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TRANSFORMING POST-OPEN NEPHRECTOMY PAIN CONTROL: THE ROLE OF THE ERECTOR SPINAE PLANE BLOCK IN PROVIDING ANALGESIA DURING PERIOPERATIVE PERIOD.

A RANDOMIZED CONTROLLED TRIAL

Running Title: *ESPB In Open Nephrectomy*

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Abstract

Objective: To determine whether ultrasound-guided erector spinae plane block (ESPB), added to standardised general anaesthesia and multimodal analgesia, reduces 24-hour opioid consumption and postoperative pain compared with systemic analgesia alone after open nephrectomy.

Methods: This prospective, assessor-blinded randomized controlled trial was conducted at the Sindh Institute of Urology and Transplantation, Karachi, from 30th May 26 to August 12th 26. Ninety-two adults (18–60 years, ASA I–III) undergoing elective open nephrectomy for benign disease were randomised 1:1 to ultrasound-guided ESPB (25 mL of 0.25% bupivacaine) after induction or no block, on an identical general anaesthetic and multimodal analgesic background (nalbuphine, paracetamol, ketorolac). Rescue nalbuphine was given for a numeric pain rating scale (NPRS) score >3. Co-primary outcomes were 24-hour nalbuphine consumption and

NPRS from PACU arrival to 24 hours; secondary outcomes included time to first rescue, nausea, vomiting, sedation and complications. Analysis was by intention-to-treat.

Results: All 92 patients were analysed (46 per group). Median 24-hour nalbuphine was 12.0 mg (IQR 10.0–14.0) with ESPB versus 25.0 mg (20.5–28.0) in controls (Hodges–Lehmann difference −12.0 mg, 95% CI −14.0 to −10.0; $p<0.001$). Median time to first rescue was 10.7 h versus 1.3 h ($p<0.001$). NPRS was lower with ESPB from PACU arrival to 6 h (all $p<0.001$) but not at 12 h ($p=0.208$) or 24 h ($p=0.159$). ESPB reduced nausea (37.0% vs 65.2%), vomiting (4.3% vs 23.9%) and sedation (28.3% vs 73.9%) (all $p\leq0.007$). Block success was 91.3%; no block-related complications occurred.

Conclusion: ESPB provided clinically meaningful opioid-sparing analgesia, prolonged the analgesia-free interval by about nine hours, and reduced opioid-related adverse effects after open nephrectomy without complications. The advantage was concentrated in the first 6 hours, supporting its use within multimodal analgesia and prompting evaluation of strategies to extend its duration.

INTRODUCTION

Open nephrectomy through a flank incision remains a frequently performed operation for non-functioning, stone-bearing, obstructed and infected kidneys, particularly where minimally invasive facilities are limited. The operation combines division of the flank musculature, rib and retroperitoneal manipulation, and dissection of the renal pedicle, and it produces intense acute pain in which somatic (incisional) and visceral (renal and ureteric) components coexist, with nociceptive input travelling through spinal segments T8–L1.[1,2] In a prospective study of patients undergoing open radical nephrectomy who received paracetamol and morphine patient-controlled analgesia, 96% still required additional analgesia in the early postoperative period and 16% developed chronic post-surgical pain at two months.[3] Poorly controlled postoperative pain delays mobilisation, impairs respiratory function, prolongs hospital stay and predisposes to chronic pain,[4] and current guidelines recommend multimodal analgesia with regional techniques wherever supporting evidence exists.[5] In our practice, however, analgesia after open nephrectomy has relied largely on systemic opioids, whose nausea, vomiting and sedation may hinder early recovery.

The erector spinae plane block (ESPB), described by Forero et al. in 2016 for thoracic neuropathic pain,[6] is an ultrasound-guided interfascial block in which local anaesthetic is deposited deep to the erector spinae muscle at the tip of a transverse process. Its target is superficial and remote from the pleura, neuraxis and major vessels, and its sonoanatomy is easily recognised, features that make it attractive where thoracic epidural or paravertebral techniques are difficult, contraindicated or unavailable. Proposed mechanisms include craniocaudal interfascial spread with diffusion into the paravertebral space and action on the dorsal and ventral rami of spinal nerves, although their relative contributions remain debated.[7,8] Imaging and anatomical studies demonstrate spread of injectate across several vertebral levels,[9] and clinical reports indicate that a single injection can provide both somatic and visceral analgesia, including for abdominal surgery.[10,11]

Evidence for ESPB in renal surgery is encouraging but heterogeneous. Randomised trials in nephrectomy have reported lower pain scores and opioid consumption after ESPB than after no block,[12] sham block[2] or intravenous patient-controlled morphine,[13] and a non-inferiority trial found analgesia comparable to paravertebral block after laparoscopic nephroureterectomy.[14] A single-arm study from Lahore likewise reported prolonged analgesia after ESPB in patients undergoing nephrectomy or pyelolithotomy.[15] Against this, injectate spread is variable between individuals,[16] a recent CT study found that paravertebral spread was common but that sensory loss over the ventral dermatomes was inconsistent and that spread

depended on patient position,[17] and placebo-controlled trials in cardiac surgery did not demonstrate an opioid-sparing effect.[18] The benefit of ESPB is therefore likely to be procedure- and technique-specific and must be confirmed in each surgical setting.

