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Research Article

Keywords:

Posted Date: October 29th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11097990/v1

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Additional Declarations: No competing interests reported.

Comparison of Erector Spinae Plane Block and Retrolaminar Block for Postoperative Analgesia After Video-Assisted Thoracoscopic Surgery: A Randomized Controlled Trial

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Abstract

Background: This study aimed to compare postoperative pain intensity at rest, assessed using the Numerical Rating Scale (NRS) at 1, 6, 12, and 24 hours, between ultrasound-guided erector spinae plane (ESP) and retrolaminar blocks in patients undergoing video-assisted thoracoscopic surgery (VATS). Secondary outcomes included postoperative rescue analgesic requirements, time to first rescue analgesia, intraoperative remifentanil consumption, and adverse events.

Methods: In this prospective, randomized, assessor-blinded trial, 54 patients with American Society of Anesthesiologists (ASA) physical status I (n = 5) or II (n = 49) undergoing VATS were allocated to receive either an ESP block (n = 27) or a retrolaminar block (n = 27). Both blocks were performed under ultrasound guidance after induction of general anesthesia and before surgery, using 30 mL of 0.5% bupivacaine and 10 mL of 2% lidocaine (40 mL; dose reduced to bupivacaine 1 mg/kg and lidocaine 2 mg/kg in patients weighing < 60 kg). The primary outcome was pain intensity at rest, assessed using the NRS at 1, 6, 12, and 24 hours postoperatively. Rescue analgesia (tramadol, then diclofenac) was offered when NRS exceeded 4. Postoperative rescue analgesic requirements, intraoperative remifentanil consumption, and adverse events were recorded. Post hoc longitudinal sensitivity analyses were performed using a linear mixed-effects model and an ordinal generalized estimating equations model.

Results: NRS scores at rest did not differ significantly between the groups at any time point; the Hodges–Lehmann median differences (ESP minus retrolaminar) were 1 (95% CI, 0 to 3) at 1 hour (p = 0.069) and 0 (95% CI, 0 to 1) at 6, 12, and 24 hours (p = 0.941, 0.192, and 0.217, respectively). In a post hoc linear mixed-effects analysis, the group-by-time interaction was not significant (p = 0.117). Rescue analgesic requirements, total tramadol consumption (p = 0.854), and intraoperative remifentanil consumption across all randomized patients (p = 0.101) did not differ significantly between groups. No local anesthetic systemic toxicity or block-related complications were observed.

Conclusions: In patients undergoing VATS, no statistically significant differences in postoperative pain scores at rest or rescue analgesic requirements were observed between ESP

and retrolaminar blocks. However, the confidence intervals, particularly at the first postoperative hour, do not exclude clinically relevant differences, and these findings do not establish equivalence between the two techniques.

Trial registration: ClinicalTrials.gov, NCT07830290. Registered on 21 September 2026 – Retrospectively registered, https://clinicaltrials.gov/study/NCT07830290.

Background

Video-assisted thoracoscopic surgery (VATS) is associated with less postoperative pain than thoracotomy; nevertheless, many patients experience moderate-to-severe pain in the early postoperative period, arising from port-site incisions, intercostal nerve injury, and chest tube placement. Inadequate pain control may impair coughing and deep breathing, predispose to atelectasis and pulmonary complications, and prolong hospital stay [1]. Multimodal analgesia combining systemic analgesics with regional techniques is therefore recommended, as it reduces opioid requirements and opioid-related adverse effects such as nausea, vomiting, and respiratory depression [2].

Thoracic epidural analgesia and thoracic paravertebral block have traditionally been regarded as the reference regional techniques for thoracic surgery; however, both are technically demanding and are associated with risks such as hypotension, pneumothorax, and neuraxial complications. Current procedure-specific recommendations for VATS therefore favor paravertebral block or erector spinae plane (ESP) block as first-line regional techniques [2].

Fascial plane blocks performed posterior to the vertebral structures have gained interest as simpler and potentially safer alternatives. The ESP block, first described by Forero et al. in 2016, involves injection of local anesthetic deep to the erector spinae muscle at the tip of the transverse process [3]. The retrolaminar block, described by Pfeiffer et al. in 2006, involves injection onto the posterior surface of the lamina, closer to the midline and further from the pleura [4, 5]. The two techniques have been compared in breast surgery [6], but direct comparisons after VATS are scarce, and their relative efficacy in this setting remains uncertain.

The primary aim of this study was to compare postoperative pain intensity at rest, assessed using the Numerical Rating Scale (NRS) at 1, 6, 12, and 24 hours, between ultrasound-guided ESP and retrolaminar blocks in patients undergoing VATS. Secondary aims were to compare postoperative rescue analgesic requirements, time to first rescue analgesia, intraoperative remifentanil consumption, and adverse events between the two techniques.

