs of toxicity.<sup>20</sup> Bupivacaine concentration exceeded 3  $\mu\text{g}/\text{ml}$  in three patients at 30–48 h.<sup>20</sup> In the only report describing the pharmacokinetics of lidocaine 1% at 0.25 ml  $\cdot$  kg<sup>-1</sup>  $\cdot$  h<sup>-1</sup> for thoracic paravertebral infusion in children over a 10-h period, plasma concentration ranged from 2.1 to 3.2  $\mu\text{g}/\text{ml}$ .<sup>52</sup>

Although total bupivacaine level increases steadily during prolonged thoracic paravertebral infusion, free bupivacaine concentrations remain unchanged.<sup>79</sup> This may be a result of the increase in  $\alpha_1$ -acid glycoprotein concentrations postoperatively<sup>79,83</sup> offering protection against bupivacaine toxicity by increasing the binding of bupivacaine. There is also a greater increase in the *S*-bupivacaine enantiomer,<sup>76,81</sup> which is associated with lower toxicity than the *R*-bupivacaine enantiomer. Because of concerns of systemic accumulation and potential for toxicity with bupivacaine, various investigators have recently resorted to using lidocaine for prolonged thoracic paravertebral infusion in adults.<sup>8,80</sup> At the same infusion rate (0.1 ml  $\cdot$  kg<sup>-1</sup>  $\cdot$  h<sup>-1</sup>), lidocaine 1% produces analgesia after thoracotomy, which is superior to placebo<sup>8</sup> and equianalgesic to bupivacaine 0.25%<sup>8</sup> and 0.5%.<sup>80</sup>

Lidocaine, with a shorter elimination half-life and lower cardiotoxicity than bupivacaine,<sup>52</sup> may prove to be an attractive alternative.

### Failure Rate and Complications

Thoracic paravertebral block is technically easy to learn,<sup>10,11</sup> has a high success rate<sup>10,11,34</sup> regardless of the number of blocks performed,<sup>11</sup> and does not appear to be operator-dependent.<sup>11</sup> The failure rate varies from 6.8 to 10%,<sup>11,68,72</sup> which is comparable with that of other commonly used regional anesthetic techniques<sup>68</sup> and reflects the technical difficulty in accurately identifying the TPVS.

Based on published data, it is difficult to quote the true complication rate of TPVB, but it appears to be relatively low.<sup>10,11,34,68,84</sup> Richardson and Sabanathan estimated it to be 5%,<sup>84</sup> whereas Coveney *et al.*<sup>11</sup> retrospectively reviewed 156 consecutive cases of TPVB using the multiple-injection technique and noted that complications occurred in only four cases (2.6%). Lönnqvist *et al.*<sup>68</sup> prospectively evaluated complications after paravertebral (thoracic and lumbar) blocks in 367 patients (319 adults, 48 children) and observed the following frequency of complications: vascular puncture, 3.8%; hypotension, 4.6%; pleural puncture, 1.1%; and pneumothorax, 0.5%.

Inadvertent pleural puncture<sup>3,46,68</sup> is uncommon<sup>34,68</sup> and may<sup>11,34,60,68,85</sup> or may not<sup>46,68</sup> result in a pneumothorax, which is usually minor and managed conservatively.<sup>11,60,85</sup> If it does occur, pleural puncture can be converted to interpleural analgesia.<sup>18</sup> Clues that suggest pleural puncture are a definite pleural "pop" sensation,<sup>68</sup> irritating cough,<sup>46,60</sup> or sharp pain in the chest<sup>11,60</sup> or shoulder<sup>11</sup> during the procedure. Air is not aspirated<sup>46</sup> unless the lung is inadvertently punctured or air that may have entered the pleural cavity *via* the needle during removal of the stylet is aspirated. Such patients need to be closely monitored for the possible development of pneumothorax. Radiologically, interpleural injection (contrast) is seen to move with respiration,<sup>46</sup> does not define any specific anatomical plane,<sup>45</sup> rapidly disperses,<sup>45</sup> and spreads to the diaphragmatic angle or horizontal fissure.<sup>46</sup> A unique case of clicking pneumothorax is also described.<sup>85</sup> This clinical entity is seen most commonly with small left apical pneumothoraces and is characterized by the "Hamman sign," a clicking, bubbling, or crunching noise heard on auscultation near the apex of the heart in certain postures.<sup>85</sup> Pulmonary hemorrhage has been reported after percutaneous TPVB in a patient who had undergone previous thoracic surgery,<sup>74</sup> which highlights the need for caution in patients with altered paravertebral anatomy.

