Thoracic paravertebral block

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Paravertebral nerve block produces ipsilateral analgesia through injection of local anaesthetic alongside the vertebral column. It is advocated predominantly for unilateral surgery, for example, thoracotomy, chest wall trauma, breast surgery, cholecystectomy, herniorrhaphy or renal surgery, although it can be used as a bilateral technique. In chronic pain, it is used for the treatment of benign or malignant neuralgia. There is confusion over the indications for this block and it is apparent that much ignorance surrounds this subject. Its place alongside extradural, intercostal and interpleural analgesia requires elucidation. The aim of this review is to describe the anatomy, techniques, analgesia, side effects and complications of paravertebral nerve blocks so that a more considered use of this form of analgesia can be undertaken.

History of paravertebral blocks

A requirement for analgesia and abdominal muscle relaxation during surgery led Hugo Sellheim of Leipzig (1871–1936) in 1905 to perform the first paravertebral block. His aim was to find a replacement technique for spinal anaesthesia, devoid of its feared hazards of cardiovascular and respiratory collapse. A surgical resident in Leipzig, Arthur Läwen (1876–1958), made a special study of this new technique. Through the painstaking injection of small quantities of procaine at the emergence of each spinal nerve in many hundreds of patients with abdominal pain who subsequently underwent laparotomy or postmortem examination, Läwen (with others), mapped out the segmental innervation of the vertebral column. It is advocated predominantly for treating supraventricular tachycardias, bronchial asthma, aiding the passage of renal and gallbladder stones, and the management of pain from herpes zoster.

Its popularity reached a peak in the 1920s and 1930s following which, during the 1950s and 1960s, publications about this technique almost completely disappeared. In the late 1970s, at the same time as negative views were being expressed in textbooks, publications slowly started to reappear. The past decade has seen an upturn of interest and study.

Anatomy and mechanism of analgesia (figs. 1 and 2)

The paravertebral space is a wedge-shaped area sandwiched between the heads and necks of the ribs. The posterior boundary is the superior costotransverse ligament and laterally, the posterior intercostal membrane. Anteriorly is the parietal pleura, and the base of the triangle (medially) is the postero-lateral aspect of the vertebral, the intervertebral disc and the intervertebral foramen. The nervous contents of each paravertebral space are: the spinal (intercostal) nerve; its dorsal ramus; the rami communicantes; and, anteriorly, the sympathetic chain. The spinal nerve as it emerges from the intervertebral foramen is devoid of a fascial sheath and is often broken up into small nerve rootlets which are therefore easily penetrated by local anaesthetic. This area also contains some loose extrapleural fascia. There is no lateral limit; it is contiguous with the tissue plane between the intercostal muscles, that is, the intercostal space. The distribution of solutions injected into the paravertebral space have been observed in cadaver studies with resin and clinically with instillation of methylene blue at thoracotomy.

Solutions can: (1)
Thoracic paravertebral block

Techniques

The standard technique of space location is by loss of resistance to air or saline. The patient can be in the prone, lateral (usually with the side to be blocked uppermost) or sitting position. Two or three centimetres lateral to the spinous process, a short bevelled 8- or 10-cm spinal needle, or a Tuohy needle if a catheter is required, is advanced perpendicular to all skin planes. At approximately 2 to 5 cm in an adult, the transverse process is entered. Under fluoroscopy, the transverse process may be impossible to palpate. In previous thoracotomy patients, the thinnest part of the chest wall, parietal pleura has been traumatized. When the needle point is radiologically embedded, it should be noted that compared with extradural space injection of air or saline than extradural fat. There may therefore be a tendency to over-inject.

Thoracic paravertebral blocks are particularly advocated for unilateral surgical procedures, for example, thoracotomy, breast surgery, cholecystectomy and renal or ureteric surgery. It can also provide analgesia for rib trauma and herniorrhaphy. It has been used as a bilateral technique in thoracic surgery and major abdominal vascular surgery. In chronic pain management, it is used for the treatment of benign or malignant neuralgia.

