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ORIGINAL RESEARCH

Efficacy Comparison of Ultrasound-Guided and Dual-Guided (Ultrasound Plus Nerve Stimulation) Subcostal Quadratus Lumborum Block in Retroperitoneal Laparoscopic Nephrectomy: A Randomized Controlled Trial

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Objective: To compare the effectiveness of ultrasound (US) guidance alone versus combined nerve stimulation (NS) and US in subcostal quadratus lumborum block (SQLB) for patients undergoing laparoscopic nephrectomy.

Methods: Eighty-four patients scheduled for laparoscopic nephrectomy were randomized to receive a SQLB with either US alone (US group) or combined US and NS guidance (US-NS group). Each patient received 25 mL of 0.5% ropivacaine for the block. The primary endpoint was the block success rate within 5 minutes after block. Secondary endpoints included the extent of sensory block, intravenous morphine equivalent consumption, NRS scores, frequency of rescue analgesia administration, puncture time, number of needle insertion attempts, ultrasonic images quality, and incidence of adverse reactions and complications.

Results: The US-NS group demonstrated significantly higher block success rate compared to the US group (92.5% vs 62.5%, $P < 0.05$). Additionally, the US-NS group exhibited lower opioid requirements and fewer rescue analgesia interventions within the initial 24-hour postoperative period, broader sensory block coverage at 5, 10, and 15 minutes following injection, and lower NRS scores both at rest and during coughing at 6, 12, 24, and 48 hours post-surgery. However, the US-NS group required a longer puncture duration and more attempts to complete the SQLB. No significant differences were found between the two groups regarding the quality of ultrasound images and the incidence of adverse effects.

Conclusion: Dual guidance with NS and US was superior to US alone for performing SQLB, resulting in higher block success rates and improved analgesic efficacy for laparoscopic nephrectomy.

Keywords: subcostal quadratus lumborum block, ultrasound guidance, nerve stimulation, laparoscopic nephrectomy

Introduction

Effective postoperative analgesia is essential for patients undergoing retroperitoneal laparoscopic nephrectomy, as inadequate pain control may delay recovery and prolong hospital stay.[1] In recent years, the use of regional anesthesia as part of a multimodal analgesia strategy has become increasingly prominent in urologic minimally invasive surgery, including nephrectomy. For retroperitoneal laparoscopic nephrectomy, ultrasound-guided fascial plane blocks such as various approaches of the quadratus lumborum block have been studied to provide both somatic and visceral pain relief, reduce perioperative opioid consumption, and promote enhanced recovery.[2]

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Subcostal anterior quadratus lumborum block (SQLB) is a commonly employed regional anesthetic approach that offers reliable pain relief following nephrectomy.[3,4] To ensure accurate and effective block administration, ultrasound (US) imaging has become the preferred modality. Initially described as an injection into the space between the quadratus lumborum (QL) muscle and the transversalis fascia (TF) at the L1–L2 vertebral level, the US-guided SQLB may be technically demanding due to anatomical variability and procedural complexity.[5,6]

First, inaccurate needle positioning can occur when US image quality is suboptimal.[7] Unintentional deposition of large volumes of local anesthetic (LA) into muscle tissue may result in postoperative weakness due to the established myotoxic effects of LAs.[8] Additionally, at the L1-2 level, the complex interplay between the TF and the bilaminar posterior renal fascia located anterior to the QL muscle complicates needle positioning. The TF often fuses with the posterior lamina of the renal fascia, with considerable inter-individual variation in the blending site.[9,10] This anatomical variability, notably in geriatric populations or patients with fibrotic muscle tissue, underscores the importance of enhancing needle placement accuracy during SQLB to minimize the risk of inaccurate LA delivery, reduce complications such as intra-abdominal puncture and toxicity, and ultimately improve block success rates.