Most nephrectomy trials to date have been relatively small, single-centre studies, often in patients undergoing radical nephrectomy for malignancy,[12,13] whereas the population served by our institution includes many patients who require nephrectomy for benign conditions such as stone disease, a non-functioning kidney, pelviureteric junction obstruction and pyonephrosis. Randomised, no-block-controlled evidence from this setting, using a standardised multimodal background and clinically relevant outcomes such as opioid consumption, time to first rescue and opioid-related adverse effects, is lacking. We therefore conducted a randomised controlled trial comparing ultrasound-guided ESPB with standard systemic analgesia alone in adults undergoing elective open nephrectomy for benign disease. We hypothesised that ESPB would reduce 24-hour opioid consumption and postoperative pain scores. Secondary aims were to assess time to first rescue analgesia, intraoperative opioid requirement, postoperative nausea, vomiting and sedation, and block-related complications.

MATERIALS AND METHODS

Study design and setting

This prospective, single-centre, parallel-group, assessor-blinded randomized controlled trial with a 1:1 allocation ratio was conducted in the operating theatres and post-anaesthesia care unit (PACU) of the Sindh Institute of Urology and Transplantation (SIUT), Karachi, Pakistan, from 30th May 26 to 12th August 26. The study is reported in accordance with the CONSORT 2010 statement.[19]

Ethical approval and registration

The protocol was approved by the SIUT Ethical Review Committee (approval no. SIUT-ERC-2026/A-657; ERC no. 657; issued 22 May 2026) under the title “Transforming Post-open Nephrectomy Pain Control: The Role of the Erector Spinae Plane Block in providing Analgesia During Perioperative Period. A Randomized Controlled Trial”, and the study was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from every participant before enrolment; for illiterate patients the consent form was read aloud and, if the patient agreed, a thumb impression was taken in place of a signature.

Participants

Adults aged 18–60 years of either sex, with American Society of Anesthesiologists (ASA) physical status I–III, who were scheduled for elective unilateral open nephrectomy for benign disease (stone disease, non-functioning kidney, pelviureteric junction obstruction or

pyonephrotic kidney) were eligible. Exclusion criteria were: refusal or lack of consent; coagulopathy; infection at the injection site; musculoskeletal or thoracic spine deformity; previous thoracic spine surgery; body mass index (BMI) above 40 kg/m²; allergy to local anaesthetics; any motor or sensory deficit; intellectual disability; and a Glasgow Coma Scale score below 14/15.

Sample size

The sample size was calculated with G*Power software on the basis of a previous randomised study of continuous regional analgesia in renal surgery,[20] yielding a total of 92 patients (46 per group). With this sample size, and a two-sided α of 0.05, the study had 80% power to detect a standardised between-group difference (Cohen's d) of approximately 0.6.

Randomisation, allocation concealment and blinding

Patients were allocated to the ESPB group or the control group (standard systemic analgesia without block) in a 1:1 ratio using a computer-generated random sequence. Group allocations were concealed in sealed opaque envelopes. Because the block was performed after induction of general anaesthesia, patients were unaware of the procedure when it was carried out; no sham block was performed, and the consultant anaesthesiologist performing the block was necessarily aware of allocation. Postoperative pain scores, vital signs, rescue analgesic requirements and adverse events were recorded by an anaesthesiologist who was unaware of group allocation.

Anaesthetic management common to both groups

Standard ASA monitoring was applied. Anaesthesia was induced with intravenous propofol 2 mg/kg, atracurium 0.5 mg/kg and nalbuphine (target dose 0.15 mg/kg), followed by tracheal intubation, and was maintained with isoflurane in an oxygen–air mixture (50:50). At the end of surgery, all patients received intravenous paracetamol (1 g, approximately 15 mg/kg) and ketorolac 30 mg, and ondansetron 0.06 mg/kg was given before extubation. Neuromuscular blockade was reversed with neostigmine 2.5mg and glycopyrrolate 0.5 mg, and the trachea was extubated in the operating theatre once spontaneous ventilation was adequate. Patients were then observed in the PACU for 2 hours.

ESPB technique (intervention group)

Once the patient had been placed in the lateral position for surgery, and before skin incision, a consultant anaesthesiologist who had previously performed at least 50 ESPBs carried out an ultrasound-guided block on the operative side under aseptic precautions. A Mindray TE7 ultrasound machine with a 10-MHz linear probe was used. The probe was placed in a parasagittal orientation over the T10 level, approximately 3 cm lateral to the midline, to identify

the tip of the transverse process and the overlying erector spinae muscle. A 22-gauge, 50-mm block needle (Stimuplex) was advanced in-plane in a cranial-to-caudal direction until the tip contacted the transverse process. Correct placement was confirmed by hydrodissection with 1–2 mL of saline, which lifted the erector spinae muscle off the transverse process, and 25 mL of 0.25% bupivacaine (62.5 mg) was then injected in fractionated aliquots with intermittent aspiration. The patient was then handed over to the surgical team. No repeat block was attempted in the event of block failure, and such patients remained in their allocated group (intention-to-treat).