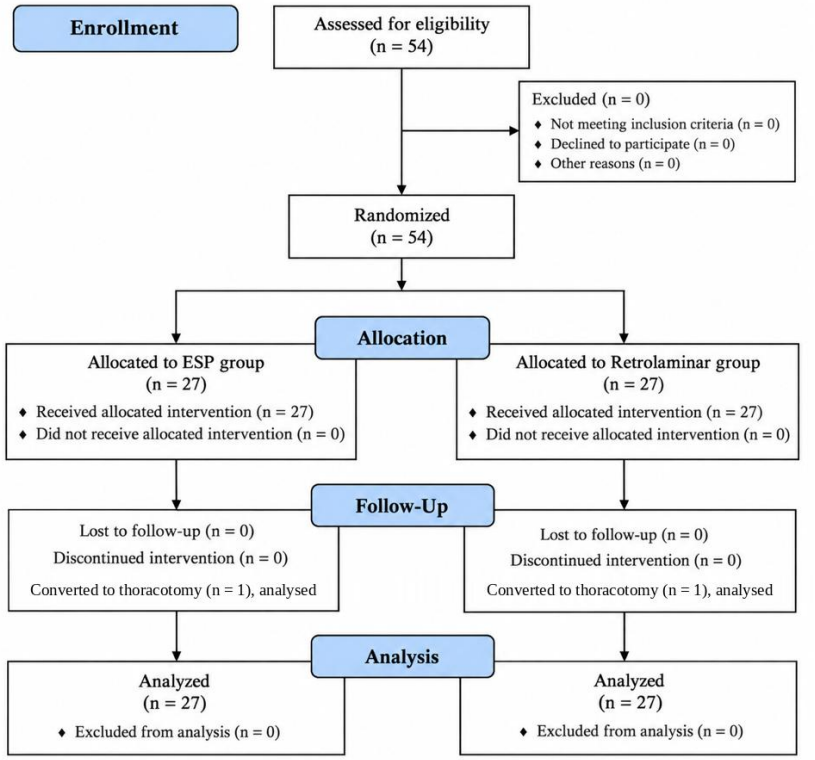
METHODS

This study was designed as a prospective, randomized, assessor-blinded, parallel-group controlled trial with a 1:1 allocation ratio. The study commenced after obtaining approval from the Clinical Research Ethics Committee of Gulhane Training and Research Hospital, Health Sciences University (ethical committee decision number 2023/54, dated March 15, 2023). The first participant was enrolled on 20 March 2023, and recruitment was completed in May 2023, when the planned sample size had been reached; all patients were recruited from the Thoracic Surgery Clinic of Gulhane Training and Research Hospital. The trial was not registered prospectively because, at the time of study initiation, the investigators were not aware that prospective registration was required for investigator-initiated trials of this type.

The trial was subsequently registered retrospectively at ClinicalTrials.gov (NCT07830290; first submitted on 14 September 2026 and first posted on 21 September 2026). The variables to be recorded were specified in the study protocol approved by the ethics committee before enrolment of the first participant, and this protocol has been provided to the journal. Participants were followed for 24 hours postoperatively for the assessment of the prespecified study outcomes. Due to the nature of the interventions, the anesthesiologist performing the block could not be blinded to group allocation. However, the attending anesthesiologist responsible for intraoperative management (including remifentanil administration), the investigator responsible for postoperative NRS assessments, and the clinician responsible for decisions regarding rescue analgesia were all blinded to group allocation. Participants were randomized in a 1:1 ratio to either the ESP or retrolaminar group using a computer-generated simple randomization sequence, without stratification or blocking. Allocation concealment was achieved using sealed, opaque envelopes containing the group assignments. The randomization sequence was generated, and the sealed, opaque envelopes were prepared and opened, by an individual who was not involved in the study procedures. The investigators responsible for participant enrollment did not have access to the randomization sequence and were unaware of the upcoming group assignment. This study was conducted and reported in accordance with the CONSORT (Consolidated Standards of Reporting Trials) guidelines. Patients and the public were not involved in the design, conduct, or reporting of this study. The ethics-approved protocol specified the variables to be recorded, including NRS scores at 1, 6, 12, and 24 hours, rescue analgesic use, intraoperative remifentanil use, and adverse events. but did not formally designate primary and secondary outcomes. No outcome measures were added or changed after trial commencement. One modification of the intervention was introduced after trial commencement: a reduction of the local anesthetic dose in patients weighing less than 60 kg (see Anesthesia Protocol). In addition, the ethics-approved protocol specified weekly randomization and no blinding; in practice, individual computer-generated randomization with sealed opaque envelopes and blinding of the attending anesthesiologist and the outcome assessor were used, as described below. Analyses that were not planned before recruitment are explicitly identified as post hoc in this manuscript.

The study included volunteer patients aged 18-81 years with ASA scores I-II who were to undergo VATS surgery. Patients with decompensated liver, heart, or kidney failure, ASA physical status > II, a body mass index > 35 or < 18 kg/m², bleeding diathesis, or known drug allergy, and pregnant patients were excluded from the study. Patients who declined participation were also excluded. Three patients whose body mass index was outside the prespecified range (35.6, 17.9, and 17.4 kg/m²; one in the ESP group and two in the retrolaminar group) were inadvertently enrolled; they were retained in the analysis according to their randomized allocation. After obtaining detailed written consent from all patients, they were included in the study. A total of 54 patients were assessed for eligibility and enrolled. No patients were excluded before randomization. All 54 patients were randomized in a 1:1 ratio to either the ESP group (n=27) or the retrolaminar group (n=27). All patients received their allocated intervention and completed the postoperative follow-up. No patients were lost to follow-up or excluded from the analysis; therefore, 27 patients in each group were included in the final analysis **(Figure 1).**

Figure 1. Flow diagram of patient enrollment, allocation, follow-up, and analysis.



Anesthesia Protocol

Following the application of standard intraoperative monitoring, general anesthesia was induced using intravenous propofol, fentanyl, and rocuronium in both groups. Anesthesia was subsequently maintained with 2% sevoflurane. Depth of anesthesia was monitored with the bispectral index (target 40–60), and neuromuscular blockade with train-of-four monitoring. Intraoperative remifentanil was not administered routinely, and no standardized protocol was used for its initiation or titration. When used, remifentanil was administered as a continuous intravenous infusion; the decision to start the infusion, as well as its rate and titration, was left entirely to the attending anesthesiologist responsible for intraoperative care, based on his or her clinical judgment and experience. No nociception-monitoring device (e.g., Analgesia Nociception Index, Surgical Pleth Index, or Nociception Level index) was used. The attending anesthesiologist was blinded to the type of block performed: the blocks were performed by a separate anesthesiologist who was not involved in intraoperative management, the attending anesthesiologist was not present during block performance, and the puncture site was covered with an identical sterile dressing in both groups. Approximately 30 minutes before completion of the surgical procedure, all patients received 1 g of intravenous paracetamol for postoperative analgesia. At the end of the procedure, residual neuromuscular blockade was reversed using sugammadex, followed by tracheal extubation after adequate recovery from anesthesia.

All blocks were performed by the same anesthesiologist, who was experienced in ultrasound-guided regional anesthesia and was not involved in intraoperative anesthetic management. Blocks were performed unilaterally on the surgical side, after induction of general anesthesia and before surgical incision, under sterile conditions, using a 100-mm, 21-gauge block needle.

A 100-mm needle was chosen as a standard needle for both techniques because the target may be deeply located in patients with a higher body mass index, and because the retrolaminar approach may require a longer needle trajectory to reach the lamina. Correct needle-tip position was confirmed by hydrodissection with 3 mL of 0.9% saline, which was not included in the local anesthetic volume. The local anesthetic injectate consisted of 30 mL of 0.5% bupivacaine (150 mg) and 10 mL of 2% lidocaine (200 mg), giving a total volume of 40 mL. During the study, after the enrolment of the first patient weighing less than 60 kg, the investigators decided, for safety reasons, to reduce the dose in patients weighing less than 60 kg to bupivacaine 1 mg/kg and lidocaine 2 mg/kg, diluted with 0.9% saline to the same total volume of 40 mL. This modification was not part of the ethics-approved protocol and was applied to all four patients weighing less than 60 kg (three in the retrolaminar group and one in the ESP group). Lidocaine and bupivacaine were combined to obtain a faster onset of action (lidocaine) together with a longer duration of analgesia (bupivacaine). With this regimen, the weight-adjusted dose did not exceed 2.5 mg/kg for bupivacaine or 3.4 mg/kg for lidocaine; however, because the systemic toxicity of local anesthetics is additive, the combined dose was high, and particular attention was paid to the prevention and detection of LAST (see below). The same regimen was used in both groups.

