BJA

*British Journal of Anaesthesia*, 125 (5): 802–810 (2020)

**doi:** 10.1016/j.bja.2020.06.020
Advance Access Publication Date: 11 July 2020
Regional Anaesthesia

# Comparing erector spinae plane block with serratus anterior plane block for minimally invasive thoracic surgery: a randomised clinical trial

Dylan T. Finnerty[1,2,3,*], Aisling McMahon[1], John R. McNamara[1], Sean D. Hartigan[1], Michael Griffin[1] and Donal J. Buggy[1,2,3,4]

[1]Division of Anaesthesiology, Mater Misericordiae University Hospital, Dublin, Ireland, [2]School of Medicine, University College Dublin, Dublin, Ireland, [3]EU COST Action 15204 Euro-Periscope, Brussels, Belgium and [4]Outcomes Research, Cleveland Clinic, Cleveland, OH, USA

*Corresponding author. E-mail: dylantfinnerty@gmail.com

This article is accompanied by an editorial: Fascial plane blocks in regional anaesthesia: how problematic is simplification? by Marhofer et al., *Br J Anaesth* 2020:125:649–651, doi: 10.1016/j.bja.2020.08.013

## Abstract

**Background:** Minimally invasive thoracic surgery causes significant postoperative pain. Erector spinae plane (ESP) block and serratus anterior plane (SAP) block promise effective thoracic analgesia compared with systemically administered opioids, but have never been compared in terms of terms of quality of recovery and overall morbidity after minimally invasive thoracic surgery.

**Methods:** Sixty adult patients undergoing minimally invasive thoracic surgery were randomly assigned to receive either single-shot ESP or SAP block before surgery using levobupivacaine 0.25%, 30 ml. The primary outcome was quality of patient recovery at 24 h, using the Quality of Recovery-15 (QoR-15) scale. Secondary outcomes included area under the curve (AUC) of pain verbal rating scale (VRS) over time, time to first opioid analgesia, postoperative 24 h opioid consumption, in-hospital comprehensive complication index (CCI) score and hospital stay.

**Results:** The QoR-15 score was higher among ESP patients compared with those in the SAP group, mean (standard deviation): 114 (16) *vs* 102 (22) ($P$=0.02). Time (min) to first i.v. opioid analgesia in recovery was 32.6 (20.6) in ESP *vs* 12.7 (9.5) in SAP ($P$=0.003). AUC at rest was 92 (31) mm $h^{-1}$ *vs* 112 (35) in ESP and SAP ($P$=0.03), respectively, whereas AUC on deep inspiration was 107 mm $h^{-1}$ (32) *vs* 129 (32) in ESP and SAP ($P$=0.01), respectively. VRS pain on movement in ESP and SAP at 24 h was, median (25–75% range): 4 (2–4) *vs* 5 (3–6) ($P$=0.04), respectively. Opioid consumption at 24 h postoperatively was 29 (31) *vs* 39 (34) ($P$=0.37). Median (25–75%) CCI in ESP and SAP was 1 (0–2) *vs* 4 (0–26) ($P$=0.03), whereas hospital stay was 3 (2–6) *vs* 6 (3–9) days ($P$=0.17), respectively.

**Conclusion:** Compared with SAP, ESP provides superior quality of recovery at 24 h, lower morbidity, and better analgesia after minimally invasive thoracic surgery.

**Clinical trial registration:** NCT 03862612.

**Keywords:** erector spinae plane block; quality of recovery; robotic-assisted thoracic surgery; serratus anterior plane block; video-assisted thoracic surgery

**Recevied:** 23 March 2020; **Accepted:** 11 June 2020

**Editor's key points**

- Pain is common after thoracic surgery, limiting functional recovery and increasing risk of postoperative complications.
- Regional interfascial 'plane' blocks have become popular.
- This study found that an erector spinae plane block provided better quality of recovery, analgesic effectiveness, and less postoperative complications when compared with a serratus anterior plane block.

Minimally invasive thoracic surgery (MITS) has become more common over the past decade, with the proportion of lung resections performed using this technique increasing from 16% in 2005 to 47% in 2015.[1] MITS includes both video-assisted and robotic-assisted techniques, with smaller skin incisions and chest wall trauma compared with open thoracotomy. Benefits include reduced postoperative pain, morbidity, and shorter hospital stay.[2,3]

Nevertheless, MITS still causes moderate to severe postoperative pain[4] and a high risk of chronic postsurgical pain (CPSP). Many patients undergoing this procedure have borderline respiratory functional reserve and multiple preoperative comorbidities. Poorly controlled early postoperative pain impairs quality of recovery, increases risk of postoperative pulmonary complications,[3] and is a risk factor for the subsequent development of CPSP.[5] Therefore, optimising acute postoperative analgesia is a priority in patients undergoing MITS.

Numerous analgesic options for video-assisted thoracic surgery (VATS) currently exist. A 2014 systematic review concluded that existing studies were too heterogenous to recommend a gold standard for analgesia in VATS.[6] Choice of analgesic regime is often influenced by the personal preference of the anaesthesiologist rather than any strong evidence base. Thoracic epidural analgesia (TEA) and paravertebral analgesia have a long history of use in thoracic surgery and despite declining popularity in some parts of the world,[7] they are still frequently used. Proponents of these techniques champion their ability to provide efficacious analgesia and anaesthesia whereas critics cite a reportedly high failure rate and complications ranging from pneumothorax to devastating spinal cord injury.[8]

Recently, ultrasound-guided interfascial plane blocks such as the serratus anterior plane (SAP) block and the erector spinae plane (ESP) block have been described in MITS.[9,10] Both blocks aim to deposit local anaesthesia away from the spinal cord in an interfascial plane through which peripheral nerves pass. Although the evidence base is minimal, both ESP and SAP blocks seem to be clinically safe and are considered technically easier to perform than TEA, and therefore are potentially attractive alternative regional anaesthesia techniques in thoracic surgery such as MITS.