Figure 1 Schematic thoracic spinal nerve. AD = anterior division, PD = posterior division, C = spinal cord, SG = spinal ganglion, RM = recurrent meningeal, SC = sympathetic chain, RC = rami communicantes, PC = posterior cutaneous, LC = lateral cutaneous AC = anterior cutaneous, P = pleura.
Either appearance leads to an adequate block. Either appearance leads to an adequate block. Pressure monitoring can be used as an alternative or supplementary technique. A transducer is connected to the end of a Tuohy needle via a three-way tap and a pressure waveform is displayed during needle advancement. In muscle, the pressure is greater on inspiration than expiration, either because the posterior spinal muscles are active during inspiration, or else that they are compressed by the expansion of the chest cage against the elastic confines of the skin. With advancement, there is a sudden lowering and inversion of pressures when the paravertebral space is reached, because of the transmission of subatmospheric intrapleural pressure on inspiration. Inadvertent puncture of the pleura is readily appreciated as both inspiratory and expiratory pressures become subatmospheric on quiet respiration. This objective technique improves sensitivity and specificity. The lateral distance from the spinous process to the paravertebral space and the depth of the skin to the paravertebral space have been found to correlate well with age, height, weight and body surface area in children and adolescents. 

Catheter techniques are straightforward but it should be noted that some manipulation of needle angulation may be necessary and greater force in feeding the catheter is needed compared with extradural catheterization. We do not recommend the insertion of more that 4 cm of catheter in an adult or 2–3 cm in children, as inadvertent lateral projection into an intercostal space may encourage just one dermatome analgesia (see below) (fig. 3).

Sabanathan described a method of catheterization for use in chest surgery. Before thoracotomy closure, the parietal pleura is then replaced and held in position by two sutures. Through the combination of direct vision and the preparation of a pocket for local anaesthetic, these modifications make for a very highly reliable technique, even in infants of a median age of 1.5 weeks (fig. 4). In thoracic surgery, these methods can be combined. A percutaneous bolus of bupivacaine given by the anaesthetist through the loss of resistance or pressure monitoring technique, provides analgesia for the intraoperative period. A catheter can be placed at the same time and methylene blue can be injected before chest closure to confirm or refute its successful position. If spread of dye is optimal, that is, over the heads and necks of the ribs above and below the injection for at least 4 dermatomes, it is left in situ. If spread is suboptimal it can be replaced by the surgeon before chest closure. The positioning of a catheter under direct vision has been described during thoracoscopy.

**Nursing surveillance**

No additional nursing skills or observations are necessary other than those required for the care of postoperative patients. An aseptic technique is required in changing an infusion syringe and an in-line bacterial filter is advocated.

**Drugs used**

Drugs used include bupivacaine, bupivacaine with epinephrine, bupivacaine with corticosteroid (personal experience) and lidocaine with epinephrine. The dose of local anaesthetic required involves a consideration of the number of dermatomes which it is
shown. A bolus dose of 0.5 ml kg\(^{-1}\) is given during chest closure to 0.5%, starting with a bolus dose of 15–20 ml, at least 10 min before skin incision. A further bolus of 0.5% bupivacaine 10 ml is given during chest closure and this is followed by an infusion of 0.5% bupivacaine for 2 days, after which the concentration is lowered to 0.25% for a further 3 days. Other authors agree that continuous infusion provides better analgesia than intermittent bolus doses.\(^{12}\)

**Pharmacokinetics**

The two local anaesthetic agents which have been studied are bupivacaine and lidocaine, both with and without epinephrine. The mean (SEM) maximum plasma concentration (Cmax) obtained with a bolus of 0.5% bupivacaine 20 ml is 1.45 (0.32) \(\mu\)g ml\(^{-1}\) with a median (range) time to Cmax (tCp max) of 25 (10–60) min. After the initial peak with the bolus injection, there is a gradual increase to a mean (SEM) peak concentration of 4.92 (0.7) \(\mu\)g ml\(^{-1}\) at 48 h (5–96).\(^{4}\) There were no symptoms or signs of toxicity in this study. Similar levels were found in a previous study using these methods, but additionally it was found that the total bupivacaine levels, there was a higher concentration of the S-enantiomer, of which there is evidence for less toxicity compared with the R-enantiomer.\(^{16}\)

Patients with a median age range of 5.3 weeks given a bolus followed by infusion of 0.25% bupivacaine for post-thoracotomy pain relief had satisfactory peak loading dose and infusion levels.\(^{34}\) In a subsequent study of even smaller infants, given 0.125% bupivacaine, satisfactory levels were again shown.\(^{15}\)

The preliminary results of a comparison of 0.25% bupivacaine compared with 0.25% bupivacaine with epinephrine 20 ml 1:200 000 given as a bolus dose of 1 mg kg\(^{-1}\) to thoracotomy patients, was reported by Snowden and colleagues.\(^{95}\) The Cmax ranged from 0.48–1.08 \(\mu\)g ml\(^{-1}\) (median 0.705) in the bupivacaine with epinephrine group, compared with 0.27–2.39 \(\mu\)g ml\(^{-1}\) (median 0.918) in the bupivacaine group. Although this difference was not statistically significant, the lowering of maximal plasma bupivacaine concentrations with epinephrine containing solutions has also been shown with intercostal nerve blocks\(^{42}\) and would seem logical. The median (range) tCp max was 5 min (5–20) for both groups.

