Ultrasound guided paravertebral catheter placement and potential future improvements  
A case report for advanced training in pain medicine

Abstract

A patient suffering with traumatic injuries including multiple rib fractures was excessively narcotized potentially impeding her recovery. A continuous infusion of local anaesthetic into the paravertebral space provided some opioid sparing effect, although the analgesic effect was less clear. The catheter was placed into the paravertebral space using a through-needle technique with ultrasound guidance.

A discussion of the anatomical issues, including the endothoracic fascia is undertaken. Features of ultrasound imaging, needle guidance and catheter location are discussed. Potential improvements to the technique of ultrasound-guided catheter placement are suggested, including speculative technological innovations that have yet to be fully evaluated but which may be of relevance. These include alternative ultrasound transducers, in-plane and out-of-plane needle approaches, modern highly echogenic needles, stimulating and coiling catheters, pressure transduction, 4D ultrasound and needle tracking sensors.

Case Presentation

Presenting Complaint

A 74-year-old lady fell down stairs, suffering multiple fractures of the right-sided ribs as well as a sub-arachnoid haemorrhage and extensive bruising. Initial management was undertaken in the critical care unit. She was suffering with an acute confusional state because of the sub-arachnoid haemorrhage and was thus unable to give pain scores
but appeared to be in severe pain, particularly during turning to enable chest
physiotherapy. She was given a continuous infusion of morphine for pain management.
This provided inadequate analgesia to allow deep breathing, but her consciousness was
further significantly impaired, such that she was unresponsive, except to painful
stimulus, and otherwise lay with stertorous breathing. Because of this her cervical spine
could not be confirmed to be free of ligamentous injury, though CT of the neck
confirmed no bony injury.

The acute pain team was consulted to consider providing regional anaesthesia for
the chest with a view to producing analgesia while reducing opioid requirement thus
improving respiratory function, neurological function and allowing clinical examination
of the neck.

**Past Medical History**

The patient was obese, with type two diabetes mellitus and hypertension. She also
suffered with chronic atrial fibrillation, for which she was taking warfarin. On admission
to hospital she had received vitamin K and Octaplex and the INR had been confirmed to
fall to 1.1.

**Examination**

The patient was lying supine with a rigid cervical collar, breathing 40% oxygen via a
Hudson mask, with an intravenous infusion of morphine at 1.5 mg per hour. There was
sinus bradycardia and hypertension. The chest was clear but quiet with obvious
bruising over the right side. The respiratory rate was 9 per minute and the oxygen
saturation was 97%. At rest, the patient had loud stertorous breathing and was roused
only by painful stimulus. Glasgow Coma Score (GCS) was 9. The pupils were 2mm in
diameter and equal. Light pressure on the right chest produced obvious discomfort, but
the patient was unable to speak any coherent words or make any concerted effort at
deep breathing.
Management

It was considered important to provide an opioid sparing technique to encourage neurorecovery and clinical examination of the neck. After consultation with ITU colleagues it was agreed that it was in the patients best interests to place a paravertebral catheter into the right paravertebral space to infuse local anaesthetic. She would not be able to consent to this treatment and there was no prospect of her becoming able to consent within a reasonable time frame, so the procedure was undertaken on a ‘best interests’ basis, having discussed the situation with the relatives. She was placed in the left lateral position with staff maintaining in-line immobilization throughout the procedure.

A SonoSite (SonoSite Ltd, Hitchin, Hertfordshire, UK) S-Nerve machine with a 13-6 MHz linear array transducer was used to visualize the right paravertebral space in both axial and parasagittal planes. The space between the transverse processes of the 6th and 7th thoracic vertebrae was selected and an 18G Touhy needle was inserted in-plane to the beam in the parasagittal plane to deliberately contact the superior edge of the 7th thoracic transverse process, similar to the view in figure 1. This was at a depth of 4.5cm to the skin. The needle was ‘walked off’ the superior edge of the transverse process under direct vision and advanced in an antero-cephalad direction until the costo-transverse ligament was seen to be pierced a further 2 cm beyond the transverse process. This was still within the field of view. 10ml of 0.125% bupivicaine was infused in aliquots after negative aspiration test and the hypoechoic area was observed to expand and displace the pleura anteriorly. A Portex (Smiths Medical UK, Ashford, Kent, UK) epidural catheter was inserted through the needle and advanced 3 cm beyond the needle tip. The same test dose of 10ml was undertaken through the catheter, observing the same result. The catheter was dressed to keep it in place and labeled clearly as a paravertebral catheter. The patient was returned safely to the supine position.
The catheter was attached to a dedicated peripheral nerve block infusion device programmed to deliver 5ml.hr\(^{-1}\) of 0.125% bupivacaine continuously. The patient was observed for potential effects of epidural infusion, which were not found. After several hours the morphine infusion was stopped. Over the next 24 hours the patient was noted to become considerably more responsive, with GCS score increasing to 12, although the pain score did not appear to change. The respiratory rate increased to 17 min\(^{-1}\), the oxygen requirement fell to 28% and pupils increased in size to 4mm. The rate of infusion of bupivacaine was increased to 10ml.hr\(^{-1}\) with some further improvement.