Control group and postoperative rescue analgesia

Patients in the control group received the identical anaesthetic and multimodal analgesic regimen but no block. In both groups, pain was assessed in the PACU and thereafter with the numeric pain rating scale (NPRS; 0 = no pain, 10 = worst pain imaginable),[21] and rescue analgesia consisted of intravenous nalbuphine 0.05–0.1 mg/kg whenever the NPRS exceeded 3 during the first 24 hours after PACU arrival.

Outcome measures

The co-primary outcomes were (i) the total dose of nalbuphine administered in the first 24 hours after PACU arrival, and (ii) NPRS at seven predefined time points: on arrival in the PACU (T0), and at 30 min (T1), 1 h (T2), 2 h (T3), 6 h (T4), 12 h (T5) and 24 h (T6). Secondary outcomes were the intraoperative nalbuphine dose; the time to the first rescue analgesic request, measured from PACU arrival to the first rescue nalbuphine dose; the total 24-hour paracetamol dose; postoperative nausea and vomiting (recorded as present or absent during the first 24 hours); sedation (Ramsay sedation score ≥3);[22] block success and failure; and block-related complications (pneumothorax, haematoma, infection at the injection site, needle-related trauma, persistent numbness beyond 24 hours, and local anaesthetic systemic toxicity, which was assessed clinically for 30 minutes after injection and would have been managed according to the ASRA practice advisory).[23]

Block success was defined as unilateral sensory reduction over the T8–L1 dermatomes and NPRS ≤3 on PACU arrival, without a requirement for rescue opioid in the first 30 minutes. Block failure was defined as absent sensory change, NPRS ≥6 on arrival, rescue opioid within the first 30–60 minutes, or persistent pain inconsistent with the expected effect of the block.

Data collection

Data were recorded prospectively on a structured proforma comprising patient identification number, age, sex, weight, height, BMI, ASA status, duration of surgery, intraoperative and

postoperative analgesic doses, time to first rescue dose, NPRS at each time point, and adverse events, and were subsequently entered into a spreadsheet and checked for completeness.

Statistical analysis

Data were analysed by intention-to-treat. Normality was assessed with the Kolmogorov–Smirnov and Shapiro–Wilk tests. Normally distributed continuous variables are presented as mean ± standard deviation (SD) and were compared with the independent-samples t-test; non-normally distributed and ordinal variables are presented as median (interquartile range, IQR) and were compared with the Mann–Whitney U test. Categorical variables are presented as number (percentage) and were compared with the χ^2 test, or Fisher's exact test when any expected cell count was below 5. Effect sizes are reported as mean differences or Hodges–Lehmann median differences with distribution-free 95% confidence intervals (CI) for continuous outcomes, and as risk ratios and risk differences with 95% CI for binary outcomes. Because NPRS was compared at seven time points, Holm-adjusted p-values are also reported. Time to first rescue analgesia was additionally displayed with Kaplan–Meier curves and compared with the log-rank test, and a Cox proportional-hazards model was used to estimate the hazard ratio. Two sensitivity analyses were prespecified for the primary consumption outcome: multivariable linear regression adjusting for duration of surgery, age and weight, and a per-protocol analysis excluding failed blocks. A two-sided p-value <0.05 was considered statistically significant. Analyses were performed with IBM SPSS Statistics version 22 (IBM Corp., Armonk, NY, USA); Hodges–Lehmann estimates, Kaplan–Meier, Cox and regression analyses were computed in Python (SciPy, statsmodels and lifelines).

RESULTS

Participant flow and baseline characteristics

Ninety-two patients were enrolled and randomised (46 to ESPB and 46 to control), received the allocated treatment and completed the 24-hour follow-up. No patient was lost to follow-up or excluded, and all 92 were included in the intention-to-treat analysis (Figure 1). Demographic characteristics, ASA physical status and body mass index were comparable between groups (Table 1). Participants were aged 19–60 years, and 54 of 92 (58.7%) were men. Duration of surgery was numerically longer in the ESPB group (184.1 ± 39.1 vs 168.0 ± 41.3 min; mean difference 16.1 min, 95% CI −0.6 to 32.8; $p = 0.058$).