The T12 intercostal nerve, also known as the subcostal nerve, is the largest among the intercostal nerves and has been identified as a key target in nerve stimulation (NS) guided transverse abdominis plane (TAP) blocks.[11] It courses inferior to the 12th rib, passes posterior to the kidney, and gives rise to the lateral cutaneous branch. Continuing its oblique path, it innervates the transversus abdominis muscle and traverses its aponeurosis near the lateral edge of the QL muscle to access the TAP plane. Functionally, the subcostal nerve contributes to the motor innervation of the rectus abdominis, intercostals, and other muscles of the anterior abdominal wall.[12,13]

Given its anatomical trajectory and contribution to anterior abdominal wall innervation, the subcostal nerve presents a feasible target for improving the accuracy of SQLB. In this study, we propose a novel approach that combines NS with US guidance to identify and stimulate the subcostal nerve anterior to the QL muscle, aiming to improve needle placement precision and enhance postoperative analgesic outcomes compared to the conventional US-guided technique alone.

Materials and Methods

Ethics

The research protocol received approval from the Ethics Committee of Beijing Chaoyang Hospital chaired by Yong Chen, affiliated with Capital Medical University, China, on November 1, 2021 (2021-ke-608). The trial was prospectively registered in the Chinese Clinical Trial Registry on January 8, 2022 (ChiCTR2200055354). All procedures were carried out in compliance with the principles outlined in the Declaration of Helsinki and the CONSORT guidelines for randomized controlled trials.

Subjects

Patients scheduled for elective laparoscopic nephrectomy under general anesthesia were recruited between January 8, 2022, and March 27, 2023 (Figure 1). Prior to participation, written informed consent was obtained from each individual. Eligible subjects were aged 20–70 years, had a body mass index (BMI) ranging from 20 to 30 $kg\cdot m^{-2}$, were classified as American Society of Anesthesiologists (ASA) physical status classification system I to III, and had normal liver and kidney function. Exclusion criteria included a documented history of chronic opioid dependence or the use of any analgesics for more than three consecutive months, known hypersensitivity to any agents used in the standardized anesthesia regimen, presence of local or systemic infections, cognitive or psychiatric conditions that could impair reliable pain assessment or communication, inability to operate the patient-controlled analgesia (PCA) system, and current pregnancy. Baseline demographic data, including age, sex, height, and weight, as well as clinical variables such as intraoperative opioid consumption, estimated blood loss, and surgical type, were documented for all participants.

Randomization and Blinding

Group allocation was determined using a computer-generated randomization sequence with a 1:1 ratio. The assignment codes were concealed in sealed, opaque envelopes and revealed only after participant enrollment was completed.