Ultrasound-guided ESP block

In Group ESP patients, the block was performed in the lateral position after induction of general anesthesia. A high-frequency linear ultrasound probe (SonoSite, Bothell, WA, USA) was placed in a parasagittal orientation approximately 3 cm lateral to the midline at the T5 level to visualize the T5 transverse process and the overlying erector spinae muscle. The needle was inserted in-plane in either a cranial-to-caudal (n = 9) or a caudal-to-cranial (n = 18) direction, according to the operator's preference, until its tip contacted the transverse process deep to the erector spinae muscle. Correct needle-tip position was confirmed by hydrodissection, after which the local anesthetic mixture was injected into the plane deep to the erector spinae muscle.

Ultrasound-guided Retrolaminar block

In Group Retrolaminar patients, the block was performed in the lateral position after induction of general anesthesia, using the same ultrasound probe. The probe was placed transversely at the T5 level to visualize the spinous process, lamina, and transverse process [5]. The needle was inserted in-plane in a lateral-to-medial direction until its tip contacted the lamina. Correct needle-tip position was confirmed by hydrodissection, after which the local anesthetic mixture was injected onto the posterior surface of the lamina.

Prevention and monitoring of local anesthetic systemic toxicity

To prevent local anesthetic systemic toxicity (LAST), the local anesthetic mixture was injected slowly in divided doses of 5 mL, with aspiration before each injection, under continuous ultrasound visualization. As the blocks were performed under general anesthesia, which may mask early neurological symptoms, patients were monitored for cardiovascular signs of LAST, including arrhythmias, electrocardiographic changes, and sudden hemodynamic instability, using continuous electrocardiography, pulse oximetry, and non-invasive blood pressure monitoring throughout surgery and in the PACU. A 20% lipid emulsion was immediately available.

Surgical technique

All procedures were performed using a two-port VATS technique, and a single 32 Fr chest drain was placed at the end of surgery in all patients.

Postoperative Pain Management Protocol

For postoperative analgesia, all patients received 1 g of intravenous paracetamol approximately 30 minutes before the end of surgery. Pain intensity at rest was assessed using the NRS at the scheduled time points (1, 6, 12, and 24 hours after the end of surgery). In addition, patients were assessed in the post-anesthesia care unit (PACU) immediately after surgery, and rescue analgesia was offered whenever the NRS score exceeded 4. Rescue analgesia followed the routine protocol of our department: intravenous tramadol 100 mg as the first-line rescue analgesic; a second dose of intravenous tramadol 100 mg if the NRS score again exceeded 4 at a subsequent assessment; and intramuscular diclofenac 75 mg if the NRS score exceeded 4 after the second tramadol dose. In four patients (two in each group), rescue analgesia was not administered despite an NRS score above 4 at a scheduled assessment because the patient declined additional analgesic medication; these patients were analysed according to the analgesics actually received. In one patient in the retrolaminar group, a third dose of intravenous tramadol 100 mg was administered by the ward nursing staff 240 minutes after surgery for persistent pain (NRS > 4), after diclofenac had been given; this deviated from the predefined protocol, and the dose was included in the analysis of total tramadol consumption. Pethidine (20 mg intravenously) was administered only to patients with postoperative shivering and was not part of the rescue analgesia protocol. Because tramadol was always the first rescue analgesic, time to first rescue analgesia was defined as the interval from the end of surgery to the first administration of tramadol. NRS assessments were performed by an investigator blinded to group allocation.

Data collection

Primary outcome

The primary outcome was postoperative pain intensity at rest, assessed using the 11-point Numerical Rating Scale (NRS; 0 = no pain, 10 = worst imaginable pain) at 1, 6, 12, and 24 hours after the end of surgery. NRS assessment at these four time points was listed in the ethics-approved protocol and was considered the main outcome of the study from the outset; no single time point was designated as the principal time point. Between-group comparisons at each of the four time points constituted the planned primary analyses. Because four comparisons were performed, the results were additionally interpreted against a Bonferroni-adjusted significance threshold of $p < 0.0125$ (0.05/4).

Secondary outcome

Secondary outcomes were (1) the proportion of patients requiring rescue analgesia (first and second doses of tramadol and diclofenac) during the first 24 postoperative hours; (2) total postoperative tramadol consumption over 24 hours; (3) time to first rescue analgesia; (4) the proportion of patients receiving intraoperative remifentanil and total intraoperative remifentanil consumption; and (5) perioperative adverse events, including intraoperative hypotension, hypertension, bradycardia, and tachycardia, postoperative nausea and vomiting, hematoma, and signs of local anesthetic systemic toxicity. Block performance time and the number of needle attempts were recorded as procedural characteristics.

Statistical analysis

A sample size of 27 patients per group (54 in total) was planned before the start of recruitment. As no randomized trial directly comparing erector spinae plane and retrolaminar blocks in patients undergoing VATS was available at the time of study planning, the randomized controlled trial by Sotome et al. in patients undergoing breast surgery [6] was used as the reference, with a two-sided significance level of 0.05 and a target power of 80%. The ethics application stated that the sample size was determined by power analysis with a two-sided α of 0.05 and a power of 80%, using standard deviations reported in previous studies, and targeted 27 patients per group (with an upper estimate of 60 volunteers); however, the expected between-group difference and the standard deviation used were not specified, and the original calculation could not be retrieved. To aid interpretation, we therefore report the smallest effect detectable with the achieved sample size: with 27 patients per group, a two-sided α of 0.05, and 80% power, the study was able to detect a standardized between-group difference of approximately 0.78 (Cohen's d). Based on the pooled standard deviations observed in this study, this corresponds to approximately 0.8 NRS points at 24 hours and 1.7 NRS points at 1 hour. Smaller differences, including some that might be clinically relevant, cannot be excluded. The interpretation of the results is therefore based primarily on the between-group effect estimates and their 95% confidence intervals rather than on p values.