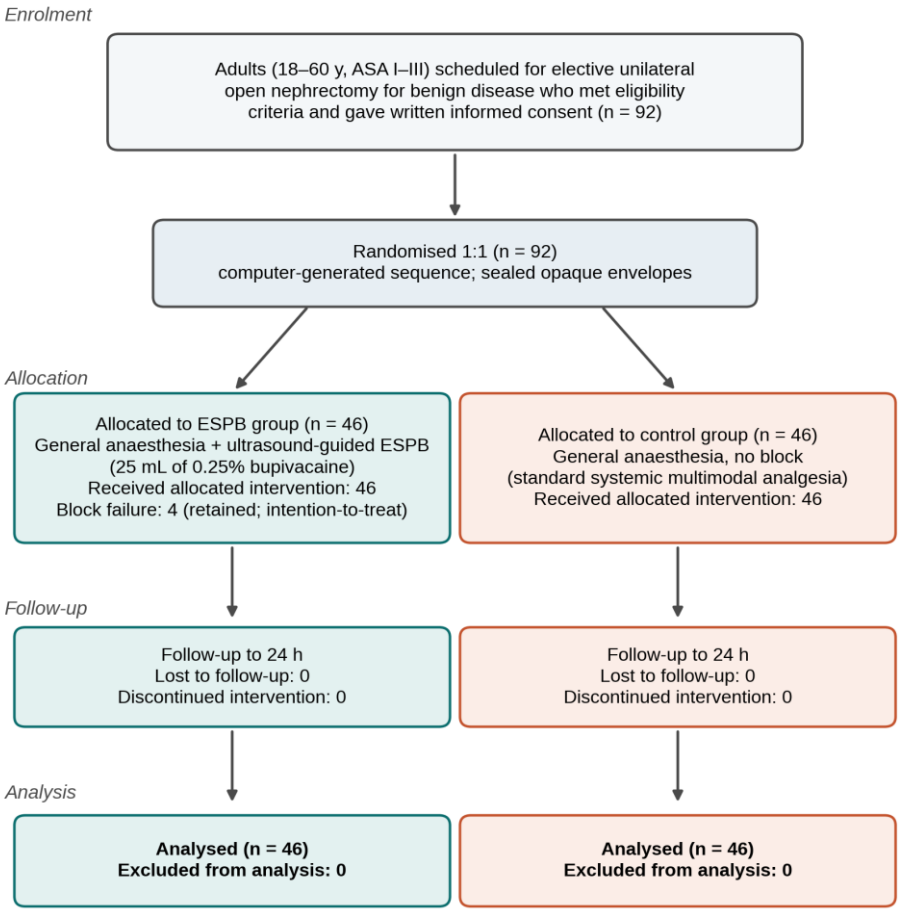


Figure 1. CONSORT flow diagram of participants. ESPB, erector spinae plane block. Numbers screened for eligibility and excluded before consent were not recorded.

Table 1. Baseline characteristics and duration of surgery of the two groups.

Characteristic	ESPB group (n = 46)	Control group (n = 46)	Test statistic	p-value
Age, years, median (IQR)	39.5 (24.0–50.0)	41.5 (35.2–52.2)	U = 927.0	0.306
Sex, n (%)				
Male	26 (56.5)	28 (60.9)	$\chi^2 = 0.18$	0.672
Female	20 (43.5)	18 (39.1)		
Weight, kg, mean ± SD	66.1 ± 6.3	65.6 ± 8.3	t = 0.30	0.766
Height, cm, median (IQR)	168.0 (165.0–169.0)	167.0 (164.2–169.0)	U = 1184.0	0.321

Characteristic	ESPB group (n = 46)	Control group (n = 46)	Test statistic	p-value
BMI, kg/m², mean ± SD	23.6 ± 2.0	23.6 ± 2.6	t = −0.15	0.881
ASA physical status, n (%)				
ASA I	2 (4.3)	1 (2.2)	Fisher*	0.522
ASA II	24 (52.2)	29 (63.0)		
ASA III	20 (43.5)	16 (34.8)		
Duration of surgery, min, mean ± SD	184.1 ± 39.1	168.0 ± 41.3	t = 1.92	0.058

Values are mean ± SD, median (interquartile range, IQR) or n (%), according to the distribution of each variable. Continuous variables: independent-samples t-test or Mann–Whitney U test; sex: χ^2 test; *ASA III versus ASA I–II, Fisher's exact test. ASA, American Society of Anesthesiologists; BMI, body mass index; ESPB, erector spinae plane block.

Primary outcome: 24-hour nalbuphine consumption

Cumulative nalbuphine consumption over the first 24 hours was markedly lower with ESPB: median 12.0 mg (IQR 10.0–14.0) versus 25.0 mg (20.5–28.0) in the control group, a Hodges–Lehmann difference of −12.0 mg (95% CI −14.0 to −10.0; $p < 0.001$; Table 2, Figure 2B). This corresponds to a 52% lower median and a 47.9% lower mean (13.0 ± 4.3 vs 24.9 ± 6.1 mg). The effect was unchanged after adjustment for duration of surgery, age and weight (adjusted difference −12.6 mg, 95% CI −14.6 to −10.5; $p < 0.001$) and in the per-protocol analysis that excluded the four failed blocks (−13.0 mg, 95% CI −15.0 to −11.0; $p < 0.001$; Table 4). Longer surgery was independently associated with higher consumption (1.8 mg per additional hour; $p = 0.032$).

Table 2. Perioperative analgesic consumption and time to first rescue analgesia (primary and secondary outcomes).

Outcome	ESPB group (n = 46)	Control group (n = 46)	Difference (95% CI)†	Mann–Whitney U	p-value
Primary outcome					
Total 24-h postoperative nalbuphine, mg	12.0 (10.0–14.0)	25.0 (20.5–28.0)	−12.0 (−14.0 to −10.0)	111.5	**<0.001**

Outcome	ESPB group (n = 46)	Control group (n = 46)	Difference (95% CI)†	Mann–Whitney U	p-value
Total 24-h nalbuphine, mean ± SD (descriptive)	13.0 ± 4.3	24.9 ± 6.1	—	—	—
Secondary outcomes					
Time to first rescue analgesia, h	10.7 (8.6–13.0)	1.3 (0.7–2.3)	9.2 (8.2 to 10.0)	1950.0	**<0.001**
Intraoperative nalbuphine, mg	7.0 (6.1–8.0)	7.5 (7.0–8.8)	−1.0 (−1.0 to 0.0)	689.5	**0.003**
Total 24-h paracetamol, g	3.0 (3.0–4.0)	4.0 (4.0–5.0)	−1.0 (−1.0 to −1.0)	301.5	**<0.001**

Values are median (IQR) unless stated. †Hodges–Lehmann median difference (ESPB minus control) with distribution-free 95% confidence interval. Time to first rescue analgesia was measured from PACU arrival. Nalbuphine and paracetamol totals refer to the first 24 hours after PACU arrival. ESPB, erector spinae plane block; PACU, post-anaesthesia care unit.

