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Original Article

Randomized Prospective Study Evaluating Single-Injection Paravertebral Block, Paravertebral Catheter, and Thoracic Epidural Catheter for Postoperative Regional Analgesia After Video-Assisted Thoracoscopic Surgery

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Objective: Video-assisted thoracoscopic surgery (VATS) has improved patient outcomes; however, postoperative pain remains potentially severe. The objective of this study was to compare adjunct analgesic modalities for VATS, including paravertebral nerve blockade (PVB) and thoracic epidural anesthesia (TEA).
Design: Prospective, randomized trial.
Setting: Large academic hospital, single institution.
Participants: Adult patients undergoing VATS.
Interventions: Ultrasound-guided PVB catheter, ultrasound-guided single-injection PVB, or TEA.
Measurements and Main Results: Postoperative visual analog scale pain scores (at rest and with knee flexion) and opioid usage were recorded. Pain scores (with movement) for the TEA group were lower than those for either PVB group at 24 hours ($p \leq 0.008$) and for the PVB catheter group at 48 hours ($p = 0.002$). Opioid use in TEA group was lower than that for either PVB group at 24 and 48 hours ($p < 0.001$) and 72 hours ($p < 0.05$). Single-injection PVB was faster compared with PVB catheter placement (6 min *v* 12 min; $p < 0.001$) but similar to TEA (5 min). Patient satisfaction, nausea, sedation, and 6-month postsurgical pain did not differ between groups.
Conclusions: TEA led to lower pain scores and opioid requirement for VATS procedures compared with PVB techniques. Single-injection PVB was faster and equally as effective as PVB catheter, and it led to similar patient satisfaction as TEA; therefore, it should be considered in patients who are not ideal candidates for TEA.

Key Words: VATS; thoracoscopy; regional analgesia; paravertebral; catheter

VIDEO-ASSISTED thoracoscopic surgery (VATS) has decreased postoperative pain and morbidity compared with traditional open thoracotomy.[1,2] However, patients undergoing VATS may still experience a painful postoperative course, and the ideal pain management techniques remain unclear.[3,4]

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A variety of regional analgesia modalities such as paravertebral nerve blockade (PVB) and thoracic epidural anesthesia (TEA) have been utilized in conjunction with standard parenteral/oral medication.[3]

TEA is effective at controlling pain after thoracoscopy, especially that incited by movement.[5] In addition to providing analgesia, TEA also may improve pulmonary function and gas exchange, and decrease the odds of prolonged ventilation and reintubation.[6] Despite these benefits, potentially serious adverse effects may be caused by TEA. More commonly seen examples are hypotension, urinary retention, nausea, and vomiting, which may be caused by opioid usage or sympathetic blockade.[7-9] Epidural hematoma formation is a particular risk for patients receiving anticoagulation or antiplatelet therapy, as well as those with severe liver or kidney disease.[9] Accidental dural puncture, the most common complication of TEA, has a reported incidence of 1.02% to 1.23%, and is associated with postdural puncture headache.[10] Although the risk of dural puncture can be reduced by choosing a more caudal insertion site, the block may be less effective to the desired spinal nerve level. Because of these potential adverse effects, in addition to TEA's exacerbation of alterations in cardiopulmonary physiology during VATS,[11] TEA has been questioned as the gold standard for adjunctive pain management after thoracic surgeries.[12]

The PVB produces ipsilateral somatosensory and sympathetic nerve blockade, leading to effective unilateral analgesia while avoiding many of the side effects observed with TEA. This procedure can be performed percutaneously using the classic landmark-based approach described by Eason and Wyatt,[13] ultrasound-guidance,[14] or stimulation technique,[15] or under direct visualization by the surgeon.[16] The PVB may involve single-dose injection (either in a large bolus at a single site, or multiple divided boluses at different sites) or continuous catheter infusion of a local anesthetic agent, both of which have previously been shown to provide postoperative pain control.[12,17,18] Single-dose PVB was shown to provide only short duration (<6 hours) postoperative analgesia[19,20]; therefore, most recent studies have evaluated PVB by continuous infusion.