Hypotension is uncommon<sup>1,34,68</sup> after TPVB in normovolemic patients because of unilateral sympathetic

blockade,<sup>1,66</sup> but TPVB may unmask hypovolemia and result in hypotension. Interestingly, hypotension does not appear to be a problem even after bilateral TPVB.<sup>13,68</sup> Some patients develop hypotension as part of a vaso-vagal episode.<sup>86</sup> Transient seizure after inadvertent intravascular<sup>71</sup> and rapid supplementary<sup>68</sup> injection of plain bupivacaine highlights the need to use epinephrine-containing solutions, although this may rarely produce clinical signs of systemic epinephrine absorption.<sup>11</sup>

Dural puncture-related complications such as intrathecal injection,<sup>34,61</sup> spinal anesthesia,<sup>60</sup> and postural headache<sup>60</sup> appear to be exclusive to the medial approach to the TPVS<sup>34,60,61</sup> and are probably related to the closer proximity of the needle to the dural cuff and intervertebral foramen. Transient ipsilateral<sup>22,34,46,72</sup> or bilateral<sup>46</sup> Horner syndrome can also develop. The former is likely to be caused by spread of local anesthetic to the ipsilateral stellate ganglion or the preganglionic fibers originating from the first few segments of the thoracic spinal cord, whereas the latter may be caused by contralateral paravertebral spread *via* the prevertebral<sup>34,37,57</sup> or epidural<sup>31,65</sup> route. Ipsilateral sensory changes in the arm<sup>11,34</sup> may also develop as a result of spread of local anesthetic to the T1 component of the brachial plexus in the thorax or the C8 component where it originates between C7 and T1, although further spread to the brachial plexus in the neck cannot be excluded. Bilateral symmetrical anesthesia<sup>69</sup> and ipsilateral thoracolumbar anesthesia<sup>1,48,50</sup> can also occur as described above. Segmental thoracic pain that lasted for 3 months after the block may be a result of intercostal nerve trauma during catheter insertion.<sup>69</sup> Neurologic complications that have resulted in significant morbidity are myelopathy after paravertebral injection of efocaine (three cases)<sup>87</sup> and Brown Sequard paralysis after paravertebral alcohol injection (one case).<sup>88</sup> No fatality directly related to TPVB has been reported to date.

### Application of Thoracic Paravertebral Block

#### *Pain Relief after Thoracic Surgery*

Continuous thoracic paravertebral infusion of local anesthetic *via* a catheter placed under direct vision at thoracotomy is a safe, simple, and effective method of providing analgesia after thoracotomy.<sup>4,6-8,19,20,22,62,64,82,89-91,92</sup>