All randomized participants were included in the analyses according to their originally assigned groups. There were no missing data for the prespecified outcomes; therefore, no imputation was required.

Continuous data are presented as mean ± standard deviation, together with median and minimum–maximum values, whereas categorical data are presented as frequencies and percentages. The normality of continuous variables was assessed using the Shapiro–Wilk test.

Postoperative NRS scores were compared between the ESP and retrolaminar groups separately at 1, 6, 12, and 24 hours using the Mann–Whitney U test. Between-group differences were estimated as Hodges–Lehmann median differences (ESP minus retrolaminar) with 95% confidence intervals. Changes in NRS scores over time within each group were evaluated using the Friedman test, followed by post hoc pairwise comparisons when appropriate. These analyses constituted the originally planned approach to evaluating postoperative pain scores. As four separate between-group comparisons were performed for the primary outcome, the potential for multiple testing was considered when interpreting the results. No formal adjustment for multiple comparisons was applied to these analyses; instead, as described above, the results were additionally interpreted against a Bonferroni-adjusted threshold ($p < 0.0125$).

A post hoc linear mixed-effects model was fitted to evaluate postoperative NRS scores across the four assessment time points. The model included treatment group, time (treated as a categorical variable), and the group-by-time interaction as fixed effects, with a patient-specific random intercept to account for repeated measurements. The group-by-time interaction was evaluated using a joint Wald test. An estimated between-group contrast averaged equally across the four assessment time points was also calculated, with its 95%

confidence interval. Model assumptions were assessed using residual diagnostics. This analysis was conducted after completion of the trial and was not specified in a prospective statistical analysis plan. As an additional post hoc sensitivity analysis accounting for the ordinal nature of NRS scores, a cumulative logit ordinal generalized estimating equations (GEE) model was fitted. The model included treatment group, categorical time, and their interaction, with an exchangeable working correlation structure and robust standard errors to account for repeated measurements within patients. The group-by-time interaction was evaluated using a joint Wald test. A post hoc sensitivity analysis excluding the three patients enrolled outside the prespecified body mass index range was performed for the primary outcome and total tramadol consumption.

For comparisons between the two groups, the independent-samples t test was applied to normally distributed continuous variables, whereas the Mann–Whitney U test was used for variables that did not meet the assumption of normality. Categorical variables were compared using Pearson's chi-square test, Fisher's exact test, or the Fisher–Freeman–Halton exact test for contingency tables larger than 2 × 2, as appropriate.

Intraoperative remifentanil consumption was compared between the groups using the Mann–Whitney U test, including all randomized patients, with zero consumption assigned to those who did not receive remifentanil. The proportion of patients requiring intraoperative remifentanil was compared using Fisher's exact test.

The original statistical analyses were performed using IBM SPSS Statistics for Windows, version 20.0 (IBM Corp., Armonk, NY, USA). Analyses added or recalculated during revision, including Hodges–Lehmann estimates, Fisher–Freeman–Halton exact tests, and the re-analysis of the corrected rescue analgesia data, were performed in Python (version 3.13) using SciPy (version 1.18.1), and the post hoc longitudinal analyses were performed using the statsmodels package (version 0.14.6). A two-sided p value of less than 0.05 was considered statistically significant.

RESULTS

A total of 54 patients (12 women [22.2%] and 42 men [77.8%]) aged 19–79 years who underwent VATS under general anesthesia were included in the study and randomized to the ESP group (n = 27) or the retrolaminar group (n = 27). Demographic characteristics were comparable between the groups (Table 1). Five (9.3%) were classified as ASA I and 49 (90.7%) as ASA II, with no significant difference in distribution between the retrolaminar and ESP groups (14.8% vs. 3.7% ASA I; p = 0.351). The most common procedures were wedge resection (42.6%) and lobectomy or segmentectomy (40.7%), and the distribution of surgical procedures did not differ between groups (p = 0.544); in particular, the number of patients undergoing anatomical lung resection was identical in the two groups (11 vs. 11). The durations of surgery and anesthesia were also similar between groups (p = 0.562 and p = 0.735, respectively) (Table 2). All patients underwent two-port VATS and had a single 32 Fr chest drain placed at the end of surgery. Conversion to thoracotomy occurred in one patient in each group; both patients were retained in the analysis according to their randomized allocation. Block performance time and the number of needle attempts did not differ significantly between groups (Table 2).

Intraoperative hemodynamic adverse events were recorded in both groups. Hypotension occurred in 2 patients (7.4%) in the retrolaminar group and 5 patients (18.5%) in

the ESP group. Hypertension occurred in 3 (11.1%) and 1 (3.7%) patients, bradycardia in 2 (7.4%) and 4 (14.8%) patients, and tachycardia in 1 (3.7%) patient in each group, respectively. Postoperative nausea was observed in one patient (3.7%) in the retrolaminar group and in none of the ESP group patients. No signs or symptoms of local anesthetic systemic toxicity were observed in either group.

Table 1. Comparison of characteristics of patients who underwent Retrolaminar and ESP blocks.

	Total (n=54)		Retrolaminar (n=27)		ESP (n=27)		Test Statistic	p
	Avg ± SD Median (Min-Max)		Avg ± SD Median (Min-Max)		Avg ± SD Median (Min-Max)			
Age	51.69±17.87 55 (19-79)		50.30±16.59 50 (21-75)		53.07±19.28 59 (19-79)		t=-0.567 [a]	0.573
Height	1.71±0.09 1.70 (1.53-1.90)		1.70±0.08 1.70 (1.53-1.87)		1.71±0.10 1.70 (1.53-1.90)		t=-0.390 [a]	0.698
Weight	76.39±11.46 75.5 (50-100)		76.30±11.33 77 (50-100)		76.48±11.81 75 (53-100)		t=-0.059 [a]	0.953
BMI	26.38±4.51 26.62(17.37-35.63)		26.40±3.98 26.51(17.37-34.17)		26.37±5.06 27.10(18.52-35.63)		t=-0.026 [a]	0.980
	n	**%**	**n**	**%**	**n**	**%**		
Gender								
Female	12	22.2	7	25.9	5	18.5	χ^2 =0.429 [b]	0.513
Male	42	77.8	20	74.1	22	81.5		
ASA physical status							Fisher's exact	0.351
I	5	9.3	4	14.8	1	3.7		
II	49	90.7	23	85.2	26	96.3		
Intraoperative hypotension								
Yes	7	13.0	2	7.4	5	18.5	χ^2 =1.477 [b]	0.420
Intraoperative hypertension								
Yes	4	7.4	3	11.1	1	3.7	χ^2 =1.080 [b]	0.610
Intraoperative bradycardia								
Yes	6	11.1	2	7.4	4	14.8	χ^2 =0.750 [b]	0.669
Intraoperative tachycardia								
Yes	2	3.7	1	3.7	1	3.7	χ^2 =0.000 [b]	1.000
PACU Nausea								
Yes	1	1.9	1	3.7	0	0	Fisher's Exact test	1.000

a:Student's t test (Independent Samples t test) b:Chi -Square test/Fisher's Exact test

Table 2. Surgical and block-related characteristics of patients who received retrolaminar and ESP blocks.