Several meta-analyses have concluded that PVB likely provides similar analgesia as TEA after thoracic surgery, with fewer adverse effects.[12,21,22] However, studies have been very heterogenous relating to techniques, local anesthetic agents, surgical procedures, etc. In a 2014 systematic review, Steinthorsdottir et al. suggested that study heterogeneity was too great to determine a clear gold standard regional analgesia technique for VATS.[23] The objective of the present study was to identify the superior regional anesthesia technique (single-injection PVB, catheter PVB, or TEA) for VATS patients with primary outcomes of postoperative pain scores and opioid requirements.

Methods

Study Design

This was a randomized, prospective study performed between February 2017 and June 2018. Data collection included patient demographic data, opioid tolerance (defined as use of ≥30-mg morphine equivalent per day), type of surgical procedure, postoperative pain scores, nausea/vomiting, sedation scores, opioid requirement, patient satisfaction scores, and incidence of chronic postsurgical pain at 6 months. This study was reviewed and approved by the Institutional Review Board of the Indiana University School of Medicine (# 1601583558).

Patient Population

All VATS cases scheduled by thoracic surgeons at Indiana University Health-University Hospital were identified for possible study inclusion. Additional inclusion criteria were American Society of Anesthesiologists (ASA) classes 1 to 4, ≥18 years of age, and patient desiring regional anesthesia for adjunct postoperative pain control. Exclusion criteria were contraindication to TEA or PVB, history of substance abuse in the prior 6 months, opioid tolerance, necessitation for intubation after surgery, and known allergy or contraindication to any study medications (oxycodone/acetaminophen, bupivacaine, or ropivacaine). Candidates were informed about the study in the preoperative care unit on the day of surgery and given copies of the informed consent and authorization forms. Subjects provided written informed consent and were randomly placed into 1 of the 3 study groups: (1) continuous infusion PVB catheter; (2) single-dose PVB; or (3) TEA. Randomization was performed using Research Randomizer (https://www.randomizer.org).

Regional Anesthesia Procedures

Procedures were completed under the guidance of an attending anesthesiologist using a sterile technique including mask, hat, and sterile gloves. All patients preoperatively received 1g of acetaminophen and 600 mg of gabapentin. Paravertebral procedures were all performed preoperatively using ultrasound guidance with an ultrasound transducer at the thoracic level, using an in-plane or out-of-plane approach (at the discretion of the attending anesthesiologist). A needle was inserted into the paravertebral space and a 30 mL of 0.5% ropivacaine was injected. For paravertebral catheter placement, a catheter (Arrow International, Inc, Reading, PA) was then placed within the injectate and secured in place. Ropivacaine, 0.2%, was delivered postoperatively at a rate of 10 mL/h by infusion pump (OnQ Pain Relief System, Kimberly-Clark, Roswell, GA).

Thoracic epidural catheters were placed using a commercially available epidural anesthesia kit (Arrow International). Anatomic landmarks were used to place the epidural catheter at the appropriate level (T7-T8). The epidural needle was advanced toward the epidural space employing a paramedian approach and loss-of-resistance technique. After a negative test dose, a sterile catheter was then secured in place, and an infusion pump delivered an epidural mixture of 0.125% bupivacaine and 0.05 mg/mL of hydromorphone (starting at the end of the surgery).

All patients who presented for VATS were intubated with a double-lumen endotracheal tube, placed in the lateral position, and received one-lung ventilation for the procedure.