We have measured plasma concentrations of lidocaine in children undergoing renal surgery.\(^{43}\) Patients were given a bolus of lidocaine 0.5 ml kg\(^{-1}\) (10 mg ml\(^{-1}\)) with epinephrine (5 \(\mu\)g ml\(^{-1}\)), followed by an infusion of 0.25 ml kg\(^{-1}\) h\(^{-1}\) of the same solution which was started 2 h after the initial bolus injection and continued for 10 h. Peak concentrations ranged between 1.7 and 3.0 \(\mu\)g ml\(^{-1}\) after the bolus with a tCp max of 15–30 min. Steady state levels of lidocaine were reached 8–10 h after the start of the infusion and ranged from 2.1–3.2 \(\mu\)g ml\(^{-1}\). These moderate levels were not associated with symptoms or signs of toxicity. We have been unable to find any clinical reports of severe central nervous system or cardiovascular system toxicity either because of excessive systemic local anaesthetic levels or profound sympathetic block.

**Efficacy**

Particularly when used as a method of providing unilateral analgesia for unilateral surgery, paravertebral blocks can provide high quality pain relief, as shown by low pain scores and an opioid sparing effect.\(^{3,11,60,72,75,83,85}\) Sufficient analgesia in some situations, particularly breast surgery, has obviated the need for general anaesthesia.\(^{30,78}\)

Pre-emptive paravertebral blocks before thoracotomy combined with continuous postoperative paravertebral blocks as part of a balanced perioperative technique has led to pain scores of less than 0.5 cm on a scale of 0–10 cm, with almost complete preservation of pulmonary function and with stress inhibition (as shown by glucose and cortisol estimation).\(^{75,80}\) Stress inhibition has also been shown after cholecystectomy,\(^{27}\) effects which cannot be demonstrated for these types of surgery with more central forms of afferent block.\(^{37,79,90}\) Post-thoracotomy pulmonary function has been studied and found to be better preserved with paravertebral blocks than with systemic opioids.\(^{3,83,85}\) Intraspinal bupivacaine\(^{76}\) or extradural bupivacaine.\(^{79}\) The ability to perform pulmonary function tests in the presence of a large chest wound is an objective measure of pain control. Postoperative pulmonary complications and hospital stays are reduced.\(^{37,83,86–88}\) as is the generation of chronic pain (post-thoracotomy neuralgia).\(^{77}\)

**Comparative studies**

**EXTRADURAL ANALGESA**

In comparing the analgesia which can be obtained with extradural compared with paravertebral blocks, Matthews and Govenden found that pain scores at rest after thoracotomy were similar with both techniques.
but the side effects of postural hypotension and urinary retention were significant problems only with extradural analgesia. We have compared extradural morphine and paravertebral bupivacaine after thoracotomy and found similar results; pain relief was similar but troublesome side effects, especially urinary retention, accompanied extradural analgesia. We have also studied extradural bupivacaine compared with paravertebral bupivacaine for perioperative thoracotomy pain management. Pain relief was the same, but opioid requirements were less in the paravertebral group, with consequently less opioid related side effects. Pulmonary function was significantly better in the paravertebral group and stress responses, as measured by cortisol and glucose assay, were suppressed in the paravertebral group, but not in the extradural group.

In a retrospective comparison of the analgesia obtained by extradural blocks compared with paravertebral blocks in children undergoing renal surgery, we found the need for supplemental morphine administration was significantly lower in the paravertebral group and the number of patients requiring no supplemental morphine was significantly higher in the paravertebral group.

In contrast with these studies that have favoured paravertebral techniques, must be set two other investigations that have shown equivocal results. Pertunen and colleagues carried out a comparison of extradural, paravertebral and intercostal blocks for post-thoracotomy pain. Similar levels of pain, opioid requirements, pulmonary function and adverse effects were found in all groups. Bigler and colleagues compared extradural bupivacaine and morphine with paravertebral bupivacaine in postcholecystectomy patients. Both groups were given boluses preoperatively followed by the same drugs by infusion postoperatively. Pain scores were significantly better in the extradural group compared with the paravertebral group. There was no difference in their effects on pulmonary function.

In conclusion, both techniques lead to high quality pain relief which can be associated with good preservation of postoperative pulmonary function. Stress modification has been shown with paravertebral blocks. The choice of an optimal regional technique probably comes down to other factors such as contraindications, side effects and possible complications (see below).