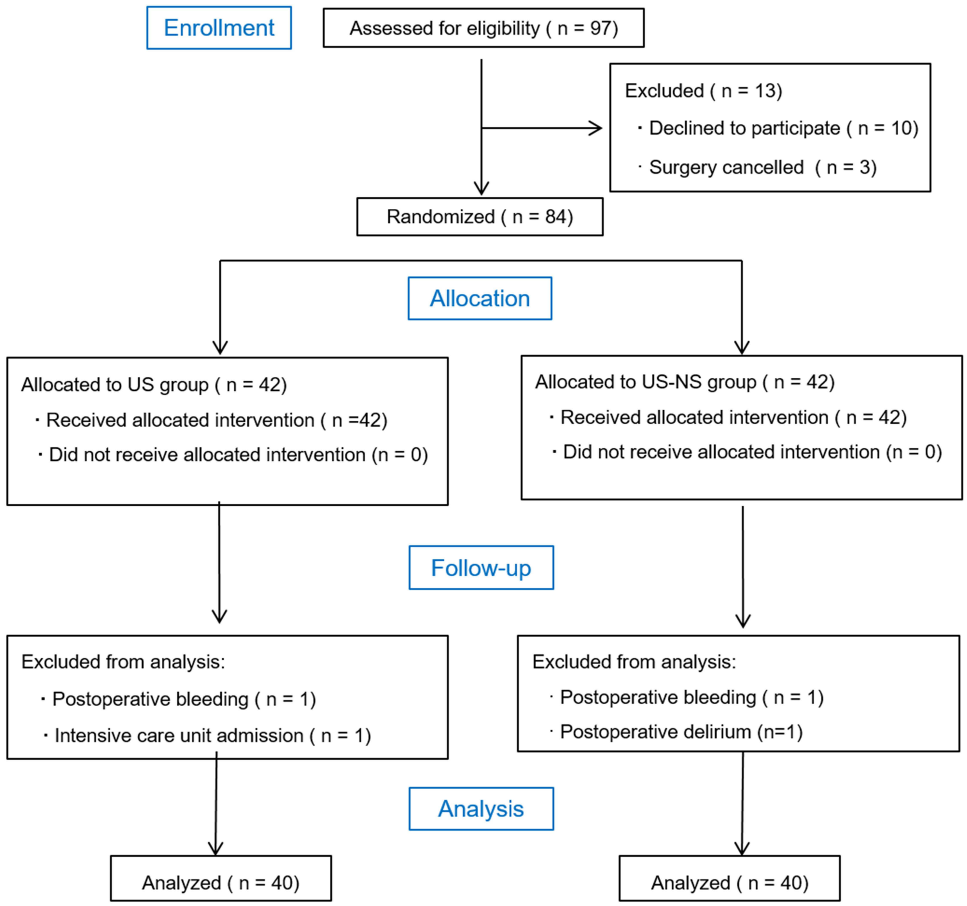

Figure 1 CONSORT flow diagram of the study. CONSORT, Consolidated Standards of Reporting Trials.
Abbreviations: US, Ultrasound; NS, nerve stimulation.

Enrolled patients were randomly assigned to undergo the SQLBs either under US guidance only (US group) or under NS in combination with US guidance (US-NS group) on the affected side. All block procedures were carried out by regional anesthesia specialists (YW, HL, RS, and DM) with established experience in these techniques. To maintain objectivity, the anesthesiologist administering the blocks was not involved in any aspect of anesthesia management, patient assessment before or after surgery, or data acquisition. Data collection was performed by a separate member of the research team, who remained blinded to group allocation and the details of regional anesthesia administration throughout the study.

Block Procedure, Anesthesia Management and Surgical Procedure

All participants received a uniform anesthesia protocol. Upon arrival in the operating room, standard ASA monitoring was applied, including electrocardiogram, noninvasive blood pressure, pulse oximetry, and capnography. Following peripheral venous cannulation, Ringer's lactate solution was administered intravenously. Thereafter, a radial artery catheter was inserted to enable continuous invasive hemodynamic monitoring. Patients were placed in the lateral decubitus position prior to the induction of general anesthesia to facilitate the regional block procedure. To eliminate any potential confounding effects of sedatives on sensory assessment, no premedication was administered. The extent of sensory blockade was assessed using an ice cube at 5, 10, and 15 minutes following block administration.

For the SQLB performed with US guidance alone, a curvilinear transducer (KONICA Minolta, Tokyo, Japan) was placed in a parasagittal oblique orientation just inferior to the 12th rib at the L1–L2 vertebral level. In this view, the QL muscle and the TF anterior to it were visualized adjacent to the lateral margin of the erector spinae muscle (Figure 2a). Following standard aseptic preparation, 2 mL of lidocaine was infiltrated subcutaneously at the needle insertion site to