Postoperative Care and Assessment

Peripheral nerve blockade was assessed in all patients in the postoperative care unit by testing cold sensation (alcohol placement) at relevant dermatomes. All groups received intravenous patient-controlled analgesia (hydromorphone, 0.2 mg, bolus dose, 10-min lock-out interval, 4 h maximum dose of 5 mg) for breakthrough pain. On postoperative day 2, patients were switched to an oral narcotic (oxycodone/acetaminophen 5 mg/325 mg q4-6 h as needed). Pain scores at rest and with movement (knee flexion) were measured by a blinded investigator using the Visual Analog Scale (VAS) from 0 to 10 (no pain = 0; worst pain imaginable = 10). For the knee flexion, patients were asked to flex their knee and raise the entire leg up toward their chest. Nausea was measured using a categorical scoring system (none = 0; mild = 1; moderate = 2; severe = 3), and sedation scores were assigned using a sedation scale (awake and alert = 0; quietly awake = 1; asleep but easily roused = 2; deep sleep = 3). These parameters were measured at 1, 24, 48, and 72 hours after TEA or PVB. Patient satisfaction was assessed at 24 and 48 hours after TEA or PVB using a categorical scoring system (dissatisfied = 0; satisfied = 1; highly satisfied = 2). Patients were encouraged to ambulate on postoperative day 1 under supervision. All catheters were removed by the acute pain service (APS) before discharge. Patients were monitored by the primary team during the postoperative period, and any adverse events or unanticipated problem were reported to the APS and research team. Patients had the opportunity to withdraw from the study at any time by contacting the research team or APS. Patients were surveyed by telephone at approximately 6 months after surgery to assess for chronic postsurgical pain.

Statistical Analysis

All data were summarized as median (interquartile range) for continuous variables and frequency (percentage) for categorical variables. Demographic data and primary outcome data (pain scores and opioid usage) were analyzed using the Kruskal-Wallis test for continuous variables and χ^2 or Fisher's exact test for the univariable data. Rank transformation was performed for non-normal distributions before mixed-model analysis of variance (ANOVA). Mixed-model ANOVA was used to assess the following: pain score and patient satisfaction outcomes (with fixed effect for study group, time, and their interactions, as well as random effect for subject). Other outcomes (postoperative nausea and sedation scores) were analyzed using Cochran-Mantel-Haenszel χ^2 tests for ordered categorical data. A p value less than 0.05 was regarded as statistically significant. Statistical testing was performed using SAS 9.4 software (SAS Institute Inc, Cary, NC). Sample size was determined with a power analysis. Based on prior studies, the coefficient of variation for the VAS score at 24 and 48 hours was estimated to be 0.70. With a sample size of 40 per group, the study would be able to detect a 60% decrease in VAS score between any 2 groups, assuming two-sided tests each conducted at a 5% significance level.

Results

Patients

The study included 120 patients, with 40 patients randomly assigned to each group (PVB catheter, single-injection PVB, or TEA). Demographics and other study group characteristics (opioid naivety or tolerance, known allergies to medications other than those used in the study protocol, other preoperative medications, surgical procedure, time required to perform the block, surgery duration, etc) are shown in Table 1. All characteristics were similar among groups except for over-representation ($p = 0.026$) by Caucasian race in the TEA group (97.5% *v* 80.0% and 82.5% for single-injection PVB or PVB catheter, respectively). Also, the median time to place the PVB catheter (12.0 min) was longer than the time required for the single-injection PVB (6.0 min) or TEA (5.0 min; $p < 0.001$).

Pain Scores

Postoperative median pain scores at rest were significantly different between groups at 24 hours ($p = 0.02$) and 48 hours ($p = 0.03$) after surgery, with the TEA group reporting lower median scores (Table 2). However, comparison of pain scores at rest by mixed-model ANOVA showed no difference between groups at any time point ($p > 0.05$). Pain with movement differed between the groups at 24 and 48 hours (Table 2). Mixed-model ANOVA showed that the TEA group reported lower pain scores with movement at 24 hours versus the single-injection PVB group ($p = 0.008$) or the PVB catheter group ($p = 0.005$). At 48 hours, pain with movement for the TEA group was lower than that for the PVB catheter group ($p = 0.002$) but similar when compared with the single-injection PVB group. Pain scores (both at rest and with movement) were similar for all groups at the other postoperative timepoints (1 h and 72 h).

