The analgesic efficacy of pre-operative bilateral erector spinae plane (ESP) blocks in patients having ventral hernia repair

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Summary
Laparoscopic ventral hernia repair is an operation associated with significant postoperative pain, and regional anaesthetic techniques are of potential benefit. The erector spinae plane (ESP) block performed at the level of the T5 transverse process has recently been described for thoracic surgery, and we hypothesised that performing the ESP block at a lower vertebral level would provide effective abdominal analgesia. We performed pre-operative bilateral ESP blocks with 20–30 ml ropivacaine 0.5% at the level of the T7 transverse process in four patients undergoing laparoscopic ventral hernia repair. Median (range) 24-h opioid consumption was 18.7 mg (0.0–43.0 mg) oral morphine. The highest and lowest median (range) pain scores in the first 24 h were 3.5 (3.0–5.0) and 2.5 (0.0–3.0) on an 11-point numerical rating scale. We also performed the block in a fresh cadaver and assessed the extent of injectate spread using computerised tomography. There was radiographic evidence of spread extending cranially to the upper thoracic levels and caudally as far as the L2–L3 transverse processes. We conclude that the ESP block is a promising regional anaesthetic technique for laparoscopic ventral hernia repair and other abdominal surgery when performed at the level of the T7 transverse process. Its advantages are the ability to block both supra-umbilical and infra-umbilical dermatomes with a single-level injection and its relative simplicity.

Introduction
Ventral hernia repair is the second-most-common hernia surgery performed after inguinal hernia repair [1]. Laparoscopic repair techniques utilising a mesh have become increasingly popular, having been shown to result in better patient outcomes, including fewer recurrences, a lower complication rate and a shorter hospital stay compared with open repair [2–5]. However, the intensity of acute postoperative pain is similar between open and laparoscopic ventral hernia repair [2, 5–7], and is attributed to the transabdominal sutures and helical tacks that are used to hold the mesh in place against the inner aspect of the abdominal wall. The pain is severe enough that patients usually require significant amounts of intravenous opioids in the first 24 h and a hospital stay of 1–2 days [4–6].
Regional anaesthetic techniques would seem a logical choice for improving acute pain management in these patients, but there are relatively few published reports in the literature. The ultrasound-guided erector spinae plane (ESP) block at the T5 transverse process is a recently-described technique for providing thoracic analgesia [8]. In that study, we demonstrated injectate spread in the ESP as far caudad as the T8 transverse process in fresh cadavers, which correlated with the observed pattern of analgesia and sensory loss in actual patients. Based on its mechanism of action, we hypothesised that, if performed at a lower vertebral level, it would provide effective truncal analgesia for abdominal surgery. Here, we describe our experience with the ultrasound-guided ESP block performed at the T7 transverse process in a pilot study of four patients undergoing laparoscopic ventral hernia repair, together with radiological data from injection in a fresh cadaver.

Methods

The data reported in this study were collected between 14 June and 11 August 2016. All patients provided written informed consent. The Institutional Review Board of Ethics of Penn State Hershey College of Medicine, Pennsylvania, USA approved the cadaver study. Bilateral ultrasound-guided ESP blocks were performed pre-operatively in all patients by one of two study authors (KC or SA). Each patient was placed in the sitting position, given supplementary oxygen and intravenous midazolam and fentanyl, and monitored with three-lead ECG, non-invasive blood pressure and pulse oximetry. The T7 spinous process was located by palpating and counting down from the C7 spinous process. A high-frequency linear array ultrasound probe was then placed in a transverse orientation at this level to identify the tip of the T7 transverse process (Fig. 1). The tip of the transverse process was centred on the ultrasound screen and the probe was then rotated into a longitudinal orientation to produce a parasagittal view, in which the following layers were visible superficial to the acoustic shadows of the transverse processes: skin and subcutaneous tissue; trapezius; and erector spinae muscle (Fig. 2). The rhomboid major muscle has its lower border at the T5–6 vertebral level and its absence was used as additional confirmation that the T7 transverse process was being viewed. Following local anaesthetic infiltration of the superficial tissues, an echogenic 22-G block needle (Pajunk Sonoplex, Geisingen, Germany) was inserted in-plane to the ultrasound beam in a cranial-to-caudal direction until contact was made with the T7 transverse process. Correct location of the needle tip in the fascial plane deep to erector spinae muscle was confirmed by injecting 0.5–1 ml saline and seeing the fluid lifting the erector spinae muscle off the transverse process while not distending the muscle (Fig. 3). A total of 20–30 ml ropivacaine 0.5% was then injected into the ESP. The procedure was repeated on the contralateral side. Surgical technique and postoperative care followed standard local clinical practice.