In children it has been used very effectively as the sole analgesic technique,<sup>19,20,22,23</sup> but in adults it is usually used in conjunction with adjunct medication (opioid or nonsteroidal antiinflammatory drugs) to provide optimal pain relief after thoracotomy.<sup>4,6,8,64,89</sup> Although supplementary analgesics are required, opioid requirements are significantly reduced.<sup>6,8,90</sup> A continuous thoracic paravertebral infusion of local anesthetic in conjunction with adjunct medications provides very effective pain relief with few side effects.<sup>7,8,64,82</sup> Pain relief is superior to placebo<sup>8,90</sup> and intravenous patient-controlled mor-

phine,<sup>6</sup> and is comparable to interpleural analgesia,<sup>4,89</sup> lumbar epidural morphine,<sup>82</sup> and thoracic epidural administration of bupivacaine<sup>5</sup> or a bupivacaine-fentanyl mixture.<sup>91,92</sup> Thoracic paravertebral analgesia preserves respiratory function better<sup>4,89</sup> and produces fewer side effects<sup>4</sup> than interpleural analgesia. Hypotension<sup>5</sup> and urinary retention<sup>5,91</sup> are also less frequent than with thoracic epidural analgesia. Continuous thoracic paravertebral infusion of local anesthetic provides better pain control after thoracotomy than an intermittent bolus regimen.<sup>93</sup> It reduces the postoperative decline in respiratory function,<sup>8,90</sup> augments the recovery of respiratory mechanics,<sup>90</sup> and reduces the generation of chronic postthoracotomy neuralgia.<sup>94</sup> A balanced analgesic regimen, which includes preoperative pain prophylaxis (opioid and nonsteroidal antiinflammatory drug premedication with preincisional TPVB) in conjunction with postoperative thoracic paravertebral infusion of bupivacaine, regular nonsteroidal antiinflammatory drug, and on-demand opioid, is very effective in patients undergoing thoracotomy.<sup>7,64</sup> It prevents the postoperative increase in plasma cortisol,<sup>7</sup> preserves preoperative respiratory function,<sup>7</sup> and is superior to a balanced analgesic regimen with thoracic epidural bupivacaine.<sup>64</sup>

#### *Pain Relief after Multiple Fractured Ribs*

Thoracic paravertebral block provides effective pain relief in patients with unilateral multiple fractured ribs<sup>2,3,37,66,95</sup> and has been used as repeated percutaneous injections,<sup>2</sup> regular top ups *via* an indwelling catheter,<sup>3,95</sup> or as a continuous infusion.<sup>66</sup> A single thoracic paravertebral injection of 25 ml (SD, 5) of bupivacaine 0.5% produces pain relief for a mean duration of 9.9 h (SD, 1.2).<sup>2</sup> It has also been shown to improve respiratory parameters and arterial blood gas tensions.<sup>2</sup> Used in a patient with associated head injury, TPVB circumvents the need for sedation and ventilation and allows continuous central neurologic assessment.<sup>73,95</sup> McKnight and Marshall<sup>66</sup> described ipsilateral flat nipple (monoplatythela) as an objective sign of a functioning TPVB in one such patient. In patients with associated lumbar spinal injury, the segmental thoracic nerve blockade spares the lumbar and sacral nerve roots, allowing regular peripheral neurologic assessment for signs of spinal cord compression.<sup>73</sup> There is a lack of comparative data, and TPVB has been overshadowed by epidural, interpleural, and intercostal nerve block for managing pain in patients with blunt chest trauma. Although no direct comparison can be made, TPVB offers technical and clinical advantages in patients with unilateral multiple fractured ribs and deserves more attention and investigation in the future.

#### *Anesthesia for Breast Surgery*

Thoracic paravertebral injection of local anesthetic at multiple levels (C7-T6)<sup>11,14,26</sup> or as a single injection at

T4<sup>72</sup> in conjunction with intraoperative sedation is safe and effective for surgical anesthesia in a majority of patients undergoing major breast surgery<sup>11,14,16,25,26,72</sup> and is associated with minimal complications<sup>11,26</sup> and a high degree of patient satisfaction.<sup>14</sup> Weltz *et al.*<sup>14</sup> reported that the block (4 ml, 0.5% bupivacaine with 1:400,000 epinephrine injected at each level, C7-T7) provides postoperative analgesia for an average of 23 h (range, 9-38 h). TPVB has significantly improved the quality of recovery after major breast surgery.<sup>11,16,72</sup> Compared with patients who undergo only general anesthesia, patients who receive TPVB have a shorter recovery time,<sup>72</sup> experience less postoperative pain,<sup>16,72</sup> require fewer analgesics,<sup>11,72</sup> and also have less painful restricted movement of the shoulder.<sup>72</sup> They also experience less postoperative nausea and vomiting,<sup>11,72</sup> tend to mobilize earlier,<sup>72</sup> and are discharged significantly earlier from hospital.<sup>11</sup> The use of TPVB in patients undergoing ambulatory breast cancer surgery has cost-saving potential.<sup>14</sup>