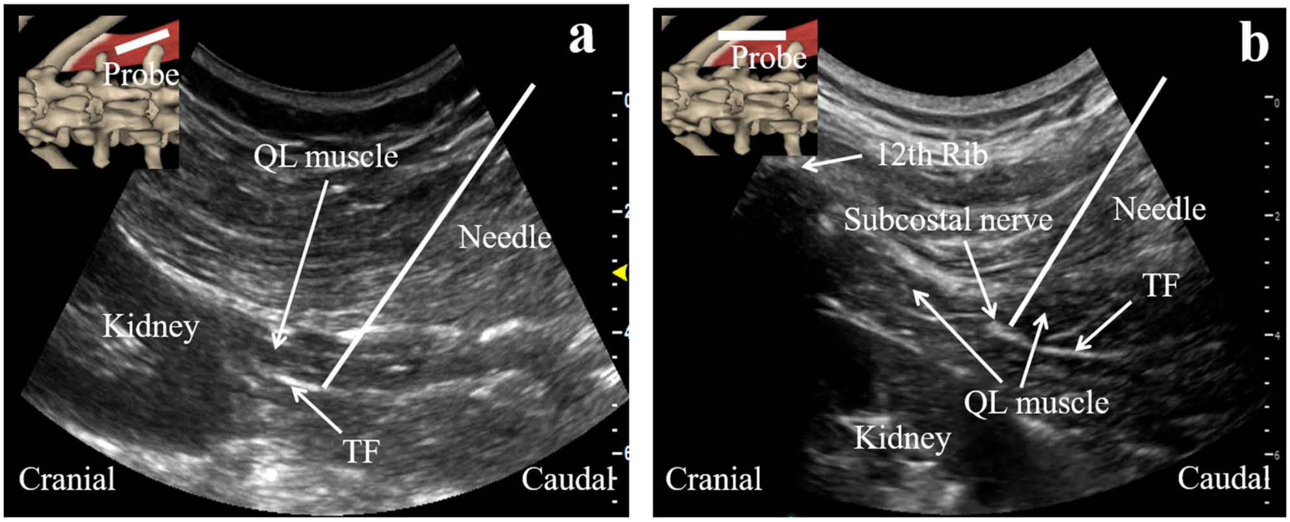

Figure 2 Ultrasound probe positioning and corresponding images for SQLB under ultrasound guidance alone and combined ultrasound-nerve stimulation guidance. Panel a illustrates the traditional US-guided SQLB, in which the ultrasound probe was placed in a parasagittal oblique orientation just inferior to the 12th rib at the L1–L2 vertebral level. In this view, the QL muscle and the TF on its anterior surface can be identified. Panel b depicts the combined ultrasound-nerve stimulation guided SQLB, in which the probe was positioned in a parasagittal orientation, immediately adjacent to the lateral edge of the L1 transverse process tip. In this view, the QL muscle and the TF on its anterior surface can be identified. The round and hyperechoic subcostal nerve could be identified ventral to the QL muscle. The insets in the upper left corners of both (**a** and **b**) highlight the precise placement of the ultrasound probe (indicated by the white box) in the illustrative diagram.
Abbreviations: QL, quadratus lumborum. TF, transversalis fascia. SQLB, subcostal quadratus lumborum block.

minimize procedural discomfort. Then, a 22 G, 10 cm puncture needle with a sharp tip (Tuoren, Henan, China) was inserted in a caudal-to-cranial direction under US guidance. After the needle tip is accurately positioned within the interfascial plane between the QL muscle and the TF, 3 mL of normal saline is initially injected to verify appropriate spread of the solution. This is subsequently followed by the administration of 25 mL of 0.5% ropivacaine.

For the SQLB guided by a combination of NS and US, the curvilinear probe was placed 6–8 cm lateral to the midline, just caudal to the 12th rib. The transducer was positioned in a parasagittal orientation with the marker directed cranially, enabling clear visualization of the anterior aspect of the QL muscle, which appeared as an elongated, curved structure with its superior attachment at the 12th rib. Subsequently, the probe position was adjusted by shifting the probe medially or laterally until the probe was placed immediately adjacent to the lateral edge of the L1 transverse process tip. The round and hyperechoic subcostal nerve could be identified ventral to the QL muscle in the US image (Figure 2b). An insulated NS needle was directed to the subcostal nerve with 1 mA current stimulation after skin infiltration of 2% lidocaine. Once the needle contacted the subcostal nerve, the strong abdominal muscle contraction could be observed. Subsequently, 25 mL of 0.5% ropivacaine was delivered when the abdominal muscle contraction still existed with the stimulation current at or below 0.5 mA.