Opioid Usage

Median consumption of opioids (converted to morphine milligram equivalents [MME]) was different ($p < 0.001$) among groups at 24, 48, and 72 hours (Table 2). At 24 hours, patients in the TEA group received a median of 15 MME compared with 88 MME for patients in the single-injection PVB group, and 76 MME for patients in the PVB catheter group. Results were similar at 48 hours, with median opioid usage at 10, 91, and 90 MME for the single-injection TEA group, PVB group, and PVB catheter group, respectively ($p < 0.001$). The difference in opioid usage at 72 hours was less, but still significant ($p = 0.02$), as the TEA group used 21 MME compared with 57 MME for the single-injection PVB group and 35 MME for the PVB catheter group.

Other Outcomes

Patient satisfaction scores were similar among groups at both survey points (24 and 48 h; $p = 0.59$). All patients in all

Table 1
Characteristics of Study Participants Receiving Regional Anesthesia for Video-assisted Thoracoscopy Procedures

	Overall (N = 120)	Single-injection PVB (n = 40)	PVB Catheters (n = 40)	TEA (n = 40)	p Value
Sex					0.12
Male	60 (50.0%)	16 (40.0%)	19 (47.5%)	25 (62.5%)	
Female	60 (50.0%)	24 (60.0%)	21 (52.5%)	15 (37.5%)	
Age in years	62.0 (48.0-70.0)	63.5 (48.5-70.0)	62.0 (45.5-69.5)	61.0 (52.0-70.0)	0.76
Race					0.03
Caucasian	104 (86.7%)	32 (80.0%)	33 (82.5%)	39 (97.5%)	
Black	13 (10.8%)	8 (20.0%)	4 (10.0%)	1 (2.5%)	
Hispanic, Latino, Spanish	2 (1.7%)	0 (0%)	2 (5.0%)	0 (0%)	
Other	1 (0.8%)	0 (0%)	1 (2.5%)	0 (0%)	
Height in cm	170.0 (162.0-177.9)	171.0 (162.0-177.8)	167.6 (165.0-173.9)	173.5 (161.3-179.3)	0.41
Weight in kg	84.1 (67.1-102.1)	88.4 (72.2-105.0)	77.7 (67.0-90.4)	87.3 (65.8-106.7)	0.09
Opioid history			3		
Naïve	105 (87.5%)	34 (85.0%)	5 (87.5%)	36 (90.0%)	0.80
Tolerant	11 (9.2%)	4 (10.0%)	4 (10.0%)	3 (7.5%)	1.0
No known allergies	53 (44.2%)	15 (37.5%)	20 (50.0%)	18 (45.0%)	0.53
Surgical procedure					
Wedge	62 (51.7%)	17 (42.5%)	19 (47.5%)	26 (65.0%)	0.11
Lobectomy	38 (31.7%)	17 (42.5%)	13 (32.5%)	8 (20.0%)	0.10
Pleurodesis	13 (10.8%)	5 (12.5%)	3 (7.5%)	5 (12.5%)	0.82
Decortication	2 (1.7%)	0 (0%0	2 (5.0%)	0 (0%)	0.33
Mediastinal	12 (10.0%)	5 (12.5%)	4 (10.0%)	3 (7.5%)	0.93
Preoperative medications					
Acetaminophen 1g	119 (99.2%)	40 (100.0%)	40 (100.0%)	39 (97.5%)	1.0
Gabapentin 300 mg	34 (28.3%)	13 (32.5%)	10 (25.0%)	11 (27.5%)	0.75
Gabapentin 600 mg	82 (68.3%)	26 (65.0%)	29 (72.5%)	27 (67.5%)	0.76
Pain block time in minutes	7.0 (4.0-12.0)	6.0 (4.0-9.5)	12.0 (8.0-18.0)	5.0 (3.0-8.0)	<0.001
Surgery duration in minutes	82.0 (50.0-156.0)	117.0 (49.5-160.0)	75.0 (54.5-155.0)	90.0 (47.0-138.0)	0.53