ESP block may provide superior analgesia because it blocks both dorsal and ventral rami of the thoracic spinal nerves and elicits some degree of sympathetic blockade,[11] whereas SAP targets superficial nerves limited to the anterior and lateral chest wall. Therefore, we tested the hypothesis that ESP compared with SAP block provides superior quality of recovery, overall morbidity, and postoperative analgesia after MITS in an RCT.

## Methods

The Mater Misericordiae University Hospital's Institutional Review Board approved this study (reference number 1/378/2039, February 22, 2019). The trial was preregistered on clinicaltrials.gov, reference number NCT 03862612 on February 28, 2019. All patients screened and meeting eligibility criteria were invited to participate in the trial, and those enrolled gave written informed consent. Consent was requested from patients on arrival to the operating suite for surgery or on the ward if they were admitted the night before surgery.

Inclusion criteria were ASA 1 to 3 patients, age range 18–80 yr, undergoing unilateral MITS under general anaesthesia between March 2019 and January 2020, and not having any contraindication to peripheral regional anaesthesia blocks. Exclusion criteria were pre-existing infection at block site, contraindication to regional anaesthesia, history of opiate abuse, and pre-existing chronic pain or cognitive dysfunction which would impede accurate engagement with postoperative quality of recovery and analgesia assessment.

The individual indications for surgery were wedge resection, pleurodesis, pleurectomy, lobectomy, decortication, bullectomy, or pleural biopsy.

Patients were assigned to one of the trial groups using a computer-generated random number table. Numbers ending in an even number integer were designated ESP patients, and those ending in odd numbers as SAP patients. The patient study code number and group allocation were typed on separate pages, folded, and concealed in sequentially numbered sealed envelopes. Block randomisation in groups of six individuals was applied to ensure an even number in each group as the study progressed. The groups were named 'ESP' (erector spinae plane) and 'SAP' (serratus anterior plane). A randomisation key was held by an independent third party.

After a period of pre-oxygenation all patients had general anaesthesia induced with i.v. fentanyl 1–2 μg $kg^{-1}$ followed by propofol titrated to loss of verbal response. Choice of neuromuscular antagonist for intubation was at the discretion of the supervising anaesthetist. All patients in the study were intubated with a Mallinckrodt double lumen tube to achieve lung isolation and fibreoptic bronchoscopy used to confirm correct positioning. Unless contraindicated, all patients received paracetamol 1 g, i.v. and dexketoprofen 50 mg. The haemodynamic goal was to maintain systolic BP within 20% of the baseline. Persistent intraoperative elevations above this point would trigger oxycodone administration intravenously. The frequency and dosage of this was at the discretion of the treating anaesthesiologist. Anaesthesia was maintained with a sevoflurane/oxygen/air mix. Routine monitoring was used in accordance with the Association of Anaesthetists Guidelines.[12] The antiemetics ondansetron 0.1–0.15 mg $kg^{-1}$ and dexamethasone 0.1–0.2 mg $kg^{-1}$ were given prophylactically depending on patients' risk for postoperative nausea and vomiting using the Apfel score. Mechanical ventilation settings, need for invasive haemodynamic monitoring, and central venous access were at the discretion of the treating anaesthesiologist. An electronic anaesthesiology recording system (Centricity™ Version 4.5, GE Healthcare, Dublin, Republic of Ireland) was used to document vital signs.

All blocks were performed or supervised by consultant anaesthesiologists with experience in regional anaesthesia

and who were familiar with the ESP and SAP block. Surgery was performed by two surgical teams. Envelopes were opened after induction of general anaesthesia to reveal the group allocation. Ultrasound-guided blocks were performed under full aseptic conditions according to the randomisation before commencement of surgery. All patients received levobupivacaine 0.25% in 30 ml volume, whichever block they received. All blocks were performed with a 22-gauge echogenic needle (Ultraplex 360 cannula; B. Braun, Hessen, Germany; 50e80 mm), using the same ultrasound machine (SonoSite Edge; SonoSite, Inc., Bothell, WA, USA) and linear ultrasound transducer (SonoSite HFL 50x; SonoSite, Inc.), which was placed in a sterile cover.

Patients randomised to the SAP group received a SAP block as follows: with the patient in the supine position and the arm abducted to 90° the skin was prepared with chlorhexidine gluconate 2%/isopropyl alcohol 70% (ChloraPrep; Becton Dickinson, Franklin Lakes, NJ, USA). The blocks were performed as originally described by Blanco and colleagues.[13] Although this original description did not specifically mention arm abduction, in our own practice we have found this position leads to improved ergonomics. The probe was first placed in a sagittal position, the mid-axillary region of the thoracic cage. The fifth rib was identified in the mid-axillary line by counting ribs in an inferior and lateral direction. The latissimus dorsi (superficial and posterior), teres major (superior), and serratus muscles (deep and inferior) were identified overlying the fifth rib. The needle was advanced with an in-plane technique and levobupivacaine 0.25%, 30 ml was injected under continuous ultrasound guidance deep to the serratus anterior muscle.

Patients randomised to the ESP group received an ESP block as follows: patients were positioned in the lateral position and the skin prepared as for SAP, the linear transducer (SonoSite HFL 50x; SonoSite, Inc.) was placed in a sterile cover. The T5 spinous process was identified and the transducer placed approximately to 2–3 cm lateral to the midline in a longitudinal orientation to identify the hyperechoic line of the transverse process with its associated acoustic shadow. After identification of trapezius, rhomboid major, and erector spinae muscle groups superficial to the transverse process, a 22-gauge echogenic needle Ultraplex 360 cannula; B. Braun, Hessen, Germany; 50e80 mm) was advanced in a craniocaudal direction. The needle tip was advanced until it was located in the interfascial plane deep to the erector spinae muscle group and superior to the transverse process. Once in position, levobupivicaine 0.25%, 30 ml was injected under ultrasound guidance. Correct needle-tip position was confirmed by the presence of linear spread between the transverse process and the erector spinae muscle group.