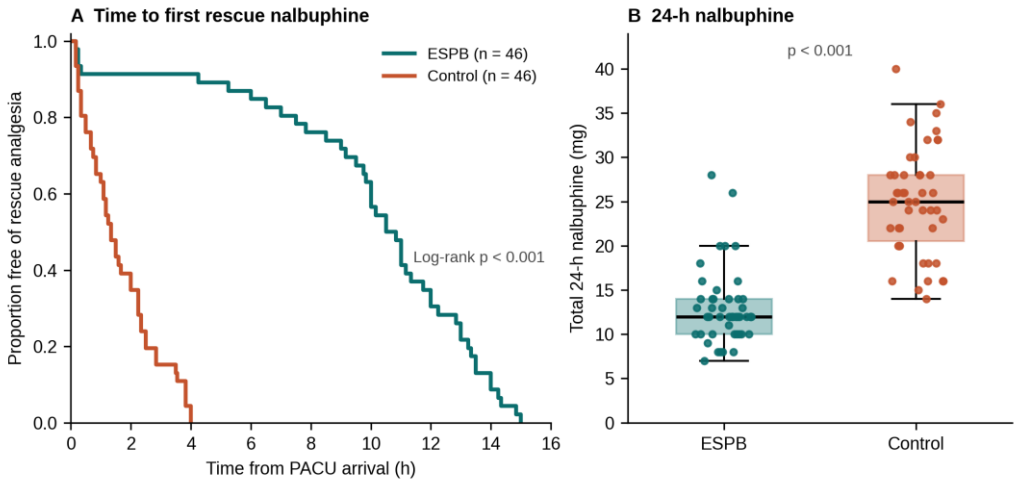


Figure 2. Time to first rescue analgesia and 24-hour nalbuphine consumption. (A) Kaplan–Meier curves of the proportion of patients free of rescue nalbuphine after PACU arrival (log-rank $p < 0.001$). (B) Total 24-hour nalbuphine consumption; boxes show median and IQR, whiskers the range within 1.5 × IQR, and dots individual patients (Mann–Whitney $p < 0.001$).

Primary outcome: pain scores

NPRS was significantly lower in the ESPB group at every time point from PACU arrival to 6 hours (T0–T4; all $p < 0.001$), with a median score of 2 versus 3 in the control group at each of these time points (Table 3, Figure 3A). These differences remained significant after Holm adjustment (all adjusted $p < 0.001$). Among patients receiving ESPB, 4.3% to 10.9% had an NPRS above the rescue threshold of 3 at T0–T4, compared with 23.9% to 43.5% of controls (Figure 3B). At 12 hours (T5) and 24 hours (T6), pain scores did not differ between groups (median 3 vs 3, $p = 0.208$; and 2 vs 2, $p = 0.159$, respectively).

Table 3. Numeric pain rating scale (NPRS) scores at predefined time points.

Time point	ESPB median (IQR)	Control median (IQR)	Difference (95% CI)†	U	p-value	Holm p	NPRS > 3, n (%) ESPB / control
T0 (On PACU arrival)	2 (2–2)	3 (2–3)	−1.0 (−1.0 to 0.0)	593.5	**<0.001**	<0.001	4 (8.7) / 11 (23.9)
T1 (30 min)	2 (2–2)	3 (2–4)	−1.0 (−1.0 to −1.0)	470.0	**<0.001**	<0.001	3 (6.5) / 18 (39.1)
T2 (1 h)	2 (2–2)	3 (3–4)	−1.0 (−1.0 to −1.0)	380.5	**<0.001**	<0.001	2 (4.3) / 16 (34.8)
T3 (2 h)	2 (2–2)	3 (3–4)	−1.0 (−1.0 to −1.0)	328.5	**<0.001**	<0.001	3 (6.5) / 18 (39.1)
T4 (6 h)	2 (2–3)	3 (2–4)	−1.0 (−1.0 to −1.0)	523.0	**<0.001**	<0.001	5 (10.9) / 20 (43.5)
T5 (12 h)	3 (2–3)	3 (2–4)	0.0 (−1.0 to 0.0)	906.0	0.208	0.318	9 (19.6) / 13 (28.3)
T6 (24 h)	2 (2–3)	2 (2–3)	0.0 (0.0 to 0.0)	905.0	0.159	0.318	2 (4.3) / 8 (17.4)

NPRS, numeric pain rating scale (0–10). †Hodges–Lehmann median difference (ESPB minus control) with 95% CI. p-values are from two-sided Mann–Whitney U tests; Holm p is adjusted for the seven time points. T0, PACU arrival; ESPB, erector spinae plane block; PACU, post-anaesthesia care unit.