NOTE. Results presented as number (percentage) or median (interquartile range).
Abbreviations: PVB, paravertebral block; TEA, thoracic epidural analgesia.

groups reported satisfaction scores of 2 (highly satisfied). No significant difference was observed in nausea and sedation scores among the 3 groups at 0, 24, 48, and 72 hours. No other major complications (eg, dural puncture, epidural hematoma, infection) were reported in any study group. Long-term follow-up to assess for chronic postsurgical pain was conducted for 67 of the original 120 patients (single-injection PVB, n = 23; PVB catheter, n = 22; TEA, n = 22). The remaining

Table 2
Summary of Postoperative Pain Scores and Opioid Consumption for Video-assisted Thoracoscopy Patients Receiving Thoracic Epidural or Paravertebral Block Techniques

Time (h)	Outcome	Overall (N = 120)	Single-injection PVB (n = 40)	PVB Catheter (n = 40)	TEA (n = 40)	p Value
1	Pain score					
	At rest	6.0 (3.0-8.0)	5.0 (3.0-8.0)	6.0 (3.5-8.0)	6.0 (3.0-7.5)	0.63
	With movement	7.0 (5.0-9.0)	6.5 (4.0-9.0)	7.0 (5.0-9.0)	7.0 (5.0-9.0)	0.76
	Opioid usage	12.0 (0-20.0)	8.0 (0-17.0)	15.0 (4.0-24.3)	12.0 (0-20.0)	0.36
24	Pain score					
	At rest	4.0 (2.0-6.0)	4.0 (3.0-5.5)	4.5 (2.5-6.0)	3.0 (1.0-5.0)	0.02
	With movement	6.0 (4.0-8.0)	6.5 (5.0-8.0)	7.0 (5.0-8.0)	6.0 (2.0-7.0)	0.005
	Opioid usage	53.0 (16.0-104.5)	88.0 (34.5-143.0)	75.5 (30.5-121.8)	15.0 (0-30.0)	<0.001
48	Pain score					
	At rest	3.0 (2.0-5.0)	3.0 (1.0-5.0)	4.0 (2.0-6.0)	2.0 (1.0-4.0)	0.03
	With movement	5.0 (3.0-7.0)	5.0 (3.0-7.0)	6.0 (3.0-8.0)	4.0 (2.0-6.0)	0.009
	Opioid usage	47.5 (8.0-103.0)	90.5 (22.5-124.0)	89.5 (30.0-137.0)	10.0 (0-45.0)	<0.001
72	Pain score					
	At rest	2.0 (0.5-4.0)	3.0 (1.0-5.0)	2.0 (0-3.0)	1.5 (0.5-4.0)	0.22
	With movement	3.0 (2.0-6.0)	4.0 (2.0-8.0)	3.0 (2.0-5.0)	3.0 (2.0-6.0)	0.40
	Opioid usage	34.5 (15.0-75.0)	57.0 (18.0-96.0)	35.0 (15.0-89.0)	21.3 (7.5-45.0)	0.02

NOTE. Pain scores presented as median (interquartile range) pain at rest or with knee flexion using Visual Analog Scale from 0-10. Opioid usage is reported as morphine milligram equivalents (MME).
Abbreviations: PVB, paravertebral block; TEA, thoracic epidural analgesia.