Blocks were performed under general anaesthesia consistent with routine practice; therefore, patients were masked to their group allocation, and hence no dermatomal sensory testing of immediate block efficacy was done. Investigators involved in data collection were also masked to the patients' group allocation and did not have access to the randomisation until after data analysis was complete. Therefore, this study had a double-blind design.

After block performance, patients were transferred from the induction room to the operating theatre. After surgery, patients were transferred to the PACU and then to ward level, once PACU discharge criteria were met. Patients were prescribed oxycodone 1–2 mg i.v. as required for postoperative pain in PACU until the verbal rating scale (VRS) pain score was ≤2 in accordance with hospital policy. On discharge to the ward, all patients were prescribed paracetamol 1 g i.v. 6 hourly, ibuprofen 400 mg orally 8 hourly, and oxycodone immediate release 5–10 mg 2 hourly as required for rescue analgesia unless contraindicated. Ondansetron 4 mg p.o./i.v. 8 hourly as required was prescribed for treatment of nausea or vomiting in the PACU or on discharge to the ward.

The primary outcome was quality of recovery, assessed using the Quality of Recovery-15 (QoR-15) scale at 24 h postoperatively. This is a validated measure of a patient's quality of recovery after surgery.[14] The score assesses five domains of patient-reported health status – pain, physical comfort, physical independence, psychological state, and emotional state – to give a holistic assessment of the patient's overall recovery experience. The QoR-15 questionnaire was given to patients on the ward, and they were then left alone to complete it in their own time. The questionnaire invites responses to 15 subjective parameters from patients, each response graded on a scale from 0 to 10. The maximum score achievable is 150 with a potential minimum score of 0. Higher scores indicate a higher quality of recovery experience. Previous studies have shown that the mean (standard deviation, SD) time to complete the QoR-15 is 2.4 (0.8) min.[14]

Secondary outcomes included area under the curve (AUC) of verbal response score (VRS) for pain at rest and on deep inspiration *vs* time over 24 h; the time to first i.v. opioid analgesia in recovery and 24 h opioid consumption. A Likert scale of 0–10 was used in assessing pain, in which 0 equals no pain and 10 equals the worst pain the patient had ever experienced. The VRS is considered a universally adopted pain assessment tool that is both patient and assessor friendly that provides valid and reproducible results.[15] Secondary outcomes also included length of stay (LOS) and postoperative complications graded using the comprehensive complication index calculator ($CCI^R$).[16] Postoperative complications were identified by visiting patients every day or alternate day during their in-hospital course, supplemented by patients' medical records review by assessors masked to group allocation, using our hospital's electronic patient record database. Patient progression was monitored for the entirety of their hospital stay or for 30 days after surgery (whichever was longer). When patients were discharged from hospital before 30 days their progress was tracked remotely using our electronic patient record system to monitor for readmission and progression at outpatient clinic appointments. We used the Clavien–Dindo Classification system from which CCI is derived. We defined a postoperative complication as any deviation from the ideal postoperative course, not inherent in the procedure itself and does not constitute a failure to cure.[17] CCI scores were calculated using the online $CCI^R$-Calculator at https://www.assessurgery.com/about_cci-calculator/.

Haemodynamic data were automatically recorded as part of our electronic anaesthesiology record (Centricity™ Version 4.5). Highest and lowest BP values and HRs were also documented. Incidence of adverse events such as pruritus, nausea and vomiting, and block complications were recorded.

## Statistical analysis

Data were analysed with GraphPad Prism version 8 (GraphPad, Salt Lake City, UT, USA). The primary outcome was the QoR-15 score at 24 h postoperatively. The established minimum clinically important difference in QoR-15 is 8.0, and the SD of QoR-15 scores after major surgery is in the order of 16 (range of QoR