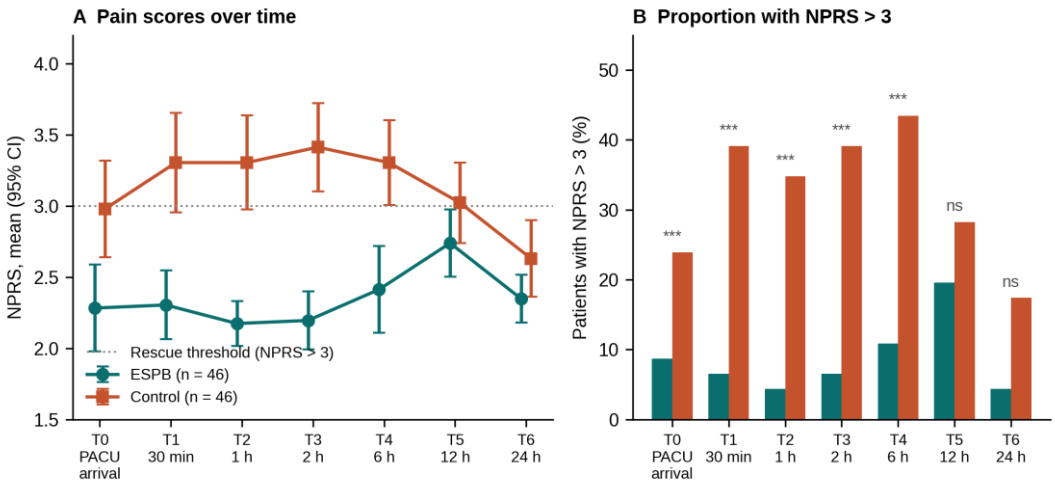


Figure 3. Postoperative pain scores. (A) Mean NPRS with 95% confidence intervals at each time point. (B) Percentage of patients with NPRS above the rescue threshold (> 3); *** $p < 0.001$, ns, not significant (Mann–Whitney U). T0, PACU arrival; T1, 30 min; T2, 1 h; T3, 2 h; T4, 6 h; T5, 12 h; T6, 24 h.

Table 4. Sensitivity and supportive analyses of the primary consumption outcome and time to first rescue analgesia.

Analysis	Estimate (95% CI)	p-value
Total 24-h postoperative nalbuphine (mg), ESPB minus control		
Intention-to-treat, Hodges–Lehmann (n = 46 vs 46)	−12.0 (−14.0 to −10.0)	**<0.001**
Adjusted for duration of surgery, age and weight (linear regression)	−12.6 (−14.6 to −10.5)	**<0.001**
Per-protocol, failed blocks excluded, Hodges–Lehmann (n = 42 vs 46)	−13.0 (−15.0 to −11.0)	**<0.001**
Time to first rescue analgesia		
Intention-to-treat, Hodges–Lehmann difference, h	9.2 (8.2 to 10.0)	**<0.001**
Per-protocol, Hodges–Lehmann difference, h	9.5 (8.6 to 10.3)	**<0.001**
Cox model, hazard ratio for first rescue request	0.03 (0.01 to 0.08)	**<0.001**
Log-rank test	—	**<0.001**

ESPB, erector spinae plane block. Per-protocol analyses exclude the four ESPB patients with block failure.

Secondary outcomes

All 92 patients required at least one rescue dose of nalbuphine within 24 hours. The median time to first rescue request was 10.7 h (IQR 8.6–13.0) with ESPB and 1.3 h (0.7–2.3) in controls (Hodges–Lehmann difference 9.2 h, 95% CI 8.2–10.0; $p < 0.001$; Table 2, Figure 2A). On Kaplan–Meier analysis, the median rescue-free time was 10.5 h versus 1.3 h (log-rank $p < 0.001$; hazard ratio for first rescue request 0.03, 95% CI 0.01–0.08). During the 2-hour PACU stay, rescue nalbuphine was required by 4 of 46 patients (8.7%) in the ESPB group, all of whom had failed blocks, compared with 30 of 46 (65.2%) in the control group (risk ratio 0.13, 95% CI 0.05–0.35; $p < 0.001$; Table 5). The intraoperative nalbuphine dose was modestly lower with ESPB (median 7.0 vs 7.5 mg; $p = 0.003$), and 24-hour paracetamol consumption was also lower (median 3.0 vs 4.0 g; $p < 0.001$).

Postoperative nausea occurred in 17 (37.0%) patients in the ESPB group and 30 (65.2%) controls (risk ratio 0.57, 95% CI 0.37–0.87; $p = 0.007$); vomiting in 2 (4.3%) and 11 (23.9%) (risk ratio 0.18, 95% CI 0.04–0.78; $p = 0.007$); and sedation (Ramsay score ≥3) in 13 (28.3%) and 34 (73.9%) (risk ratio 0.38, 95% CI 0.23–0.62; $p < 0.001$) (Table 5). Block success, as defined in the protocol, was recorded in 42 of 46 patients (91.3%). Four blocks (8.7%) were classified as failures, each identified by a rescue nalbuphine request within 20 minutes of PACU arrival, and these patients remained in the ESPB group for analysis. No block-related complications (pneumothorax, haematoma, infection at the injection site, needle-related trauma, local anaesthetic systemic toxicity or persistent numbness) were recorded.