Table 3
Survey Results to Assess for Chronic Pain 6 Months After Video-assisted Thoracoscopy With Thoracic Epidural or Paravertebral Block Techniques

Survey Question	Result				p Value
	Overall (N = 67)	Single-injection PVB (n = 23)	PVB Catheter (n = 22)	TEA (n = 22)	
Throughout our lives, most of us have had pain from time to time (such as minor headaches, sprains, and toothaches). Have you had pain other than these everyday kinds of pain today? Yes or No	23 (34.3%)	9 (39.1%)	8 (36.4%)	6 (27.3%)	0.68
Rate your pain that best describes your pain at its WORST in the last 24 hours. 0 = No pain; 10 = Pain as bad as you can imagine	0.5 (0-5)	0 (0-5)	1 (0-4)	1 (0-6)	0.83
Rate your pain that best describes your pain in the LEAST in the last 24 hours	0 (0-2)	0 (0-2)	0 (0-1)	0 (0-2)	0.84
Rate your AVERAGE pain	1 (0-4)	0 (0-4)	1 (0-4)	2 (0-4)	0.91
Rate your pain RIGHT NOW	0 (0-2)	0 (0-1)	0 (0-2)	0 (0-3)	0.44
In the last 24 hours, how much relief have pain treatments or medications provided? (1 = None, 2 = 10%, ..,10 = 90%, 11 = Complete)	9 (4-11)	9 (5-10)	8 (3-11)	9 (4-11)	0.83
What best describes how much pain has interfered in the past 24 hours with your GENERAL ACTIVITY. 0 = Does Not Interfere; 10 = Completely Interferes	0 (0-4)	0 (0-4)	2 (0-4)	0 (0-4)	0.81
What best describes how much pain has interfered in the past 24 hours with your MOOD? 0 = Does Not Interfere; 10 = Completely Interferes	0 (0-5)	0 (0-6)	0 (0-5)	0.5 (0-5)	0.91
What best describes how much pain has interfered in the past 24 hours with your WALKING ABILITY? 0 = Does Not Interfere; 10 = Completely Interferes	0 (0-3.5)	1 (0-5)	0 (0-3)	0 (0-4)	0.57
What best describes how much pain has interfered in the past 24 hours with your NORMAL WORK (WHICH INCLUDES BOTH WORK AND INSIDE THE HOME - HOUSEWORK)? 0 = Does Not Interfere; 10 = Completely Interferes	0.5 (0-5)	2 (0-7)	1 (0-4)	0 (0-6.5)	0.81
What best describes how much pain has interfered in the past 24 hours with your RELATIONS WITH OTHER PEOPLE? 0 = Does Not Interfere; 10 = Completely Interferes	0 (0-3.5)	0 (0-5)	0 (0-0)	0 (0-4.5)	0.36
What best describes how much pain has interfered in the past 24 hours with your SLEEP? 0 = Does Not Interfere; 10 = Completely Interferes	1 (0-5)	2 (0-5)	2 (0-4)	0 (0-5)	0.92
What best describes how much pain has interfered in the past 24 hours with your ENJOYMENT OF LIFE? 0 = Does Not Interfere; 10 = Completely Interferes	0 (0-4)	0 (0-7)	0 (0-1)	2 (0-4)	0.31

NOTE. Results presented as number of positive responses (percentage) or median (interquartile range).
Abbreviations: PVB, paravertebral block; TEA, thoracic epidural anesthesia.

patients were lost to follow-up. Chronic postsurgical pain indicators (based on 13 survey questions) were similar for all 3 groups ($p > 0.05$; Table 3).

Discussion

In this randomized prospective trial, the authors aimed to identify the superior regional anesthesia technique for VATS procedures. The previous literature on this topic included many heterogenous studies and lacked a clear standard of care. In this study, TEA produced lower postoperative pain scores and less opioid usage compared with either single-injection PVB or continuous catheter infusion PVB. However, the small difference in pain scores may not be clinically significant; therefore, either TEA or single-injection PVB are acceptable choices for regional anesthesia for VATS. One clear conclusion from this study is that PVB catheter placement is not justified given the lower efficacy, increased risks, and larger cost/time burden.