Pain scores at rest and on movement were measured on an 11-point numeric rating scale (NRS) where 0 was no pain and 10 the worst pain imaginable. Opioid consumption was calculated as oral morphine equivalents (OME) for ease of comparison, using an opioid conversion ratio of 20:1 for intravenous hydromorphone, 4:1 for oral hydromorphone [9] and 1.5:1 oral oxycodone [10]. Pain scores and opioid consumption data were collected and recorded by nursing staff who were not involved in the study.

Cadaveric investigation

Bilateral ultrasound-guided ESP blocks were performed at the T7 level in a single fresh human cadaver in the Multidisciplinary Laboratory of Penn State College of Medicine, Milton S. Hershey Medical Center, Hershey, Pennsylvania, USA, using the approach described above. Twenty millilitres of a contrast injectate mixture, composed of 10 ml iodinated contrast material (Omnipaque 300; GE Healthcare, Princeton, NJ, USA), diluted in 90 ml saline was deposited in the fascial plane deep to erector spinae muscle on each side. Within 30 min of completing the blocks, the cadaver was transferred to a 128-slice multidetector computed tomography (CT) scanner (Siemens SOMATON Definition Flash; Siemens Healthcare, Forchheim, Germany), where abdominal and thoracic imaging was performed in order to assess injectate distribution. Images were acquired using routine clinical imaging protocols.
with the following parameters: kVp 120, effective mAs 210, rotation time 0.5 s, pitch 0.8 and detector collimation 1.2 mm. Images were reconstructed using a soft tissue algorithm at 3-mm slice thickness at 3-mm intervals. Three-dimensional volume rendered images were reconstructed using an independent workstation (TeraRecon, Inc, San Mateo, CA, USA). All images were reviewed and interpreted by a consultant radiologist (NS).

**Results**

**Case 1**

An 80-year-old man (weight 98 kg, height 172 cm) presented for repair of a large recurrent supra-umbilical ventral hernia. His other comorbidities included myasthenia gravis which was controlled with pyridostigmine and azathioprine, Type-1 diabetes mellitus and atypical chest pain with basal and inferior hypokinesia of the left ventricle demonstrated by echocardiography. Repair
of the hernia had previously been attempted under local anaesthesia but this had failed. The patient declined a neuraxial block but agreed to bilateral ESP blocks performed before induction of general anaesthesia to assist with peri-operative analgesia. A bolus of 20 ml ropivacaine 0.5% with adrenaline 5 µg.ml⁻¹ was injected on each side at the T7 level. General anaesthesia was induced with propofol 200 mg, fentanyl 150 µg, remifentanil 100 µg and rocuronium 10 mg. Anaesthesia was maintained with desflurane in a 50:50 air:oxygen mixture and remifentanil infusion set at 0.05 µg.kg⁻¹.min⁻¹. The patient received a further dose of fentanyl 200 µg and hydromorphone 1 mg intra-operatively. A 15 × 20 cm polypropylene mesh was secured in place using a combination of transfascial sutures, stay sutures and spiral tacks (Fig. 4). Reversal of neuromuscular blockade, emergence from anaesthesia and tracheal extubation were uneventful. In the recovery area the patient reported no pain and there was decreased sensation over the anterior abdomen from the T6 to T12 dermatomes. Postoperatively, the patient received oral paracetamol 1 g 6-hourly and received intravenous morphine patient-controlled analgesia (PCA), but made no demands overnight and it was discontinued on postoperative day (POD) 1. The patient received his first dose of opioid (oral hydromorphone 1 mg) 28 h following performance of the block and 24 h after completion of surgery. He received a total oral hydromorphone dose of 11 mg (44 mg OME) during the next 24 h before being discharged home on POD 2. The patient was unable to quantify his pain in terms of a NRS score but reported it as ‘mild’ at rest and ‘moderate’ on movement.