#### *Anesthesia for Inguinal Herniorrhaphy*

Paravertebral injection of local anesthetic at multiple thoracic and lumbar segments,<sup>24,96</sup> or as a single injection at T11 behind the endothoracic fascia,<sup>50,51</sup> produces ipsilateral thoracolumbar anesthesia effective for inguinal herniorrhaphy. Klein *et al.*<sup>96</sup> used multiple paravertebral injections at T10-L2 using 5 ml of bupivacaine 0.5% with epinephrine (2.5 µg/ml) at each level and produced surgical anesthesia with few side effects, which in conjunction with intraoperative sedation was adequate for inguinal herniorrhaphy. The block also provided long-lasting postoperative analgesia, and the time to first opioid requirement was 22 ± 18 h.<sup>96</sup> Wassef *et al.*<sup>24</sup> reported that paravertebral block of the ipsilateral T12-L2 nerve roots is more successful than field block for surgical anesthesia during inguinal herniorrhaphy. In addition, the paravertebral block not only required fewer needle insertions and total amount of local anesthetic than the field block, but was also devoid of side effects and was acceptable to the patients.<sup>24</sup> Saito *et al.*<sup>51</sup> described "extended unilateral anesthesia" for inguinal herniorrhaphy. In this variation of the paravertebral technique, the needle is inserted more laterally (5 cm from the midline), and loss of resistance is used to locate the space beneath the endothoracic fascia.<sup>51</sup> A single injection of 12 ml 2% mepivacaine posterior to the endothoracic fascia at T11 results in extended thoracolumbar anesthesia over an average of seven dermatomes, which was effective for herniorrhaphy in 60% of patients studied.<sup>51</sup> The efficacy of paravertebral block makes it a potential choice for outpatient inguinal herniorrhaphy and warrants further investigation.

**Table 3. Drug and Dosage for Thoracic Paravertebral Block**

| Age Group | Drug        | Concentration (%)        | Bolus Dose            | Infusion Rate (ml · kg <sup>-1</sup> · h <sup>-1</sup> ) |
|-----------|-------------|--------------------------|-----------------------|--|
| Adults    | Bupivacaine | 0.25–0.5                 | 15–20 ml or 0.3 ml/kg | 0.1  |
|           | Lidocaine   | 1                        | 15–20 ml              | 0.1  |
| Children  | Bupivacaine | 0.125–0.25 ± epinephrine | 0.5 ml/kg             | 0.2  |
|           | Lidocaine   | 1 + epinephrine          | 0.5 ml/kg             | 0.25   |

#### *Pain Relief after Cholecystectomy and Renal Surgery*

Data on the use of TPVB in patients undergoing cholecystectomy and renal surgery *via* a subcostal incision are limited, and the results are inconclusive. Giesecke *et al.*<sup>97</sup> reported that a single preincisional thoracic paravertebral injection of bupivacaine 0.5%, 20 ml before cholecystectomy, attenuates the stress response to surgical stimuli during isoflurane anesthesia and provides complete pain relief for 1–6 h. In contrast, Bigler *et al.*<sup>69</sup> reported that TPVB with 0.5% bupivacaine, a 15-ml bolus dose followed by an infusion of 5 ml/h postoperatively, is inadequate as the only analgesic after cholecystectomy, whereas a thoracic epidural infusion of bupivacaine 0.5% (5 ml/h) and morphine (0.2 mg/h) produced total pain relief. Pain scores were higher in the paravertebral group, as was the use of systemic morphine.<sup>69</sup> The author is unaware of any published data evaluating the analgesic efficacy of TPVB in adults undergoing renal surgery. In children, Lönnqvist and Olsson<sup>17</sup> retrospectively compared the analgesic efficacy of a continuous thoracic paravertebral infusion with that of lumbar epidural infusion of bupivacaine. They reported that the requirement for supplementary morphine was lower and the number of children with no need for supplementary morphine was higher in patients treated with a TPVB.<sup>17</sup>