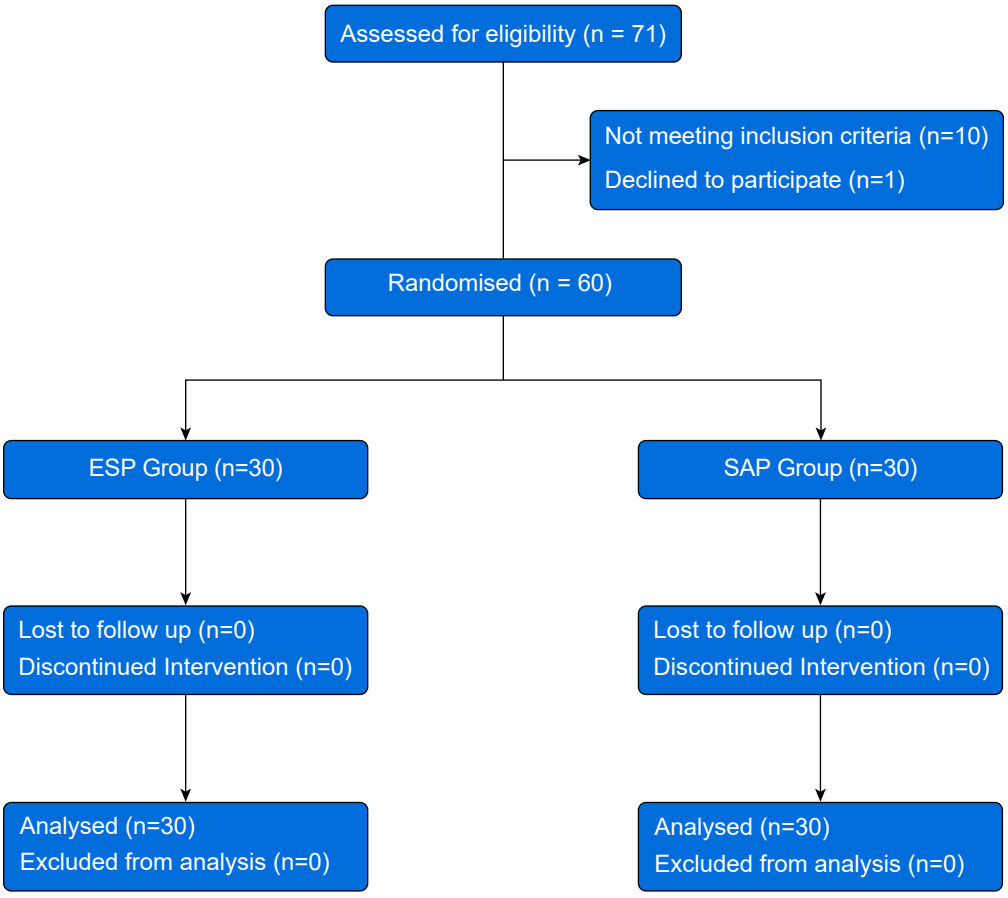


Fig 1. CONSORT flowchart. CONSORT, Consolidated Standards of Reporting Trials; ESP, erector spinae plane; SAP, serratus anterior plane; VRS, verbal rating scale.

score is 1–150).[18] Therefore, assuming Type I error=0.05 and Type II error=0.2 (80% power to detect this difference), then 30 patients were required in each group.

Data were recorded in Excel™ (Microsoft Corp., Redmond, WA, USA) and imported into Prism v8 for analysis. All data were stored according to EU Directive 2019 on General Data Protection Regulations. Data were inspected and tested for distribution according to the Kolmogorov–Smirnov test. Normally distributed data were compared between study arms using the unpaired *t* test, whereas non-normally distributed data were compared using the Mann–Whitney *U* test. All data were summarised as mean (SD) or median (25–75% range) as appropriate. Fisher's exact test was used for comparing categorical data.

## Results

The Consolidated Standards of Reporting Trials (CONSORT) flow diagram for this trial is shown in Fig 1. Seventy-one patients were initially screened for suitability, with 60 meeting the inclusion criteria and were randomly assigned to receive either ESP block or SAP block. All patients enrolled were followed successfully, with no patients lost to follow-up.

Baseline patient data were comparable between both groups, apart from pleurectomy/pleurodesis, which had 11 patients in the SAP group and six patients in the ESP group. The most common indication for VATS in the ESP group was wedge resection ($n$=6), whereas the most common operation in the SAP group was a pleurectomy ($n$=8; Table 1).

Patient haemodynamic data and adverse events profiles for each group are shown in Table 2. There were no statistically significant differences in the minimum or maximum HR or systolic BP measured after block performance. The incidence of nausea, postoperative hypotension, and pruritus was low overall with similar rates between each group. There were no adverse events related to the use of the regional anaesthesia techniques.

The primary outcome, QoR-15 at 24 h postoperatively, is shown in Table 3. ESP had a mean (SD) QoR-15 score of 114 (16) *vs* 102 (22) in SAP ($P$=0.02). The time (min) to use of opioid analgesia in PACU was 32.6 (20.6) in ESP *vs* 12.7 (9.5) in SAP ($P$=0.003). The mean (milligrams) opiate consumption in the first 24 h postoperatively was 29.3 in ESP and 39.9 in SAP ($P$=0.24). The median (25–75%) CCI was 1 (0–2) *vs* 4 (0–26) for ESP and SAP ($P$=0.03), respectively. Regarding LOS, median (25–75%) was 3 (2–6) *vs* 6 (3–9) for ESP and SAP ($P$=0.17), respectively.

The VRS pain scores at rest and on deep inspiration were similar at all time intervals except at 24 h, median (25–75% range): 4 (2–4) and 5 (3–6) and for the ESP and SAP groups

Table 1 Comparison of patient and surgical characteristics

| Variable | ESP group (n=30) | SAP group (n=30) |
|---|---|---|
| Age (yr) | 58.8 (13) | 53.1 (20) |
| Sex | | |
| Female | 11 | 12 |
| Male | 19 | 18 |
| BMI (kg m$^{-2}$) | 28.6 (9.5) | 25.9 (7.4) |
| American Society of Anesthesiologists physical status (1/2/3) | 1/15/14 | 7/11/12 |
| Duration of surgery (min) | 94 (46) | 100 (50) |
| Duration of anaesthesia (min) | 136 (48) | 142 (53) |
| **Procedure** | | |
| Wedge resection | 6 (20%) | 4 (13%) |
| Bullectomy | 4 (13%) | 4 (13%) |
| Pleurodesis | 2 (6.6%) | 3 (10%) |
| Pleurectomy | 4 (13%) | 8 (27%) |
| Decortication | 5 (17%) | 4 (13%) |
| Pleural biopsy | 4 (13%) | 1 (3.3%) |
| Lobectomy | 5 (17%) | 6 (20%) |
| Robotic-assisted surgery | 2 (6.6%) | 2 (6.6%) |
| Intraoperative oxycodone (mg) | 5.10 (5.0) | 7.09 (3.5) |

Data are expressed as mean (standard deviation) or *n* (%).

(P=0.04), respectively. The area under the pain VRS *vs* time curve (AUC) at rest was ESP 92 (31) mm h$^{-1}$ *vs* SAP 112 (35) (P=0.03; Fig 2a), whereas AUC on deep inspiration was ESP 107 (32) mm h$^{-1}$ *vs* SAP 129 (32) (P=0.01; Fig 2b). Complications are reported in Table 4.