	Total (n=54)		**Retrolaminar (n=27)**		**ESP (n=27)**		**Test Statistic**	**p**
Surgical characteristics	n	%	n	%	n	%		

	Total (n=54)		Retrolaminar (n=27)		ESP (n=27)		Test Statistic	p
Type of surgery								
Wedge resection	23	42.6	11	40.7	12	44.4	FFH [e]	0.544
Upper lobectomy	12	22.2	4	14.8	8	29.6		
Segmentectomy or middle/lower lobectomy	10	18.5	7	25.9	3	11.1		
Pleural biopsy	3	5.6	1	3.7	2	7.4		
Paracardiac cyst excision	2	3.7	2	7.4	0	0		
Mediastinal lymph node excision	2	3.7	1	3.7	1	3.7		
Nodule excision	2	3.7	1	3.7	1	3.7		
Anatomical lung resection [f]	22	40.7	11	40.7	11	40.7	Fisher's exact	1.000
Operation side								
Left	25	46.3	13	48.1	12	44.4	$\chi^2 = 0.074$ [b]	0.785
Right	29	53.7	14	51.9	15	55.6		
Conversion to thoracotomy	2	3.7	1	3.7	1	3.7	Fisher's exact	1.000
	Avg ± SD, Median (Min–Max)		Avg ± SD, Median (Min–Max)		Avg ± SD, Median (Min–Max)			
Duration of surgery (min)	142.22 ± 70.11, 125 (25–300)		137.22 ± 68.28, 120 (50–300)		147.22 ± 72.85, 140 (25–285)		U = 331.0 [c]	0.562
Duration of anesthesia (min)	162.13 ± 73.23, 150 (40–330)		159.26 ± 71.65, 150 (60–330)		165.00 ± 76.03, 150 (40–315)		U = 345.0 [c]	0.735
Block characteristics	Avg ± SD, Median (Min–Max)		Avg ± SD, Median (Min–Max)		Avg ± SD, Median (Min–Max)			
Block performance time (min)	2.68 ± 1.31, 2 (1–6)		3.02 ± 1.44, 3 (1–5)		2.33 ± 1.07, 2 (1–6)		U = 268.0 [c]	0.072
Bupivacaine dose (mg) [g]	142.72 ± 25.97, 150 (50–150)		139.04 ± 31.60, 150 (50–150)		146.41 ± 18.67, 150 (53–150)		U = 336.0 [c]	0.278
Bupivacaine dose (mg/kg)	1.87 ± 0.33, 1.94 (1.00–2.50)		1.80 ± 0.33, 1.88 (1.00–2.14)		1.94 ± 0.33, 2.00 (1.00–2.50)		U = 285.0 [c]	0.168
Lidocaine dose (mg) [g]	192.85 ± 25.52, 200 (100–200)		189.19 ± 31.18, 200 (100–200)		196.52 ± 18.09, 200 (106–200)		U = 336.0 [c]	0.278
Lidocaine dose (mg/kg)	2.54 ± 0.33, 2.58 (2.00–3.33)		2.48 ± 0.27, 2.50 (2.00–2.86)		2.61 ± 0.38, 2.67 (2.00–3.33)		U = 286.0 [c]	0.173
Number of needle attempts	n	%	n	%	n	%		
1	37	68.5	17	63.0	20	74.1	FFH [e]	0.766
2	15	27.8	9	33.3	6	22.2		
3	2	3.7	1	3.7	1	3.7		

[b] Chi-square test/Fisher's exact test; [c] Mann–Whitney U test; [e] Fisher–Freeman–Halton exact test; [f] lobectomy or segmentectomy; [g] 30 mL of 0.5% bupivacaine (150 mg) and 10 mL of 2% lidocaine (200 mg); reduced to 1 mg/kg and 2 mg/kg, respectively, in patients weighing < 60 kg (n = 4).

Intraoperative remifentanil was administered to 3 patients (11.1%) in the retrolaminar group and 9 patients (33.3%) in the ESP group, with no statistically significant difference in the proportion of patients receiving remifentanil (Fisher's exact test, p = 0.099). When all randomized patients were included, total remifentanil consumption did not differ significantly between groups (41.48 ± 152.31 µg vs. 24.44 ± 44.84 µg, respectively; p = 0.101). Among patients who received remifentanil, the administered dose was higher in the retrolaminar group (373.33 ± 340.20 µg vs. 73.33 ± 50.00 µg, respectively; p = 0.027). This comparison was restricted to patients who received remifentanil, a post-randomization subgroup of only three and nine patients, respectively; it was not planned before recruitment and is reported as post hoc only. Total postoperative tramadol consumption did not differ significantly between the retrolaminar and ESP groups (144.44 ± 80.06 mg vs. 148.15 ± 70.00 mg, respectively; p = 0.854) (Table 4). A second dose of tramadol was required in 15 (55.6%) and 16 (59.3%) patients, and diclofenac in 8 (29.6%) and 3 (11.1%) patients, respectively, with no significant differences between groups (Table 3). One patient in the retrolaminar group received a third dose of tramadol outside the predefined protocol; this dose was included in the analysis of total tramadol consumption. Four patients (two in each group) declined rescue analgesia offered for an NRS score above 4 at a scheduled assessment. Pethidine (20 mg IV) was administered for postoperative shivering to six patients (22.2%) in the retrolaminar group and eight patients (29.6%) in the ESP group, with no significant difference between groups (p = 0.535) (Table 3).

Table 3. Comparison of analgesic use rates in patients underwent Retrolaminar and ESP blocks.