Case 2
A 65-year-old man with obstructive sleep apnoea, previous pulmonary embolism and fibromyalgia managed with nightly oral amitriptyline 50 mg, presented for laparoscopic repair of a large ventral hernia. He weighed 133 kg and was 191 cm tall. The patient had an inferior vena cava filter in situ and was anticoagulated with warfarin and bridged with oral enoxaparin 30 mg 12-hourly for surgery. Bilateral ESP blocks were performed at the T7 level with 30 ml ropivacaine 0.5% plus preservative-free dexamethasone 4 mg injected on each side. Anaesthesia was induced with propofol 200 mg, fentanyl 100 µg and rocuronium 70 mg and maintained with sevoflurane in a 50:50 air:oxygen mixture. The patient received a further 50 µg fentanyl intra-operatively. A 15 × 25 cm polypropylene mesh was secured using
transfascial and stay sutures, complicated by formation of a small 3 × 2 cm abdominal wall haematoma. The patient reported an NRS pain score of 4 on arrival in recovery and received a total intravenous dose of hydromorphone 1.5 mg (30 mg OME) before being discharged to the ward 2 h later with a pain score of 3. Postoperatively, he received paracetamol 650 mg 6-hourly, nightly amitriptyline 50 mg and oxycodone 10–20 mg as required. His pain scores at rest in the first 24 h averaged 3–4. The patient began to ambulate 12 h postoperatively and reported average pain scores of 5–7 on movement. These scores remained the same throughout his hospital stay. The patient required oxycodone 20 mg (13 mg OME) and 40 mg (26 mg OME) on the first and second postoperative days (POD) respectively. The patient remained in hospital until POD 3 in order to monitor for surgical complications related to his anticoagulation therapy. He required an additional dose of oral oxycodone 30 mg (20 mg OME) during the last 12 h of his hospital stay.

Case 3
A 55-year-old woman (weight 83 kg, height 170 cm) presented with a ventral hernia following gastric bypass surgery and was scheduled for elective repair as a day case. Her past medical history included depression and anxiety. Bilateral ESP blocks were performed at the T7 level with 20 ml ropivacaine 0.5% plus preservative-free dexamethasone 4 mg injected on each side. Anaesthesia was induced with propofol 200 mg, fentanyl 100 µg, rocuronium 70 mg and maintained with sevoflurane in a 50:50 air:oxygen mixture. A further bolus of fentanyl 100 µg was administered intra-operatively. The ventral hernia was repaired with a 5 × 5 cm polypropylene mesh through an open incision due to difficulties encountered during the laparoscopic approach. The patient reported a pain score of 3 on arrival in the recovery area. During her 4 h stay in hospital she received an intravenous bolus of hydromorphone 0.2 mg and oral oxycodone 5 mg (total of 7.3 mg OME). At telephone follow-up the next day, she reported resting and dynamic pain scores of 2–3, and had required oxycodone 5 mg (3.3 mg OME) in addition to paracetamol 1 g every 6 h.

Case 4
A 65-year-old man (weight 94 kg, height 161 cm) presented for laparoscopic robotic-assisted ventral hernia repair that occurred following a hemicolectomy for colonic cancer. His comorbidities included well-controlled hypertension and ischaemic heart disease with coronary artery stents in-situ. Bilateral ESP blocks were performed at the T7 level with 20 ml ropivacaine 0.5% plus preservative-free dexamethasone 4 mg injected on each side. Anaesthesia was induced with propofol 200 mg, fentanyl 150 µg, rocuronium 70 mg and maintained with sevoflurane in a 50:50 air:oxygen mixture. The patient received a further bolus of fentanyl 100 µg intra-operatively. A 15 × 20-cm polypropylene mesh was secured in place with transfascial and stay sutures. The patient reported a pain score of 5 on admission to recovery and received intravenous hydromorphone 1 mg (20 mg OME) during his 2 h stay in the recovery area. He was discharged home 23 h later, during which time he reported resting and dynamic pain scores ranging between 3–4 and 4–5, respectively, and received a total oxycodone dose of 10 mg (6.7 mg OME) in addition to oral paracetamol 650 mg every 6 h.

The data from all four patients on postoperative opioid consumption and pain scores during the first 24 h is summarised in Table 1.

Figure 4 The surgical site in patient 1 following a laparoscopic 15 × 20 cm mesh repair of a ventral hernia. The four dressings around the umbilicus indicate the sites of transfascial sutures and the approximate dimensions of the mesh. The other dressings cover laparoscopic trocar and port sites. The white arrows show the upper and lower limits of sensory loss to pinprick.
Cadaveric radiological data
Following injection of 20 ml contrast material at T7 on each side, there was cranio-caudal spread between the levels of the T2 and L3 transverse processes on the right side, and between the C5 and L2 transverse processes on the left side (Fig. 5). On both sides contrast was observed to have spread laterally beyond the lateral border of the erector spinae muscle and into the intercostal spaces at the T10 to T12 levels. There was medial spread as far as the medial border of the erector spinae muscle. Contrast was noted on both the anterior and posterior surfaces of erector spinae muscle.