Unfortunately, three days later the patient developed pneumonia and the respiratory function deteriorated, requiring mechanical ventilation.

**Discussion**

In this case the placement of a paravertebral catheter and infusion of local anaesthetic produced an important opioid sparing effect for the patient, but the observed effect on actual pain scores was small. This did not prevent the deterioration of the patient. It may have been possible to place more than one catheter. This would have necessitated further time in the lateral position with a potentially unstable cervical spine, and further needle punctures in a patient with recently corrected warfarinisation. On balance this was felt not to be the best course. The placement of the catheter with ultrasound visualization provided an important benefit in that it is recommended that the needle is only advanced a maximum of 1-2cm beyond the transverse process with the loss of resistance technique.\(^{(1)}\) In this case this may not have been sufficient to puncture the costo-transverse ligament, resulting in failure of catheter placement.

**Anatomical considerations**

The somatic nerves, which were the target of this infusion, are found posterior to the endothoraic fascia.\(^{(2)}\) Questions have been raised even as to the existence of the fascia, but a recent paper found it to be consistently present in rats.\(^{(3)}\) There is no clear
method of identifying the fascia in vivo,(4) and the possibility of producing specific patterns of block (for example a selective somatic or autonomic block) is uncertain. It is not certain whether or not the endothoracic fascia was punctured, as it was not visualized in this patient. One possibility in this case is that the needle and catheter may have been placed anterior to the endothoracic fascia and produced a less effective somatic block because of this. Using an oblique parasagittal in-plane technique on cadavers accurately located the needle tip in the paravertebral space in a study by Luyet et al.(5) However, correct spread of contrast was only achieved in half (11 of 20) of the cases, suggesting that anaesthetic spread may be intrinsically unpredictable. A more recent paper by the same authors in anaesthetized patients using the landmark technique found that only 70% (21/30) of catheters could be fluoroscopically confirmed in the paravertebral space immediately after insertion.(6) Further, of those that were correctly located, only 81% (17/21) actually provided good analgesia. It is also important to note that of those patients whose catheter was not within the paravertebral space as defined fluoroscopically, two thirds (6/9) still received good analgesia, suggesting that the correlation between accurate anatomic location and analgesic effect is not high.

**Confirming catheter location in paravertebral space**

In this case a pure ultrasound image based method relying on hydrolocation (the injection of small amounts of liquid is observed to confirm location) was used. Other techniques for locating the paravertebral space that have been used include loss of resistance,(7) direct vision during surgery, and pressure inversion.(8) Loss of resistance is said to be difficult to detect in this situation in comparison with the epidural technique. It would also be difficult to undertake while holding an ultrasound transducer and manipulating the needle, although a combined ultrasound and loss of resistance technique is described.(9) The pressure inversion technique involves using a pressure-transducing device attached to a liquid filled tubing to display pressure on a
monitor. The monitoring equipment is widely available in ITU and specific needle sets (e.g. Contiplex needle with side port adapter, B Braun) might provide a way of connecting the pressure transducer to a needle. This might produce a further improvement in accuracy of location of the needle and catheter.