Table 5. Opioid-related adverse effects, early rescue requirement and block outcomes.

Outcome	ESPB group (n = 46)	Control group (n = 46)	Risk ratio (95% CI)	Risk difference, % points (95% CI)	p-value
Opioid-related adverse effects and early rescue, n (%)					
Postoperative nausea	17 (37.0)	30 (65.2)	0.57 (0.37–0.87)	−28.3 (−47.9 to −8.7)	**0.007**
Postoperative vomiting	2 (4.3)	11 (23.9)	0.18 (0.04–0.78)	−19.6 (−33.2 to −5.9)	**0.007**

Outcome	ESPB group (n = 46)	Control group (n = 46)	Risk ratio (95% CI)	Risk difference, % points (95% CI)	p-value
Sedation (Ramsay score ≥ 3)	13 (28.3)	34 (73.9)	0.38 (0.23–0.62)	−45.7 (−63.8 to −27.5)	**<0.001**
Rescue nalbuphine during 2-h PACU stay	4 (8.7)	30 (65.2)	0.13 (0.05–0.35)	−56.5 (−72.5 to −40.5)	**<0.001**
Block outcomes (ESPB group only), n (%)					
Block success (per protocol definition)	42 (91.3)	—	—	—	—
Block failure	4 (8.7)	—	—	—	—
Block-related complications*	0 (0)	—	—	—	—

p-values from χ^2 test. All patients who vomited also reported nausea. *Pneumothorax, haematoma, infection at the injection site, needle-related trauma, local anaesthetic systemic toxicity, or persistent numbness > 24 h. The four failed blocks accounted for all four ESPB-group patients requiring rescue nalbuphine in the PACU. ESPB, erector spinae plane block; PACU, post-anaesthesia care unit.

DISCUSSION

In this randomised trial of 92 adults undergoing open nephrectomy for benign disease, a single-injection, ultrasound-guided ESPB with 25 mL of 0.25% bupivacaine, added to a standardised multimodal regimen, halved 24-hour nalbuphine consumption (median 12 vs 25 mg), delayed the first rescue analgesic request by about nine hours (median 10.7 vs 1.3 h), and lowered pain scores throughout the first six postoperative hours. It also reduced the incidence of postoperative nausea, vomiting and sedation, and no block-related complication was recorded. The reduction in opioid consumption was very large (a standardised mean difference of about 2.3), and it persisted after adjustment for duration of surgery, age and weight, and in the per-protocol analysis, which argues against baseline imbalance or block failure as explanations. Surgery was numerically longer in the ESPB group, and longer surgery was itself associated with greater opioid use, so any residual confounding would, if anything, have biased the result against ESPB.

These findings are consistent with the small body of randomised evidence in nephrectomy. Amer et al., who used the same volume and concentration of bupivacaine in open renal surgery, reported a median time to first analgesic requirement of 300 versus 30 minutes and a halving of 24-hour morphine consumption (9 vs 18 mg) compared with a sham block.[2] Şahin and Baran found lower pain scores, less opioid use and fewer rescue doses after ESPB than after no block in patients undergoing nephrectomy,[12] and Abdelgalil et al. found a longer time to first request, lower morphine consumption and lower pain scores at rest and on movement with continuous ESPB than with intravenous patient-controlled morphine after open nephrectomy for malignancy.[13] A Pakistani single-arm series reported peak rescue analgesia demand 15–16 hours after ESPB in nephrectomy and pyelolithotomy,[15] which corresponds to the upper end of the time to first rescue in our study (maximum 15 h). Our median analgesia-free interval of 10.7 hours was longer than that reported by Amer et al.; differences in the rescue threshold, the opioid used, the reference point for timing and the multimodal background may all contribute, and cross-trial comparisons should therefore be made cautiously.

The anatomical rationale for a lower thoracic ESPB in this operation is that the flank wall, kidney and ureter are supplied by spinal segments within the craniocaudal spread reported after a single injection.[7,9] Whether analgesia arises from paravertebral and epidural spread, intercostal spread, or action on the dorsal rami remains debated,[7,8] and injectate distribution varies considerably between individuals.[16] In a CT study, Shan et al. showed that contrast reached the paravertebral space in 96.5% of patients but that sensory loss over the ventral dermatomes was inconsistent, and that prone positioning increased paravertebral spread compared with supine positioning.[17] Our blocks were performed and maintained in the lateral decubitus position, which may have favoured anterior spread, although we did not image the injectate and cannot test this hypothesis. The observation that clinical analgesia can occur without demonstrable cutaneous sensory loss has been attributed by some authors to differential blockade of small-fibre afferents, a proposition that remains unproven.[24] Block success in our study was assessed according to a prespecified clinical definition (91.3%), which is pragmatic but does not replace radiological confirmation of spread.

The analgesic advantage of ESPB was confined to the first six hours: pain scores at 12 and 24 hours did not differ between groups, and 19.6% of patients in the ESPB group scored above the rescue threshold at 12 hours. This time course is expected after a single injection of 0.25% bupivacaine, and the median first rescue request at 10.7 hours suggests that the block had largely regressed by then. Two considerations aid interpretation. First, because rescue nalbuphine was titrated to an NPRS above 3 in both groups, pain scores in the control group

were suppressed by higher opioid doses (median 25 mg), so that convergence of scores at later time points reflects treatment as much as equivalence; this is why 24-hour consumption was prespecified as a co-primary outcome alongside pain scores. Second, the shortfall in pain control as the block wore off suggests a role for a scheduled non-opioid or opioid-sparing plan at 8–12 hours. Continuous ESPB catheters, which lowered 48-hour morphine consumption after open nephrectomy in one trial,[13] or the use of adjuvants, are logical strategies to extend the benefit, but were not tested here.