Discussion
Laparoscopic ventral hernia repair has been shown to decrease recurrence rates, reduce patient morbidity and shorten hospital length of stay compared with an open approach [2–5]. It has become the standard of care in many centres but is an operation associated with considerable pain, especially in the early postoperative period [2, 5–7, 11]. There is also some evidence suggesting that a proportion of these patients develop chronic pain [12, 13]. Patients are often kept in hospital, primarily to manage their pain, and interventions targeted at reducing opioid requirements and optimising analgesia have been shown to result in shorter length of stay [14]. Despite this, regional anaesthetic techniques have not been extensively studied in this context. In the largest study reported to date, Fields et al. [15] randomly allocated 100 patients to receive bilateral surgical transversus abdominus plane (TAP) blocks at the start of surgery with either 25–30 ml bupivacaine 0.25% or saline injected in the mid-axillary line. The intervention group had lower pain scores in the recovery area and a 40% reduction in 24-h opioid requirements. Other methods of regional anaesthesia for laparoscopic ventral hernia repair include local anaesthetic infiltration of transabdominal suture sites [16] and instillation of bupivacaine between the mesh and parietal peritoneum [17, 18]. However, there was

Table 1 Post operative opioid consumption and pain scores over the first 24 h in patients receiving bilateral pre-operative erector spinae plane (ESP) blocks for laparoscopic ventral hernia repair. Doses have been converted to oral morphine equivalents. Pain scores were reported using a 11-point numeric rating scale (0–10).

<table>
<thead>
<tr>
<th>Opioid consumption; mg</th>
<th>Patient 1</th>
<th>Patient 2</th>
<th>Patient 3</th>
<th>Patient 4</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–24 h</td>
<td>0.0</td>
<td>43.0</td>
<td>10.7</td>
<td>26.7</td>
<td>18.7</td>
</tr>
<tr>
<td>24–48 h</td>
<td>44.0</td>
<td>26.0</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>48–72 h</td>
<td>N/A</td>
<td>20.0†</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Postoperative pain score</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PACU – highest</td>
<td>0.0</td>
<td>4.0</td>
<td>3.0</td>
<td>5.0</td>
<td>3.5</td>
</tr>
<tr>
<td>PACU – lowest</td>
<td>0.0</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>1st 24 h – highest</td>
<td>0.0</td>
<td>4.0</td>
<td>3.0</td>
<td>5.0</td>
<td>3.5</td>
</tr>
<tr>
<td>1st 24 h – lowest</td>
<td>0.0</td>
<td>3.0</td>
<td>2.0</td>
<td>3.0</td>
<td>2.5</td>
</tr>
</tbody>
</table>

*includes opioids administered in recovery area. PACU, postoperative care unit (recovery area).
†Patient was discharged at 60 h.
only modest and short-lived (< 4 h) analgesia in two of the studies [16, 17] and no difference compared with placebo in the third [18]. The application of a transdermal lidocaine patch over the mesh site has also been described, but this did not produce a significant reduction in postoperative analgesic use [19].

The ESP block is a novel ultrasound-guided technique that has recently been described for the management of acute and chronic thoracic pain [8]. In that initial report, we demonstrated that injection into the fascial plane deep to erector spinae muscle (the erector spinae plane, ESP) at the level of the T5 transverse process can produce profound analgesia of the ipsilateral hemithorax. Anatomical dissection indicates that the likely mechanism of action is diffusion of local anaesthetic anteriorly through the connective tissues and ligaments spanning the adjacent transverse processes and into the vicinity of the spinal nerve roots. This is consistent with other reports of successful analgesia following injection into a similar tissue plane in the thorax [20, 21]. Radiological imaging in a cadaver model further showed that a single injection at the level of the T5 transverse process produced cranio-caudal spread between C7 and T8, accounting for the extensive sensory block that was observed [8]. The erector spinae muscle is a complex composite of three muscles: iliocostalis, longissimus and spinalis. It origi