**INTERCOSTAL BLOCKS**

These blocks are done by injecting local anaesthetic into the same tissue plane as for a paravertebral injection, but usually approximately 8 cm from the midline. This single difference makes for very dissimilar effects:

1. **Multiple level spread** is discouraged. Johansson, carefully studying healthy volunteers found that 0.5% bupivacaine 20 ml deposited 8 cm from the midline (that is, intercostally) blocked just one level.

2. **Catheter techniques** are cumbersome and unreliable: the use of up to 4 catheters at any one time has been described. Repeated intercostal nerve blocks are therefore required which are painful, time consuming and compound the risks of a pneumothorax.

(3) In this relatively distal position along the length of the intercostal nerve, it could not be expected that the sympathetic chain, the rami communicantes or the dorsal ramus are reliably blocked. Studies on the use of intercostal nerve blocks for pain after postero-lateral thoracotomy have reported unrelieved back pain (caused by damaged costotransverse and costovertebral structures), or unrelieved shoulder pain probably because of failure to block these structures.

(4) The complications of pleural or pulmonary damage would be expected to be greater than with paravertebral blocks, because of the relative shallowness of the intercostal space distally compared with its triangular shape alongside the vertebral column (paravertebrally). Comparisons are difficult but the incidence of pneumothorax after intercostal block has been reported to range from 0.073% to 19%, compared with approximately 0.5% with paravertebral blockade.

Having made these observations, we are aware of only one direct comparison, that of Pertunen and colleagues. They compared extradural, paravertebral and intercostal blocks for post-thoracotomy pain in 45 patients divided into three groups and found similar levels of pain, opioid requirements, pulmonary function and adverse effects.

**INTRAPLEURAL ANALGESIA**

Intrapleural analgesia arises as a result of injection of local anaesthetic between the pleurae (compared with outside the parietal pleura with paravertebral analgesia). Almost all studies have shown a lowering of pain scores and opioid requirements. More objective measures such as the study of postoperative pulmonary function have not conclusively shown any improvement with intrapleural blocks. In a prospective randomized comparison of post-thoracotomy pain managed with paravertebral or intrapleural analgesia involving 53 patients, we found that pain scores were the same but pulmonary function was significantly worse with intrapleural blocks. We questioned whether respiratory muscle function was being actively impaired by gravity-dependent pooling of local anaesthetic on the diaphragm as we routinely nurse our postoperative patients in the sitting position. Bupivacaine after intrapleural administration is known to be avidly taken up by the diaphragm. Dependent chest drain losses of local anaesthetic, which can be approximately 30% to 40% with intrapleural blocks, are much less with paravertebral infusion. For this reason we have questioned the continued use of intrapleural analgesia for post-thoracotomy pain relief.

Intrapleural analgesia is known to be positional and it is generally recommended that patients are nursed supine, temporarily after bolusing, or continuously in the case of infusions. We challenge the wisdom of this approach to postoperative care as it would mitigate against maintenance of functional residual capacity and accelerated mobilisation regimes. Paravertebral administration does not radiologically or clinically respond as if it is gravity dependent. Qualitative differences also separate these techniques. Lack of block of the posterior
ramus of the intercostal nerve with intrapleural analgesia means that after thoracotomy, patients can suffer from pain from the proximal wound edge and from damaged vertebral muscles and ligaments. In clinical settings other than after thoracotomy, it does not appear that these two techniques have been directly compared.

The risk of pleural or pulmonary damage with intrapleural blocks is greater than with paravertebral techniques as pleural penetration is necessary for intrapleural catheterization. An accurate incidence of pneumothorax is difficult to determine as it depends upon efficient reporting of this complication. In retrospective literature reviews, there was a 2% incidence of pneumothorax with intrapleural blocks compared with a 0.5% incidence with paravertebral blocks. A prospective, multiple-centre study agreed with the latter figure.

**Contraindications**

Paravertebral blocks have a low potential for neurological damage. Except in the case of inadvertent extradural or intrathecal entry, or the use of proteolytic agents, damage to nervous structures other than peripheral (spinal or intercostal) nerves has not (to our knowledge) occurred. Paravertebral blocks can be safely performed in anaesthetized patients. Because of the low potential for neurological damage, the presence of a coagulation disorder or the use of anticoagulants are relative rather than absolute contraindications: the neurological consequences of a paravertebral haematoma are probably small, especially if compared with an extradural haematoma. In a number of patients undergoing major lung or oesophageal resection who have been fully anticoagulated, we have successfully used paravertebral analgesia. Venous puncture has been recorded in one patient which required no specific treatment.