Reducing opioid exposure is a central aim of multimodal analgesia,[5] and the lower incidence of nausea (risk ratio 0.57), vomiting (0.18) and sedation (0.38) with ESPB is clinically relevant. It is noteworthy that all patients received ondansetron prophylaxis yet nausea affected almost two-thirds of controls, in keeping with consensus guidance that minimising perioperative opioids is a core strategy for reducing baseline PONV risk.[25] Nalbuphine, a mixed κ-agonist and μ-antagonist opioid, exhibits a ceiling effect and can cause dose-related sedation and nausea, so our findings may not extrapolate directly to regimens based on morphine or fentanyl. Furthermore, the absence of an opioid-sparing effect in placebo-controlled cardiac surgical trials[18] illustrates that the effect of ESPB is context-dependent; our trial adds procedure-specific, no-block-controlled evidence for flank surgery, in which incisional and visceral pain arise from the lower thoracic and upper lumbar segments.

No block-related complication was recorded in 46 blocks, in keeping with the favourable safety profile of a superficial fascial plane block performed under ultrasound guidance, a feature that has led some authors to advocate ESPB as a first-choice truncal block.[24] The bupivacaine dose (62.5 mg, approximately 0.7–1.2 mg/kg in our patients) was modest, yet the risk of local anaesthetic systemic toxicity, whose neurological features may be masked by general anaesthesia, should be borne in mind and managed according to current advisories.[23] From a resource standpoint, ESPB requires only a standard ultrasound machine, a block needle and inexpensive plain bupivacaine, which makes it feasible in high-volume public-sector centres in which epidural or paravertebral techniques may be impractical. Block failure occurred in 8.7% of patients and was evident within 20 minutes of PACU arrival, so an early, titrated rescue plan should accompany any ESPB pathway. Future multicentre trials should compare ESPB with active regional comparators, incorporate dynamic pain scores, functional recovery and chronic pain at three to six months, and evaluate catheter-based and adjuvant strategies to prolong analgesia.

Strengths and limitations

Strengths of this study include random allocation with concealed sealed envelopes, blocks performed by experienced consultants using a fixed technique and dose, an identical multimodal background in both groups, a blinded outcome assessor, intention-to-treat analysis with complete follow-up, and clinically relevant co-primary outcomes. Several limitations should be acknowledged. First, this was a single-centre study, and the results apply to adults aged 18–60 years with ASA I–III status undergoing nephrectomy for benign disease. Second, no sham block was used; patients were anaesthetised when the block was performed, but the anaesthesiologist performing the block was aware of allocation, and blinding of the outcome assessor may have been compromised at later time points. Third, pain scores did not distinguish rest from dynamic pain (deep breathing and coughing), which is more relevant to respiratory recovery; sensory dermatome mapping, the intraoperative haemodynamic response to incision (a planned secondary outcome), functional recovery, length of stay and chronic pain were not analysed. Fourth, the rescue threshold (NPRS >3) was conservative and every patient received at least one rescue dose, so the principal contrasts concern timing and dose rather than the need for rescue. Fifth, a single injection of a fixed volume at one vertebral level was studied, and neither injectate spread nor plasma local anaesthetic concentrations were assessed. Finally, nalbuphine was the only opioid used, surgeon- and indication-specific effects were not analysed, and surgery was numerically longer in the ESPB group ($p = 0.058$), which, if anything, would bias against the block.

CONCLUSION

In adults undergoing open nephrectomy for benign disease, ultrasound-guided erector spinae plane block added to multimodal general anaesthesia halved 24-hour nalbuphine consumption, prolonged the interval to first rescue analgesia by about nine hours, improved pain control during the first six postoperative hours and reduced nausea, vomiting and sedation, with no block-related complications. ESPB is a simple, low-cost and safe component of multimodal analgesia for open nephrectomy in resource-constrained, high-volume settings. Larger multicentre trials with dynamic pain, functional and long-term outcomes, and strategies to prolong the block, are warranted.

ABBREVIATIONS

ASA, American Society of Anesthesiologists; BMI, body mass index; CI, confidence interval; CONSORT, Consolidated Standards of Reporting Trials; ERC, Ethical Review Committee; ESPB, erector spinae plane block; IQR, interquartile range; NPRS, numeric pain rating scale;

PACU, post-anaesthesia care unit; PONV, postoperative nausea and vomiting; SD, standard deviation; SIUT, Sindh Institute of Urology and Transplantation.

DECLARATIONS

Ethical approval: The study was approved by the SIUT Ethical Review Committee (approval no. SIUT-ERC-2026/A-657; ERC no. 657; 22 May 2026).

Informed consent: Written informed consent (or thumb impression after verbal explanation in illiterate participants) was obtained from all participants.

Conflict of interest: The authors declare that they have no conflict of interest.

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