#### *Chronic Pain Management*

Thoracic paravertebral block has been used to manage benign<sup>1,3,9,10,48,56</sup> and malignant<sup>3,55,59</sup> neuralgia involving the thoracic dermatomes, and long-term results have been more favorable in the former group of patients. Kirvelä and Antila<sup>10</sup> used a single thoracic paravertebral injection of bupivacaine 0.5%, 15–20 ml, to relieve chronic postoperative (postthoracotomy and postmastectomy) pain.<sup>10</sup> Initial results were good in 99% of blocks, but the long-term pain relief in the postthoracotomy group was better than in the postmastectomy group.<sup>10</sup> In the postthoracotomy group, pain relief lasted a month after 58%, at least 2 months after 30%, more than 4 months after 8%, and more than 5 months after 3% of blocks, as opposed to less than a month in 88% of blocks performed for chronic postmastectomy pain.<sup>10</sup> Ferrandiz *et al.*<sup>9</sup> also managed postthoracotomy pain syndrome using TPVB and achieved complete pain relief in 50% of patients who were pain free for a variable time after thoracotomy, which the investigators called “free

time,” as opposed to 33% of patients who had long-term postthoracotomy pain with no free time. Neurolytic TPVB, because of the high risk of neurologic damage, is limited to the management of intractable thoracic pain in cancer patients with poor prognosis, but preliminary results using 1–4 ml of 7% phenol per spinal segment has demonstrated limited long-term benefits.<sup>55</sup>

#### *Miscellaneous Applications*

Thoracic paravertebral block has been used in several other situations, including pain management after appendectomy,<sup>68,71</sup> video-assisted thoracoscopic surgery,<sup>15,98</sup> and minimally invasive cardiac surgery.<sup>99</sup> It has also been used to manage acute postherpetic neuralgia,<sup>85,100</sup> control liver capsule pain after blunt abdominal trauma,<sup>101</sup> control hyperhydrosis,<sup>28</sup> manage reflex sympathetic dystrophy of the chest,<sup>34</sup> relieve angina pectoris,<sup>88</sup> and explore a chest wound in a single lung transplant recipient.<sup>102</sup>

#### **Conclusions**

Thoracic paravertebral block is a technically simple, easy-to-learn technique with few contraindications and is associated with a low overall incidence of complications. TPVB produces unilateral somatic and sympathetic nerve blockade, which suppresses the neuroendocrine stress response to surgery and is adequate for surgical anesthesia in patients undergoing major breast surgery and inguinal herniorrhaphy. It has significantly improved the quality of recovery after major breast surgery. Continuous TPVB as part of a balanced analgesic regimen provides effective pain relief with very few side effects after thoracotomy, which is comparable to thoracic epidural analgesia—the gold standard—and should be considered a safe alternative. The same efficacy has not been demonstrated after cholecystectomy or renal surgery, but one may expect a significant opioid-sparing effect. A single thoracic paravertebral injection is also effective for pain control in patients with multiple fractured ribs and benign thoracic neuralgia. The role of bilateral thoracic paravertebral block is still to be defined. Based on published data, one can recommend that this simple yet highly versatile regional anesthetic–analgesic technique should be in the repertoire of every anesthesiologist and more widely applied.

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