ates from the sacrum and the lumbar spinous processes, and extends upwards as a gradually tapering column of muscle in the paravertebral groove on either side of the spinous processes, with insertions on the thoracic and cervical vertebrae as high as C2. This muscular column is encased in a retinaculum (a complex sheet of blended aponeuroses and fasciae) that extends from the sacrum to the skull base. In the lower back this retinaculum is referred to as the thoracolumbar fascia [22]. The columnar arrangement of erector spinae muscle and its associated retinaculum provides an anatomical basis for fluid injected in the ESP to spread extensively in a cranio-caudal direction and, furthermore, implies that injection at levels caudal to T5 should result in spread to the lower thoracic nerve roots supplying the abdomen. In this pilot study, we have demonstrated that the ESP block can indeed provide effective abdominal analgesia following injection at the T7 transverse process. We detected spread of injectate as far caudal as the L2–L3 transverse process in a fresh cadaver model, and documented a sensory block from T6 to T12 in one of our patients. The patients in our case series had pain scores in the recovery area that ranged from 0 to 5 despite minimal doses of intra-operative opioid, and the median 24-h opioid requirement was 18.7 mg. This compares favourably with the results of Fields et al. [15] whose average 24-h oral morphine consumption was 64.0 mg in the group who received surgical TAP blocks compared with 106.5 mg in their control group. Average NRS pain scores in recovery were 5.2 vs. 6.5 at rest in the TAP and control groups, respectively, and 6.2 vs. 7.3 with movement.

Transversus abdominus plane blocks performed in the mid-axillary line only reliably cover the T10 to T12 dermatomes medial to the mid-clavicular line [23, 24] and thus may fail to anaesthetise the supra-umbilical and lateral portions of the mesh repair. The ESP block, on the other hand, by virtue of its site of action proximal to the origin of the lateral cutaneous branches of the thoracoabdominal wall and the extensive cranio-caudal spread of injectate, can potentially provide sensory blockade of the entire abdominal wall. In this respect, the ESP block is similar to thoracic paravertebral blockade and thoracic epidural analgesia, which are alternative analgesic strategies for abdominal surgery. Thoracic paravertebral block has been reported in open, but not laparoscopic, ventral hernia repair [25, 26]; however, it is technically more challenging than the ESP block and is associated with more serious complications such as pneumothorax [27]. The risk:benefit ratio for thoracic epidural analgesia is unlikely to be favourable in this setting, particularly since early discharge is a key goal [14]. Two of our patients were discharged within 24 h of surgery but the other two required prolonged hospitalisation for reasons other than inadequate analgesia or opioid-related complications.

Currently, we only have limited evidence for the clinical utility of the ESP block, but we believe it has theoretical advantages that include its simplicity, thanks to easily identifiable ultrasonographic landmarks and an endpoint for injection, as well as low risk for serious complications, because the injection is into a tissue plane that is distant from pleura, major

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blood vessels and discrete nerves. Limitations of the technique include the need to perform bilateral injections for incisions that cross the midline, and the limited duration of analgesia with single-shot injections. However, the use of adjuncts such as dexamethasone may help prolong analgesia [28–30], and the ESP also lends itself well to catheter insertion for intermittent boluses [8] or continuous infusions of local anesthetic. Finally, we would like to note that as with all plane blocks, there is likely to be interindividual variability in the physical spread of local anesthetic and the consequent intensity and extent of analgesia. This is illustrated by the discrepancy in the degree of cranial spread between right and left sides in the fresh cadaver, the specific cause of which is unclear. Pooling the data from this pilot study and our previous report indicates that injection of 20 ml into the ESP produces clinical and radiographic evidence of spread that extends at least three vertebral levels cranially and four levels caudally from the site of injection. Pending further investigation, we therefore believe that it would be most appropriate to perform the ESP block at a vertebral level that corresponds to the midpoint of the desired area of analgesia. Further investigation is required to determine if there is a proportional relationship between the volume injected and the extent of analgesia.

This pilot study is limited in that we have only included a small number of patients and a single cadaver. Nevertheless we have demonstrated the potential of bilateral ESP block as an effective regional anesthetic technique in laparoscopic ventral hernia repair when performed at the T7 transverse process level. The analgesic benefit may extend to other types of painful abdominal surgery and further prospective randomised, controlled trials are warranted.

Acknowledgements
KJC was supported by a Merit Award from the Department of Anesthesia, University of Toronto. No other external funding or competing interests declared.

References
elastomeric pain pump devices used after laparoscopic ventral hernia repair. *Surgical Endoscopy* 2009; **23**: 2637–43.