	Total(n=54)		Retrolaminar (n=27)		ESP (n=27)		Test Statistic	p
	n	**%**	**n**	**%**	**n**	**%**		
Patients requiring intraoperative remifentanil	12	22.2	3	11.1	9	33.3	Fisher's exact test	0.099
First dose of tramadol								
Yes	47	87.0	23	85.2	24	88.9	Fisher’s exact test	1.000
Second dose of tramadol								
Yes	31	57.4	15	55.6	16	59.3	$\chi^2 = 0.076$ [b]	0.783
Third dose of tramadol[ı]								
Yes	1	1.9	1	3.7	0	0	Fisher’s exact test	1.000
Diclofenac								
Yes	11	20.4	8	29.6	3	11.1	$\chi^2 = 2.854$[b]	0.091

Pethidine for shivering (20 mg IV)								
Yes	14	25.9	6	22.2	8	29.6	$\chi^2 = 0.386$ [b]	0.535

[b] Chi-square test; [l] administered outside the predefined rescue analgesia protocol.

Table 4. Comparison of analgesic doses and timing in patients underwent Retrolaminar and ESP blocks.

	Total(n=54)	Retrolaminar (n=27)	ESP (n=27)	Test Statistic	p value
	Avg ± SD Median (Min-Max)	Avg ± SD Median (Min-Max)	Avg ± SD Median (Min-Max)		
Remifentanil consumption, all patients (µg)	32.96 ± 111.54	41.48 ± 152.31	24.44 ± 44.84	U=295.5[c]	0.101
Remifentanil consumption, recipients only (µg)	148.33±203.15 80 (20-760)	373.33±340.20 240 (120-760)	73.33±50.00 60 (20-180)	U=1.5[c]	**0.027**
Total postoperative tramadol consumption (mg)	146.30 ± 74.51 200 (0–300)	144.44 ± 80.06 200 (0–300)	148.15 ± 70.00 200 (0–200)	U = 355.0 [c]	0.854
Time to first tramadol administration (min)	109.47 ± 132.61 60 (5–540)	119.13 ± 143.45 60 (5–480)	100.21 ± 123.71 60 (5–540)	U = 275.0 [c]	0.983
Time to second tramadol administration (min)	352.90 ± 323.15 200 (60–1200)	366.00 ± 311.56 240 (60–1200)	340.62 ± 343.40 180 (60–1200)	U = 109.0 [c]	0.663
Time to diclofenac administration (min)	362.73 ± 230.13 360 (120–800)	378.75 ± 256.93 270 (150–800)	320.00 ± 173.21 420 (120–420)	U = 10.0 [c]	0.682

Time to first and second tramadol administration was analysed only among patients who received the respective doses (first: n = 47; second: n = 31), and time to diclofenac only among patients who received diclofenac (n = 11). Total tramadol consumption and intraoperative remifentanil consumption were analysed in all randomized patients (n = 54), with zero assigned to patients who did not receive the respective drug.

Postoperative NRS scores at rest did not differ significantly between the retrolaminar and ESP groups at any of the assessed time points: 1 hour (p=0.069), 6 hours (p=0.941), 12 hours (p=0.192), and 24 hours (p=0.217) (Table 5). Within-group analysis using the Friedman test demonstrated a significant change in NRS scores over time in both the retrolaminar and ESP groups (both p<0.001), with NRS scores decreasing over the 24-hour postoperative period. Post hoc pairwise comparisons are presented in Table 5. In an additional post hoc linear mixed-effects analysis, postoperative NRS scores decreased over time in both groups. The group-by-time interaction was not statistically significant (p = 0.117), indicating that there was insufficient evidence of a difference in postoperative pain trajectories between the two groups. The estimated between-group difference averaged across the four assessment time points (ESP minus retrolaminar) was 0.50 NRS points (95% CI, 0.02 to 0.98; p = 0.043). These findings should be interpreted cautiously because the longitudinal analysis was conducted post hoc and the model residuals showed some deviation from normality. In an additional post hoc sensitivity analysis using an ordinal generalized estimating equations model, the group-by-time interaction was not statistically significant (Wald $\chi^2(3) = 5.17$, p =

0.160). This finding was consistent with the linear mixed-effects analysis and did not provide evidence of a statistically significant difference in postoperative pain trajectories between the groups. In the sensitivity analysis excluding the three patients enrolled outside the prespecified body mass index range (n = 51), the results were unchanged (all p > 0.05; Hodges–Lehmann median differences 1 [95% CI, 0 to 3] at 1 hour and 0 or 1 [95% CI, 0 to 1] at 6, 12, and 24 hours; total tramadol consumption p = 0.815).

Table 5. Comparison of postoperative Numerical Rating Scale scores at rest between the retrolaminar and erector spinae plane block groups at 1, 6, 12, and 24 hours.

	Retrolaminar	ESP			
	Avg ± SD Median (Min-Max)	Avg ± SD Median (Min-Max)	Test Statistic	HL median difference (95% CI) [e]	p
NRS 1. hr	4.11±1.99 3 (2-8)	5.33±2.40 6 (1-9)	261.0 [c]	1 (0 to 3)	0.069
NRS 6. hr	3.22±1.19 3 (2-7)	3.15±1.17 3 (0-7)	360.5 [c]	0 (0 to 1)	0.941
NRS 12. hr	2.22±1.28 2 (1-6)	2.70±1.54 2 (0-6)	291.5 [c]	0 (0 to 1)	0.192
NRS 24. hr	1.15±0.95 1 (0-3)	1.52±1.05 1 (0-3)	296.0 [c]	0 (0 to 1)	0.217
Test Statistic [d]	50.723	44.047			
p	**<0.001**	**<0.001**			
Post hoc	1.hr-6.hr p=1.000	1.hr-6.hr p=0.122			
	1.hr-12.hr p=0.007	1.hr-12.hr p=0.004			
	1.hr-24.hr p<0.001	1.hr-24.hr p<0.001			
	6.hr-12.hr p=0.092	6.hr-12.hr p=1.000			
	6.hr-24.hr p<0.001	6.hr-24.hr p=0.001			
	12.hr-24.hr p=0.019	12.hr-24.hr p=0.050			

c:Mann Whitney U test, d:Friedman test, [e] Hodges–Lehmann estimate of the median difference (ESP minus retrolaminar) with 95% confidence interval.

Values are presented as mean ± standard deviation and median (minimum–maximum). Between-group comparisons were performed using the Mann–Whitney U test, and within-group comparisons over time were performed using the Friedman test. Additional post hoc longitudinal analyses using a linear mixed-effects model and an ordinal generalized estimating equations model are reported in the Results section.