## Discussion

This is the first randomised, double-blind clinical trial comparing ESP *vs* SAP block in MITS using the patient-centred outcome measure, QoR-15. We demonstrated a clinically meaningful improvement in quality of recovery at 24 h for patients who received ESP block in comparison with a SAP block. Furthermore, ESP had longer time to first opioid analgesia in recovery and a smaller burden of pain over time (AUC of VRS) at rest and on deep inspiration.

Table 2 Monitoring and adverse events profile

| Monitoring and adverse events | ESP (n=30) | SAP (n=30) | P-value |
|---|---|---|---|
| Lowest systolic BP (mm Hg) | 82 (11) | 84 (8.7) | 0.60 |
| Highest systolic BP recorded (mm Hg) | 146 (20) | 142 (28) | 0.69 |
| Highest HR (beats min$^{-1}$) recorded intraoperatively | 95 (22) | 97 (20) | 0.76 |
| Antiemetics used in recovery (%) | 3 (10) | 4 (13.3) | 0.61 |
| Hypotension requiring intervention in recovery (%) | 1 (3.3) | 2 (6.6) | 0.65 |
| Pruritus | 0 | 0 | 0.99 |
| Reported block complications | 0 | 0 | 0.99 |

Data are shown as mean (SD) or as *n* (%). Adverse events are reported as any incidents over the 24-h observation period of the study. There were no significant differences between the two groups. ESP, erector spinae plane block group; SAP, serratus anterior plane block group.

In terms of assessing the efficacy of anaesthetic intervention, there has been a recent international movement to adopt more patient-centred outcomes.[19] Although lower pain scores are important, they may not be perceived by the patient as a better recovery experience if they are accompanied by other debilitating side-effects. The QoR-15 score is internationally recognised as a validated means of assessing patients' quality of recovery after surgery.[19]

Although a study has recently compared these blocks in similar surgical patients, their measured outcome was limited to pain severity and time to postoperative opioid requirements.[20] The most striking difference between this work and ours was in time to first analgesia administration postoperatively. This was 379 (7.7) vs 296 (6.6) min, mean (SD), in ESP and SAP respectively, 10-fold longer than our patients, who also received intraoperative opioids. This trend was also continued in postoperative opioid consumption where their patients required only two doses of meperidine (0.5 mg kg$^{-1}$) over the first 24 h postoperatively. In contrast, our patients required significantly more opioid in the same postoperative period despite our use of a larger volume of local anaesthesia (levobupivacaine 30 *vs* 20 ml). These large differences in opioid consumption between the two studies are difficult to reconcile and can only be partially explained by the additional use of lidocaine 1% (5 ml) infiltration to each port site in the study performed by our colleagues.[20] In addition, it is worth noting that the trigger point for anaesthesiologists to intervene with analgesia in the postoperative period differed between the two studies: Our patients had a pain VRS score of >2 as a threshold for intervention, whereas our colleagues intervened only when VRS pain score was ≥4. This may partially explain the large differences in opioid consumption between the studies. In any event, opioid consumption is not recommended as a primary standardised endpoint in assessing patient comfort in perioperative trials.[19]

First described in 2013 by Blanco and colleagues,[13] SAP block has recently been shown to improve the quality of recovery after VATS compared with placebo (normal saline) using the QoR-40.[21] Although both ESP and SAP blocks are interfascial plane blocks of the thoracic wall, our findings may be explained by the observation that ESP blocks both dorsal and ventral rami of the thoracic spinal nerves and elicits some degree of sympathetic blockade[11] as opposed to SAP block, which targets only branches of the intercostal nerve. However, there is conflicting evidence from cadaveric and MRI studies as to whether or not local anaesthetic consistently spreads to the paravertebral space with ESP blocks.[22–24]

Optimum postoperative pain control is desirable not only for acute pain relief, but also to reduce the risk of CPSP, which has an incidence as high as 25% after VATS.[25] Poorly controlled postoperative pain is also associated with postoperative pulmonary complications, which in turn increases time to mobilisation and length of hospital stay.[3]

Our study also shows, for the first time, a difference in overall morbidity as measured by the CCI between two blocks, ESP and SAP, after major surgery. A derivation of the Clavien–Dindo scale,[17] the CCI$^{R}$-Calculator ascribes a numerical score between 0 and 100, with higher scores indicating both greater impact of a given morbidity and the aggregation of complications in different body systems.[16] For example a patient developing postoperative pneumonia responsive to antibiotics receives a lower score than a patient whose postoperative pneumonia required intubation and ventilation in an ICU. The magnitude of the therapy required to treat a

Table 3 Primary and secondary outcomes

| | Erector spinae plane block | Serratus anterior plane block | P-value |
|---|---|---|---|
| **Primary outcome** | | | |
| QoR-15 score | 114 (16) | 102 (22) | 0.02 |
| **Secondary outcomes** | | | |
| AUC Pain VRS *vs* time (at rest) | 92 (31) | 112 (35) | 0.03 |
| AUC Pain VRS *vs* time (on deep inspiration) | 107(32) | 129 (32) | 0.01 |
| Time (min) to first opioid analgesia in PACU | 33 (21) | 13 (9.5) | 0.003 |
| Total postoperative opioid consumption (mg) at 24 h | 29 (31) | 40 (34) | 0.24 |
| LOS (days) | 3 (2–6) | 6 (3–9) | 0.17 |
| Comprehensive complication index | 1 (0–2) | 4 (0–26) | 0.03 |

All values are presented as mean (standard deviation) apart from length of stay (LOS) and comprehensive complication index (CCI) which are presented as median and interquartile range (IQR). AUC, area under the curve; VRS, verbal rating scale.

specific complication is the basis of the classification and allows a weighting to be attributed to each complication in the case of multiple complications.