A variety of orientations of the transducer and needle have been described, including axial and parasagittal and oblique image planes with in-plane and out-of-plane needle direction. A commonly described technique is the axial view with in-plane lateral to medial needle direction.(10) A concern with this technique is the passage of the needle/catheter or infused anaesthetic through the intervertebral foramen into the epidural space. Epidural spread of contrast was confirmed in one case of this study.(10)

**Ultrasound transducer and needle visualisation**

The choice of linear array 13-6MHz ultrasound transducer was governed by availability in this case. While satisfactory images were obtained the depth of the pleura from the skin was close to the maximum depth penetration capability of the transducer and the field of view only allowed one transverse process to be viewed at a time in the parasagittal plane. A lower frequency transducer would have allowed more depth penetration at the expense of some resolution. These transducers are more commonly curvilinear arrays, which have a wider field of view. Griffin and Nichols recommend both types of array for thoracic paravertebral imaging.(11)

The echogenicity of a needle is related to its angle relative to the beam of ultrasound. A needle perpendicular to the beam produces the highest echogenicity. Specific needles designed to have high ultrasound echogenicity are available. These have been shown to improve visualisation of the needle and tip during in plane approaches, particularly at steep angles.(12) Another way to improve echogenicity is to change the relationship between the beam and the needle. In some procedures the needle can be oriented by changing the skin entry point to achieve improved visibility while still approaching the
same target, in others the transducer can be reoriented to achieve a shallower angle, such as with the ‘heel-in’ manoeuvre.(13) Another possibility is beam steering, in which the direction of the beams relative to the transducer head are weighted to give emphasis to the elements perpendicular to the needle, such as is available with the SonoMB Multi-beam Imaging software. Curvilinear arrays have the advantage of having a wide field of view that diverges away from the transducer array. This has the effect of making steeper needle angles effectively closer to perpendicular to the edge of the beam, which might have been useful in this case, where the needle cannot be reoriented because of the constraint of having to pass between two transverse processes. However, Gray suggests that needle visibility may be worse with curvilinear arrays.(14) Preliminary laboratory tests have shown that very small sensors can be fitted to needles that can be used to track their location and overlay it in real time on the ultrasound image.(15)

Unfortunately correct needle tip localisation does not guarantee correct catheter placement, as demonstrated by Luyet et al.(5) Catheters cannot be reliably steered and visualization is difficult. They are much less echogenic than needles, and in this case the catheter position could only be inferred by the spread of local anaesthetic injected through it. A recent editorial describes the difficulties with catheter location under ultrasound guidance.(16) One possible development that may improve this is 4D ultrasound: three dimensional imaging in real time. A bench study on a phantom has shown good catheter placement.(17) Another possible area for innovation may be in the catheter itself. Catheters that have an embedded electrode are available, so that the catheter itself can be used to produce electrical nerve stimulation to confirm proximity to the nerve. This technique resulted in some differences in a small volunteer study of femoral nerve block.(18) A coiling catheter has been shown to remain close to the sciatic nerve(19) and within the paravertebral space(20) in cadavers, and a comparative trial of coiling against conventional catheters in the femoral nerve is under way.(21)
Conclusions

In this case the use of paravertebral local anaesthetic infusion provided important opioid sparing for the patient, but the effectiveness of the infusion was not as good as might have been hoped for. This seems broadly in keeping with the balance of evidence that paravertebral needle location can be accurately achieved but catheter location is much less predictable and that anaesthetic spread is also unpredictable. These combine to produce a failure rate of up to 25% for the infusion technique overall.(22) There is no certainty any technique would result in systematic improvement in reliability since the procedure may be inherently unpredictable given our inability to delineate the importance of the endothoracic fascia, image it, or consistently to locate a catheter in relation to it. There are several techniques described suggesting that there is no consensus on a single best method of approaching the paravertebral space. The technique used was an ultrasound guided one using a parasagittal view with a linear array transducer and in-plane needle advancement combined with depth ascertainment by deliberate contact with the transverse process. The technique used here could possibly be refined in future by a curvilinear ultrasound transducer, or steerable beam, a high echogenicity needle and pressure transduction to add information about entry to the paravertebral space. There is limited evidence to support the use of stimulating and coiling catheters. Other more speculative future developments that may be helpful include 4D ultrasound and real time needle tracking sensor technologies.

Figures

Figure 1. Ultrasound image obtained with transducer in parasagittal position showing 4th and 5th thoracic vertebral transverse processes (2). Arrow 1 shows direction of needle and asterisk the target point for the needle. Reproduced from Vogt.(23)
References


8. Richardson J, Cheema SP, Hawkins J, Sabanathan S. Thoracic paravertebral space location. A new method using pressure measurement. Anaesthesia [Internet].


18. Salinas F, Neal J, Sueda L, Kopacz D, Liu S. Prospective comparison of continuous femoral nerve block with nonstimulating catheter placement versus stimulating catheter-guided perineural placement in volunteers. Regional Anesthesia and