DISCUSSION

In this randomized controlled trial, we compared ultrasound-guided ESP and retrolaminar blocks in patients undergoing VATS. Postoperative pain scores at rest did not differ

significantly between the two groups at any of the four prespecified time points. The Hodges–Lehmann estimates of the between-group median difference (ESP minus retrolaminar) were 1 point (95% CI, 0 to 3) at 1 hour and 0 points (95% CI, 0 to 1) at 6, 12, and 24 hours, and none of the comparisons reached statistical significance, whether or not a Bonferroni-adjusted threshold was applied. Notably, the upper confidence limit of 3 points at 1 hour indicates that a clinically relevant difference in early postoperative pain cannot be excluded. Pain scores decreased over time in both groups. In a post hoc linear mixed-effects analysis, the group-by-time interaction was not significant, but the model estimated a small average difference of 0.50 NRS points in favor of the retrolaminar group (95% CI, 0.02 to 0.98). Because this analysis was not prespecified, its assumptions were not fully met, and the corresponding ordinal model did not confirm a difference, we regard this finding as hypothesis-generating only. Rescue analgesic requirements and intraoperative remifentanil consumption across all randomized patients also did not differ significantly between groups. As our study was able to detect only moderate-to-large differences, these results should not be interpreted as evidence of equivalence between the two techniques.

The analgesic effects of ESP and retrolaminar blocks may be explained by the distribution of injectate within the thoracic paraspinal region. In a cadaveric study of the ESP block, Ivanusic et al. observed extensive craniocaudal spread deep to the erector spinae muscle involving the dorsal rami, with limited spread to the ventral rami and paravertebral space [7]. In a direct comparison using magnetic resonance imaging and cadaveric dissection, Adhikary et al. reported that both ESP and retrolaminar injections could reach the paravertebral and epidural spaces, but the ESP injection produced more extensive craniocaudal and lateral spread, including spread into the intercostal spaces, whereas retrolaminar injectate remained more localized around the laminae [8]. These differences suggest that the two techniques may provide analgesia through partially overlapping mechanisms. However, because sensory distribution was not assessed in our patients, the relationship between injectate spread and clinical analgesic effect cannot be established from our data.

To our knowledge, the most directly comparable study is the three-arm randomized noninferiority trial by Zhu et al., which compared ESP, retrolaminar, and paravertebral blocks, each performed with 20 mL of 0.5% ropivacaine, in 76 patients undergoing single-incision VATS [9]. Using the area under the curve of NRS scores at rest and during coughing over 24 hours as the primary outcome, both ESP and retrolaminar blocks were noninferior to paravertebral block, and the values in the ESP and retrolaminar groups were similar (107.8 ± 10.5 and 104.8 ± 8.1, respectively). In addition, no differences were found among the three groups in intraoperative remifentanil consumption, 24-hour morphine consumption, time to first analgesic request, or quality of recovery [9]. These findings are consistent with our observation that postoperative pain scores and rescue analgesic requirements did not differ significantly between ESP and retrolaminar blocks. However, the two studies differ in several respects. Zhu et al. compared each technique with paravertebral block rather than directly with each other, used a single local anesthetic at a lower volume, administered remifentanil routinely under bispectral index guidance, and provided postoperative patient-controlled analgesia. In contrast, all patients in our study underwent two-port rather than single-incision VATS, and we used a larger volume of a lidocaine–bupivacaine mixture, non-standardized intraoperative remifentanil, and a stepwise rescue protocol. In both studies, blocks were performed after induction of general anesthesia, which precluded the assessment of sensory block extent [9].

Other clinical studies have reported varying findings depending on the surgical population and the outcomes evaluated. Sotome et al. compared ESP and retrolaminar blocks in 45 patients undergoing breast surgery, using 20 mL of 0.375% levobupivacaine at the T4 level, and found no significant differences in time to first rescue analgesia (the primary outcome), intraoperative remifentanil consumption, or resting pain scores during the first 24 postoperative hours [6]. In contrast, Zhao et al. reported lower intraoperative remifentanil and postoperative morphine consumption with retrolaminar block than with ESP block in patients with multiple rib fractures [10]. In thoracic surgery, findings regarding the retrolaminar block have been inconsistent. In 60 patients undergoing uniportal VATS, Wang et al. compared paravertebral and retrolaminar blocks, each performed with 30 mL of 0.5% ropivacaine divided between the T3 and T5 levels, and found lower pain scores at rest and during coughing, lower sufentanil consumption, and less nausea with paravertebral block [11]. In contrast, Zhu et al. found retrolaminar block to be noninferior to paravertebral block after single-incision VATS[9], and the retrolaminar block has also been compared with epidural analgesia after minor VATS [12]. In a randomized noninferiority trial after less-invasive lung surgery, Sugiyama et al. found that retrolaminar block was faster to perform than paravertebral block but did not demonstrate noninferior analgesia [13]; as discussed by Zhu et al., differences in local anesthetic concentration between the groups may have contributed to this finding [9]. These discrepancies may reflect differences in surgical procedures, pain mechanisms, local anesthetic regimens, and perioperative analgesic protocols. In particular, pain after VATS arises from multiple sources, including port-site incisions, intercostal nerve injury, and chest tube placement, so the analgesic effect of a single-level paraspinal block may depend on the location of the surgical stimulus relative to the block level.

In our study, intraoperative remifentanil was administered to 3 patients (11.1%) in the retrolaminar group and 9 patients (33.3%) in the ESP group, a difference that was not statistically significant ($p = 0.099$). When all randomized patients were included, total remifentanil consumption also did not differ significantly between groups ($p = 0.101$). Among patients who received remifentanil, the administered dose was higher in the retrolaminar group ($p = 0.027$). However, this comparison was restricted to a small, post-randomization subgroup of remifentanil recipients and is therefore susceptible to selection bias. In addition, remifentanil administration was not standardized and depended on the clinical judgment of individual attending anesthesiologists, who, although blinded to group allocation, may have differed in their thresholds for opioid administration. Intraoperative remifentanil consumption should therefore be regarded as an imprecise surrogate of intraoperative analgesic efficacy, and our findings do not support any conclusion regarding differences in intraoperative opioid requirements between the two techniques.