This study shows a high incidence of postoperative complications. A propensity-matched analysis of outcome from the European Society of Thoracic Surgeons database reported a complication rate of 29.1% for patients undergoing VATS lobectomy for lung cancer.[26] Eleven patients of our study group underwent a VATS lobectomy. Similarly, high postoperative complication rates (almost 60%) have been reported in patients undergoing lung volume reduction surgery by the National Emphysema Treatment Trial group.[27] Twelve of our patients underwent VATS as part of lung volume reduction surgery. In addition, a postoperative complication has a broad definition and ranges from a short course of antibiotics for a presumed respiratory infection to an unanticipated admission to ICU. Therefore, we feel our reported incidence of postoperative complications is in keeping with previous studies.

The association we have demonstrated between ESP block and lower CCI scores in comparison with SAP block is interesting and merits further discussion. Postoperative pneumonia was the most common complication observed. It is plausible that the superior overall analgesia, evidenced by the lower AUC VRS time and enhanced QoR-15 observed in our ESP patients, may have contributed to lowering the incidence of postoperative pneumonia. The mechanism of this improvement in morbidity may have been faster mobilisation attributable to better and longer duration analgesia. Previous studies have demonstrated that regional anaesthesia can reduce the incidence of postoperative pneumonia, particularly in patients with pre-existing chronic obstructive pulmonary disease (COPD).[28,29] Effective analgesia is of paramount importance in this cohort, as many patients presenting for MITS will already have a diagnosis of COPD. Whether ESP block reduces overall morbidity after other major surgeries is currently unknown.

Our study was not powered to determine differences in LOS. It is noteworthy that although there was a 3 day reduction in median LOS in patients who received ESP, consistent with

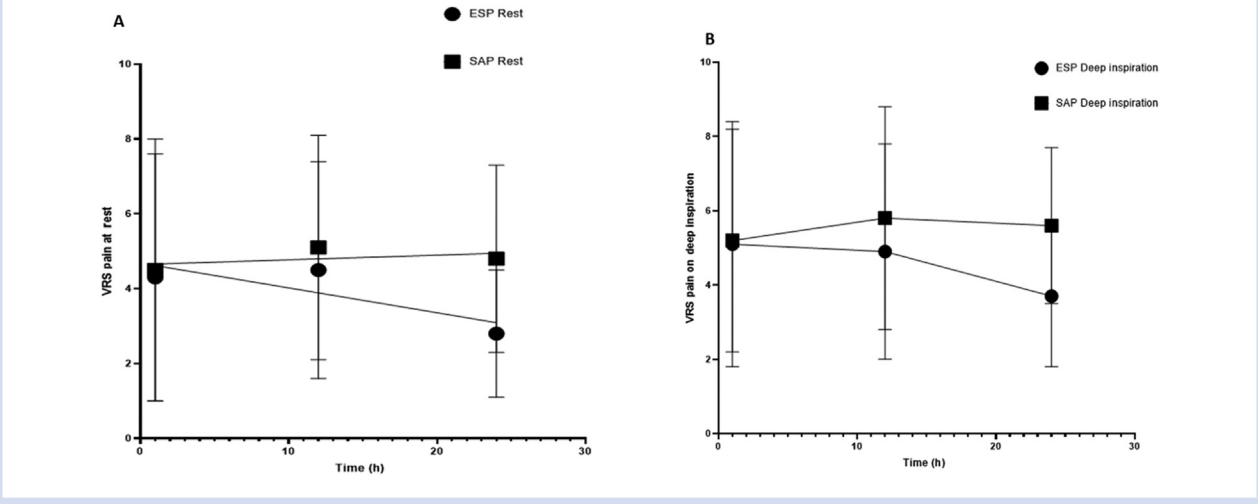


Fig 2. (a) Area under the curve (AUC) of VRS pain over time at rest; P=0.03. (b) AUC of VRS pain over time on deep inspiration; P=0.01. VRS, verbal rating scale.

Table 4 Postoperative complications in each group

| | ESP ($n$=30) | SAP ($n$=30) | P-value* |
|---|---|---|---|
| Postoperative pneumonia | 2 (7) | 8 (27) | 0.17 |
| Surgical site infection | 1 (3) | 1 (3) | 0.99 |
| Acute kidney injury | 2 (7) | 3 (10) | 0.78 |
| Recurrent pneumothorax/air leak requiring further intervention | 4 (13) | 5 (17) | 0.67 |
| Arrhythmia | 1 (3) | 1 (3) | 0.99 |
| Bleeding requiring transfusion | 0 | 1 (3) | 0.86 |
| Unplanned ICU admission | 1 (3) | 2 (7) | 0.79 |
| Total number of patients with a postoperative complication | 7 (23) | 15 (50) | 0.06 |

Data are shown as $n$ (%).
* Fisher exact test. ESP, rector spinae plane; SAP, serratus anterior plane.

their lower median morbidity, our sample size was too small and the interpatient variability too wide for this difference in LOS to have been statistically significant. In addition, two patients in the SAP group had considerably longer LOS than expected (111 and 39 days), which may have skewed our data in favour of the ESP group. Therefore, we are uncertain regarding the reliability of our observation of the effect of ESP block on LOS.