Local sepsis at the proposed site is a contraindication, as is sepsis in the chest cavity, for example, an empyema. Pus between the pleurae should not theoretically be disturbed by paravertebral cannulation but the accompanying acidosis would be expected to adversely affect local anaesthetic ionization (and hence nerve penetration) and any accompanying hyperaemia would encourage its systemic absorption. Occupation of the paravertebral space by tumour is also a contraindication although a chest wall tumour lateral to the paravertebral space is not. Care is needed in the case of severe chest deformity or scoliosis to avoid injection into the meninges or pleura.

A planned pleurectomy is not a contraindication. As long as the parietal pleura covering the vertebral bodies and a few centimetres distally is left intact, catheterization and a satisfactory block can be achieved.

**Side effects and complications**

Paravertebral blocks generally have a low incidence of adverse effects. In retrospectively reviewing this subject, we estimated that the overall incidence of side effects or complications was less than 5%. In a multiple-centred, prospective study of 367 paediatric and adult patients, we found an overall failure rate of 10.1%. The frequency of complications was: hypotension 4.6%; vascular puncture 3.8%; pleural puncture 1.1%; and pneumothorax 0.5%.

Neurological or haemodynamic complications from accidental extradural or intrathecal entry have not been associated with any long-term morbidity or mortality, even after total spinal anaesthesia. Three patients (out of 206 injections) in one of these studies developed postural headaches indicating that meningeal trauma had probably occurred. The most serious complication ever reported was a Brown Séguard paralysis which followed the use of paravertebral alcohol for the treatment of angina pectoris in 1931. At that time, this frequently used destructive treatment would not have involved radiological screening.

Accidental extradural injection is a rare event which indicates a faulty technique. Extradural spread of local anaesthetic can occur but it is not known whether or not this event contributes to the block. Occasionally a 1 or 2 dermatome contralateral block occurs but only rarely is a fully bilateral block observed. It is possible that injection inferior to the transverse process, directly adjacent to an intervertebral foramen, encourages this phenomenon.

A unilateral Horner’s syndrome means spread up to the cervical region has occurred. It is not itself a cause for concern, although the patient will need reassurance. The unique case of a bilateral Horner’s syndrome is disconcerting. The actual spinal level of injection was not stated. Anterior vertebral spread of solution may have occurred, or else, there may have been some cross-over of sympathetic fibres. A bilateral block, if it is associated with a bilateral phrenic nerve or recurrent laryngeal nerve block, would be dangerous. However, there are no data as to whether a posterior approach to the stellate ganglion (via a paravertebral injection) is more or less hazardous in this respect than the more frequently used anterior approach.

Segmental thoracic pain has been observed in one patient after cholecystectomy and caused chronic pain for three months, the likely cause being intercostal nerve trauma. This event is probably quite common, but a surgical incision within the same or an adjacent dermatome with its associated acute and possibly chronic pain makes the diagnosis of needle or catheter intercostal nerve damage difficult. Urinary retention is not a problem, either from our experience or from published studies.

The haemodynamic consequences of a correctly placed bolus of local anaesthetic in a normally hydrated patient are minimal. A study of thoracic paravertebral blocks using 0.5% bupivacaine 15 ml produced a mean unilateral sympathetic block of 8 dermatomes but without any significant change between supine and sitting arterial pressures. The occurrence of hypotension in 4.6% of (mainly) perioperative blocks (see above) may be multifactorial, with unmasking of relative hypovolaemia by unilateral vasodilatation.

**Discussion**

We believe that paravertebral blocks are effective and safe, although this may not be the commonly accepted view in the anaesthetic literature. We are
unable to explain this difference of interpretation, but counsel that descriptions of paravertebral blocks as “ineffective and hazardous,” 2,22 or lack of descriptions of the technique in textbooks19 should no longer be allowed to suppress interest and research in this technique. At the beginning of this century, it was thought that more central forms of afferent block were not completely effective and had life-threatening complications. This situation may not Have substantially changed.1,8,9,21,65,68,90 No ideal regional anaesthetic block exists; all must be carefully compared. Paravertebral blocks are relatively easy to learn, they have few contraindications and require no additional nursing surveillance. They are applicable to large numbers of patients and, because of their low side-effect profile (especially hypotension), they contribute to accelerated postoperative mobilization regimens. “Is it (yet) time for revivification of paravertebral blocks?”69

Acknowledgement
We dedicate this review to the memory of the surgeon, Emeritus Hunterian Professor Sabarathan Sabanathan. A great proponent of paravertebral nerve blocks, a great scientist and a great friend.

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