Rescue analgesic requirements provide additional clinically relevant information. During the first 24 postoperative hours, seven patients did not receive any rescue analgesia (four in the retrolaminar group and three in the ESP group), one of whom declined rescue analgesia offered for an NRS score above 4; the remaining 47 patients received at least one dose of tramadol. The proportions of patients receiving a first or second dose of tramadol or rescue diclofenac, total tramadol consumption, and the timing of rescue analgesia did not differ significantly between groups. The high proportion of patients requiring rescue analgesia in both groups is consistent with reports that single-level paraspinal fascial plane blocks may provide less complete analgesia after VATS than paravertebral block [11], and indicates that neither technique alone was sufficient for most patients in our study. In addition, because single-injection blocks were performed before incision and the duration of surgery exceeded 2 hours in many patients (median 125 minutes), part of the block effect may have elapsed by the

early postoperative period, which may also explain the relatively high pain scores at the first postoperative hour in both groups. Because all patients also received intravenous paracetamol, and some received pethidine for shivering, the observed outcomes should be interpreted within the context of the multimodal analgesic regimen used rather than as isolated effects of the blocks.

The safety and practicality of the two techniques are also relevant. In our study, block performance time and the number of needle attempts did not differ significantly between groups, and no hematoma, pneumothorax, or signs of local anesthetic systemic toxicity were observed. Because both techniques target bony landmarks (the transverse process and the lamina, respectively) distant from the pleura, they may carry a lower risk of pleural puncture than paravertebral block; Zhu et al. reported two pleural punctures in the paravertebral group and none with ESP or retrolaminar block [9]. However, our regimen combined fixed doses of 150 mg bupivacaine and 200 mg lidocaine in a volume of 40 mL, with dose reduction in patients weighing less than 60 kg introduced only after the study had started. Although no signs of toxicity occurred, the combined local anesthetic dose was high and toxicity is additive; lower-dose and lower-volume regimens, such as the 20 mL used by Sotome et al. and Zhu et al. [6, 9], are likely to be preferable, and we do not recommend our regimen without weight-based dose adjustment. Our sample size was also too small to detect uncommon complications, so no conclusions regarding the comparative safety of the two techniques can be drawn.

In summary, we found no statistically significant differences between ultrasound-guided ESP and retrolaminar blocks in postoperative pain scores, rescue analgesic requirements, or intraoperative remifentanil consumption after VATS, within the multimodal analgesic regimen used in this study. Together with the findings of Zhu et al. [9], our results suggest that the two techniques may provide broadly similar analgesia after VATS. However, given the limited precision of our estimates, the absence of sensory block assessment, and the variability in perioperative analgesic management, clinically relevant differences between the techniques cannot be excluded. Adequately powered head-to-head trials with standardized intraoperative opioid protocols and assessment of sensory block distribution are needed to determine whether either technique offers a meaningful advantage.

STUDY LIMITATION

This study has several limitations. First, blocks were performed under general anesthesia, so sensory distribution and block success could not be assessed. Second, intraoperative remifentanil was administered at the discretion of the attending anesthesiologist without a standardized protocol or nociception monitoring; although the anesthesiologist was blinded to group allocation, variability in clinical practice may have influenced remifentanil consumption. Third, one patient in each group required conversion to thoracotomy and was analysed according to randomized allocation, which may have increased postoperative pain scores in these patients. Fourth, the sample size calculation was not documented before recruitment and was based on a trial in breast surgery; with 27 patients per group, only moderate-to-large differences (Cohen's $d \approx 0.78$) could be detected, so clinically relevant smaller differences cannot be excluded and the nonsignificant findings do not establish equivalence. Fifth, the mixed-effects and ordinal GEE analyses were post hoc, and their model assumptions were not fully met; these findings are therefore hypothesis-generating.

Sixth, a fixed dose of 150 mg bupivacaine and 200 mg lidocaine (40 mL) was used, with a weight-based dose reduction in four patients weighing less than 60 kg that was introduced during the study without a protocol amendment; although no LAST occurred, the combined dose was high, lower-dose regimens may be sufficient, and the study was not designed to assess safety. In addition, pethidine for shivering (14 patients, evenly distributed between groups), a protocol-deviating third tramadol dose in one patient, and refusal of offered rescue analgesia by four patients (two per group) may have influenced pain scores and analgesic consumption. Three patients were enrolled despite a body mass index outside the prespecified range, and the randomization method and blinding differed from those described in the ethics application; excluding these three patients did not change the results. Finally, the single-center design and inclusion of only ASA I–II patients may limit generalisability.

CONCLUSION

In patients undergoing video-assisted thoracoscopic surgery, no statistically significant differences in postoperative pain scores at rest or rescue analgesic requirements were observed between ESP and retrolaminar blocks. However, the confidence intervals, particularly at the first postoperative hour, do not exclude clinically relevant differences, and these findings do not establish equivalence between the two techniques. Larger, adequately powered randomized controlled trials are warranted to clarify their comparative analgesic effectiveness.

DECLARATIONS

Abbreviations

ASA: American Society of Anesthesiologists; Avg: Average; BMI: Body Mass Index; CI: Confidence Interval; ESP: Erector Spinae Plane; FFH: Fisher–Freeman–Halton; GEE: Generalized Estimating Equations; hr: Hour; IV: Intravenous; LAST: Local Anesthetic Systemic Toxicity; min: Minute; NRS: Numerical Rating Scale; PACU: Post-Anesthesia Care Unit; SD: Standard Deviation; VATS: Video-Assisted Thoracoscopic Surgery

Ethics approval and consent to participate

The study was approved by the Gülhane Clinical Research Ethics Committee (approval no. 2023/54; March 15, 2023). Written informed consent was obtained from all participants prior to enrollment. The study was conducted in accordance with the Declaration of Helsinki and relevant guidelines and regulations.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and/or analysed during the current study are not publicly available due to patient privacy and confidentiality considerations but are available from the corresponding author upon reasonable request. A de-identified participant-level dataset, a data dictionary, and the statistical output have been provided to the journal for confidential editorial

assessment. The study protocol approved by the institutional ethics committee has been provided as a supplementary file. A separate statistical analysis plan was not prepared. The analysis code used for the post hoc longitudinal analyses is available from the corresponding author upon reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Authors' contributions

YG contributed to the study conception and design, data collection, data analysis, interpretation of the results, and drafting of the manuscript. MBE contributed to the study conception and design, interpretation of the results, and critical revision of the manuscript. Both authors read and approved the final manuscript.

Acknowledgements

Not applicable.

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