Our observation that ESP block offers increased duration of analgesia in comparison with SAP block is consistent with the original observation of ESP block, which reported a block duration of approximately 24 h.[11] By comparison, the first description of the SAP block using the 'deep' technique (which we used) reported a mean block duration of 386 (160) min among volunteers.[13] These four volunteers were not exposed to any surgical insult, and block duration was assessed by the presence of paraesthesia as defined by the loss of pin prick sensation with a hypodermic needle. This is very different to the 'surgical anaesthesia' we require blocks to have in clinical practice and hence may explain the large discrepancy in block duration between these original descriptions and our study. It is noteworthy that there is a wide range of values reported in the literature regarding the duration of ESP and SAP blocks. This is to be expected, because all interfascial blocks depend on the spread of local anaesthetic within a tissue plane, the extent of which will differ greatly from patient to patient and is dependent on multiple factors.[30]

There is some debate whether the 'deep' or 'superficial' SAP block provides superior analgesia.[31] *Post-hoc* analysis of a recent systematic review and meta-analysis was unable to definitively answer this question.[32] Our institutional experience has been that injecting deep to the serratus anterior muscle is technically easier, particularly in obese patients and provides more easily recognisable sono-anatomy as opposed to superficial injection.

ESP block is effective for analgesia in VATS[33] compared with routine systemic analgesia. There is also some evidence that it gives comparable analgesia to paravertebral analgesia in thoracotomy and with a lower incidence of complications.[34] Given that each block is relatively easy to perform and are both in current use, the findings of our study suggest that although both blocks are beneficial, ESP has further merit over SAP in VATS.

There are limitations in this trial. We enrolled patients who were scheduled to have either robotic-assisted or video-assisted thoracic surgery. Our rationale for this was that, although the surgical port sites created for the robotic-assisted technique are slightly smaller, the number of port sites may be higher and recent published expert opinion to date suggests that pain levels are similar to patients who undergo video-assisted surgery.[3] We believe it is unlikely that this introduced any significant heterogeneity to our trial cohorts.

Despite our robust randomisation process, there were differences in the type of surgery performed between the study groups, with a preponderance of pleurectomy in the SAP group. Pleurectomy can be associated with significant postoperative pain, and this has the potential to influence our results. However, these differences were statistically not significant. Furthermore, the SAP group had slightly younger patients with lower BMI, which would have tended to enhance QoR. Overall, we believe that these differences in baseline characteristics were small and would have neutralised each other.

We did not assess patients' preoperative QoR-15, and consequently did not have a baseline from which to compare postoperative scores. Nonetheless, QoR-15 was designed for postoperative use, and we applied this tool equally to both randomised cohorts. Furthermore, the ability of QoR-15 in the immediate preoperative period to give an accurate baseline has been questioned, owing to patient factors such as fatigue and anxiety related to impending surgery.[35]

The blocks were conducted under general anaesthesia; therefore, formal dermatomal assessment of block function was not performed. This raises the possibility that some blocks may not have been fully effective. However, the practice of administering these and other peripheral nerve blocks under ultrasound guidance after induction of general anaesthesia is consistent with routine clinical practice, and therefore our findings should be relevant to widespread practice.

In conclusion, this single-centre, prospective, randomised, double-blind RCT among MITS patients has shown that patients who received an ESP block had better QoR-15 scores at 24 h and lower overall morbidity after surgery in comparison with those who received the SAP block.

## Authors' contributions

Trial concept: DTF, MG, DJB
Trial design: DTF, DJB
Research justification for the trial: DJB
Patient enrolment: DTF, AMcM, JMcN, MG, DJB

Management of clinical recording forms and data: DTF, AMcM, JMcN, SDH, MG
Data analysis: DTF, DJB
Data interpretation: DJB
IRB approval: DJB
Drafting of the manuscript: DTF, SDH, MG, DJB
Approval of final version of the manuscript: DTF, AMcM, JMcN, SDH, MG, DJB

## Declarations of interest

DJB is an editorial board member of the *British Journal of Anaesthesia*. The other authors involved have no conflicts of interest to declare.

## Funding

Division of Anaesthesiology & Perioperative Medicine, Mater University Hospital.

## Acknowledgements

We thank our anaesthesiology and thoracic surgery consultant colleagues (D Eaton and K Redmond) for their co-operation in facilitating this trial. We are also grateful to our PACU nurse colleagues for their kind assistance.