The secondary endpoints evaluated in this study (sedation, nausea, and patient satisfaction scores and incidence of chronic postsurgical pain) were similar for all groups. This was noteworthy because there was no disadvantage for TEA in these parameters. No adverse outcomes occurred in the 40 patients receiving TEA, which likely would have impacted patient satisfaction, although the relatively small cohorts might limit the broader application of these results, and larger studies may be needed. The potential for adverse effects (accidental dural puncture, neurologic dysfunction, epidural hematoma, hypotension, urinary retention, etc) from TEA warrants consideration of alternative techniques such as PVB. Similar patient satisfaction scores for PVB and TEA, despite lower pain scores for TEA, indicate that single-injection PVB is an acceptable alternative to TEA. This block may be preferable in higher-risk patients or in cases where TEA should be avoided. Because there was no difference in the incidence of chronic postsurgical pain between TEA and PVB, either technique would be acceptable when one considers chronic pain avoidance after surgery.

The comparison of PVB techniques yielded unexpected results, as the authors anticipated continuous infusion of ropivacaine through a paravertebral catheter to provide longer-lasting

analgesia than a single-injection PVB. However, these results showed no significant benefit in pain scores or opioid consumption for the catheter compared with single-injection PVB. This may be owing to the high-volume nature of the PVB block; therefore, continuous infusion of 10 mL/h might be less effective in providing analgesia.[24] Given these results, and the faster placement time for single-injection PVB, the authors would favor using the single-injection PVB for any patients who are not ideal candidates to receive TEA. Future studies might examine the use of liposomal bupivacaine in the PVB to determine if longer duration analgesia can be provided. The addition of dexmedetomidine might also prolong the analgesic effect, as Ding et al. recently showed that single-injection PVB with 0.5% ropivacaine and dexmedetomidine provided similar analgesia as TEA up to 48 hours postoperatively.[25]

Single-injection PVB is appealing because placement of indwelling catheters, either epidural or paravertebral, may be complicated by displacement, misplacement, and infection.[26] Although rare, infection from commensal skin flora may occur, and typically is seen in immunosuppressed patients.[27-29] Infections of this variety require a lengthy treatment course and a prolonged hospital stay, increasing the risk for additional nosocomial infections and further morbidity. Correct placement of catheters is more difficult in obese patients (body mass index $\geq$30 kg/m^2), and failure and difficulty rates in this population have been observed at 4.3% and 3.0%, respectively.[30]

One clear limitation of this study was that the number of subjects was not high enough to rigorously evaluate uncommon adverse events from TEA. Given the somewhat low subject numbers, the authors did not include rare adverse events in the outcomes. These potentially severe adverse events might still lead physicians to select PVB over TEA. Another possible study limitation is block placement error (eg, misidentification of landmarks). Precautions were taken to avoid errors, including the presence of a staff anesthesiologist (as opposed to a resident trainee—since the study was performed at an academic hospital) during the entire procedure. Also, ultrasonography was used for placement of all blocks, as it has been shown to be superior to manual palpation in terms of decreased puncture attempts, puncture levels, and needle redirections.[31] All blocks were assessed for effective nerve blockade in the postanesthesia care unit; therefore the authors do not anticipate that block failure impacted the study results. Additionally, the intraoperative medication course could not be standardized owing to patient-specific reactions to anesthesia, variations in operative pain, etc. VATS procedures were not performed by a single surgeon; therefore, variations in surgical technique and postoperative management may have affected outcomes. Different teams may have variable recognition of patient pain and, therefore, opioid dispensing; however, some bias was mitigated by the use of patient-controlled analgesia in the first 48-hour postoperative period.

In conclusion, pain scores and opioid consumption after VATS procedures were lower with TEA than either PVB technique. Although these results support TEA as the superior technique, the small difference in pain scores may not be clinically significant, and the risk of rare adverse events with TEA might lead one to consider single-injection PVB. In the authors' institution, single-injection PVB is performed for most VATS cases owing to the shorter placement time and lower risk for serious adverse events. Clearly, use of PVB catheters adds no benefit and cannot be justified.

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Conflict of Interest

The authors declare no conflicts of interest.

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