## References

1. Batchelor TJ, Rasburn NJ, Abdelnour-Berchtold E, et al. Guidelines for enhanced recovery after lung surgery: recommendations of the enhanced recovery after surgery (ERAS®) society and the European society of thoracic Surgeons (ESTS). *Eur J Cardio-thorac Surg* 2019; **55**: 91–115
2. Klapper J, D'Amico TA. VATS versus open surgery for lung cancer resection: moving toward a minimally invasive approach. *J Natl Comp Canc Netw* 2015; **13**: 162–4
3. McCall P, Steven M, Shelley B. Anaesthesia for video-assisted and robotic thoracic surgery. *BJA Educ* 2019; **19**: 405–11
4. Nagahiro I, Andou A, Aoe M, et al. Pulmonary function, postoperative pain, and serum cytokine level after lobectomy: a comparison of VATS and conventional procedure. *Ann Thorac Surg* 2001; **72**: 362–5
5. Schug SA, Bruce J. Risk stratification for the development of chronic postsurgical pain. *Pain Rep* 2017; **2**: e627
6. Steinthorsdottir KJ, Wildgaard L, Hansen HJ, et al. Regional analgesia for video-assisted thoracic surgery: a systematic review. *Eur J Cardio-Thorac Surg* 2014; **45**: 959–66
7. Shanthanna H, Moisuik P, O'Hare T, et al. Survey of postoperative regional analgesia for thoracoscopic surgeries in Canada. *J Cardiothorac Vasc Anesth* 2018; **32**: 1750–5
8. Cook T, Counsell D, Wildsmith J. Major complications of central neuraxial block: report on the third national audit project of the royal college of Anaesthetists. *Br J Anaesth* 2009; **102**: 179–90
9. Semyonov M, Fedorina E, Grinshpun J, et al. Ultrasound-guided serratus anterior plane block for analgesia after thoracic surgery. *J Pain Res* 2019; **12**: 953
10. Wilson JM, Lohser J, Klaibert B. Erector spinae plane block for postoperative rescue analgesia in thoracoscopic surgery. *J Cardiothorac Vasc Anesth* 2018; **32**. e5–7
11. Forero M, Adhikary SD, Lopez H, et al. The erector spinae plane block: a novel analgesic technique in thoracic neuropathic pain. *Reg Anesth Pain Med* 2016; **41**: 621–7
12. Checketts M, Alladi R, Ferguson K, et al. Recommendations for standards of monitoring during anaesthesia and recovery 2015: association of Anaesthetists of Great Britain and Ireland. *Anaesthesia* 2016; **71**: 85–93
13. Blanco R, Parras T, McDonnell J, et al. Serratus plane block: a novel ultrasound-guided thoracic wall nerve block. *Anaesthesia* 2013; **68**: 1107–13
14. Stark PA, Myles PS, Burke JA. Development and psychometric evaluation of a postoperative quality of recovery ScoreThe QoR-15. *Anesthesiology* 2013; **118**: 1332–40
15. Holdgate A, Asha S, Craig J, et al. Comparison of a verbal numeric rating scale with the visual analogue scale for the measurement of acute pain. *Emerg Med* 2003; **15**: 441–6
16. Slankamenac K, Graf R, Barkun J, et al. The comprehensive complication index: a novel continuous scale to measure surgical morbidity. *Ann Surg* 2013; **258**: 1–7
17. Dindo D, Demartines N, Clavien P-A. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. *Ann Surg* 2004; **240**: 205
18. Myles PS, Myles DB, Galagher W, et al. Minimal clinically important difference for three quality of recovery scales. *Anesthesiology* 2016; **125**: 39–45
19. Myles PS, Boney O, Botti M, et al. Systematic review and consensus definitions for the Standardised Endpoints in Perioperative Medicine (StEP) initiative: patient comfort. *Br J Anaesth* 2018; **120**: 705–11
20. Gaballah KM, Soltan WA, Bahgat NM. Ultrasound-guided serratus plane block versus erector spinae block for postoperative analgesia after video-assisted thoracoscopy: a pilot randomized controlled trial. *J Cardiothorac Vasc Anesth* 2019; **33**: 1946–53
21. Kim D-H, Oh YJ, Lee JG, et al. Efficacy of ultrasound-guided serratus plane block on postoperative quality of recovery and analgesia after video-assisted thoracic surgery: a randomized, triple-blind, placebo-controlled study. *Anesth Analg* 2018; **126**: 1353–61
22. Ivanusic J, Konishi Y, Barrington MJ. A cadaveric study investigating the mechanism of action of erector spinae blockade. *Reg Anesth Pain Med* 2018; **43**: 567–71
23. Schwartzmann A, Peng P, Maciel MA, et al. A magnetic resonance imaging study of local anesthetic spread in patients receiving an erector spinae plane block. *Can J Anesth* 2020: 1–7. https://doi.org/10.1007/s12630-020-01613-8
24. Yang HM, Choi Y, Kwon HJ, et al. Comparison of injectate spread and nerve involvement between retrolaminar and erector spinae plane blocks in the thoracic region: a cadaveric study. *Anaesthesia* 2018; **73**: 1244–50
25. Wildgaard K, Ravn J, Nikolajsen L, et al. Consequences of persistent pain after lung cancer surgery: a nationwide questionnaire study. *Acta Anaesthesiol Scand* 2011; **55**: 60–8
26. Falcoz P-E, Puyraveau M, Thomas P-A, et al. Video-assisted thoracoscopic surgery versus open lobectomy for primary non-small-cell lung cancer: a propensity-matched analysis of outcome from the European Society of Thoracic Surgeon database. *Eur J Cardiothorac Surg* 2016; **49**: 602–9
27. DeCamp Jr MM, McKenna Jr RJ, Deschamps CC, et al. Lung volume reduction surgery: technique, operative mortality, and morbidity. *Proc Am Thorac Soc* 2008; **5**: 442–6

28. 1van Lier F, van der Geest PJ, Hoeks SE, et al. Epidural analgesia is associated with improved health outcomes of surgical patients with chronic obstructive pulmonary disease. *Anesthesiology* 2011; **115**: 315–21
29. Guay J, Choi P, Suresh S, et al. Neuraxial blockade for the prevention of postoperative mortality and major morbidity: an overview of Cochrane systematic reviews. *Cochrane Database Syst Rev* 2014
30. Elsharkawy H, Pawa A, Mariano ER. Interfascial plane blocks: back to basics. *Reg Anesth Pain Med* 2018; **43**: 341–6
31. Piracha MM, Thorp SL, Puttanniah V, et al. "A tale of two planes": deep versus superficial serratus plane block for postmastectomy pain syndrome. *Reg Anesth Pain Med* 2017; **42**: 259–62
32. Chong M, Berbenetz N, Kumar K, et al. The serratus plane block for postoperative analgesia in breast and thoracic surgery: a systematic review and meta-analysis. *Reg Anesth Pain Med* 2019; **44**: 1066–74
33. Ciftci B, Ekinci M, Celik EC, et al. Efficacy of an ultrasound-guided erector spinae plane block for postoperative analgesia management after video-assisted thoracic surgery: a prospective randomized study. *J Cardiothorac Vasc Anesth* 2020; **34**: 444–9
34. Fang B, Wang Z, Huang X. Ultrasound-guided preoperative single-dose erector spinae plane block provides comparable analgesia to thoracic paravertebral block following thoracotomy: a single center randomized controlled double-blind study. *Ann Transl Med* 2019; **7**: 174
35. Chazapis M, Walker E, Rooms M, et al. Measuring quality of recovery-15 after day case surgery. *Br J Anaesth* 2016; **116**: 241–8

*Handling editor: Paul Myles*