General anesthesia was induced via intravenous administration of propofol (2–2.5 $mg \cdot kg^{-1}$), sufentanil (0.2 $\mu g \cdot kg^{-1}$), and rocuronium (0.8 $mg \cdot kg^{-1}$). Standard endotracheal intubation was subsequently performed, and controlled mechanical ventilation was initiated. Anesthesia was maintained through continuous infusions of propofol (0.1–0.15 $mg \cdot kg \cdot min^{-1}$) and remifentanil (0.1–0.3 $\mu g \cdot kg \cdot min^{-1}$). Supplemental doses of rocuronium were administered intraoperatively as clinically indicated. To enhance postoperative analgesia, an additional dose of intravenous sufentanil (0.15 $\mu g \cdot kg^{-1}$) was given approximately 15 minutes prior to surgical completion in both study groups. Upon conclusion of the procedure, neuromuscular blockade was reversed using intravenous neostigmine (40 $\mu g \cdot kg^{-1}$). The total anesthesia time, defined from intubation to extubation, was documented.

The surgical intervention performed in this study was laparoscopic partial nephrectomy, comprising a series of critical steps aimed at achieving effective tumor resection with minimal invasiveness and favorable perioperative outcomes. No patient required conversion to open surgery, and all operations were performed by the same experienced surgical team to ensure procedural consistency and minimize technical variability. Patients were positioned in the lateral decubitus posture with the operating table flexed to optimize surgical exposure. A 12-mm camera trocar was initially inserted at the level of the umbilicus to establish transperitoneal access. Under direct vision, three 8-mm robotic ports were subsequently placed, along with a 12-mm assistant trocar located 5 to 8 cm superior to the umbilicus along the midline. In cases involving right renal tumors, an additional 5-mm port was introduced just inferior to the xiphoid process to facilitate liver retraction. Surgical dissection advanced toward the renal hilum, where the kidney was mobilized around the tumor. Depending on intraoperative requirements, the main renal artery, its selective branches, or an off-clamp strategy was employed prior to tumor removal or enucleation. The excised tumor or kidney was extracted by the urologist through a longitudinal incision measuring 6 to 8 cm, created approximately 5 cm medial to the anterior superior iliac spine.[14,15]

The quality of ultrasound images were evaluated based on the clarity of the TF and QL muscle using a 4-grade scale (0 = not discernible, 1 = faintly visible, 2 = well visualized, 3 = excellently delineated). Pain intensity was assessed using the numerical rating scale (NRS), where 0 indicated no pain and 10 represented the most severe pain imaginable. Evaluations were performed at rest and during coughing at 6, 12, 24, and 48 hours following the nerve block procedure. Postoperative analgesia for both groups was managed using PCA devices programmed to administer 2 μg boluses of sufentanil with a 15-minute lockout interval and no continuous background infusion. In instances where analgesia was inadequate, defined as an NRS score greater than 4 at rest, a 50 mg intravenous dose of flurbiprofen was administered as rescue medication, with additional doses provided if necessary. All participants received standardized preoperative education regarding the use of the PCA device and the pain scoring system. Total sufentanil consumption and the requirement for rescue analgesia within the first 24 hours postoperatively were systematically documented.

Outcomes

The primary outcome of this study was the block success rate, defined as a sensory block reaching the T10 dermatome or higher within 5 minutes of LA administration. This definition was based on the anatomical premise that correct deposition of the drug between the TF and the QL muscle facilitates rapid cranial spread to the thoracic paravertebral space, allowing effective blockade of the T10 nerve.[16] Alternatively, incorrect placement outside the intended fascial plane leads to constrained diffusion, often limiting anesthetic spread to the T12 nerve and delaying or preventing cephalad extension to higher thoracic dermatomes.[17]

The secondary outcomes included the following:

The cumulative consumption of intravenous opioids, expressed in morphine milligram equivalents (MME), within the first 24 hours following surgery. For the purpose of analgesic potency conversion, 1 mg of sufentanil was regarded as roughly equianalgesic to 1000 mg of morphine.

The NRS scores, elevated at rest and during coughing at 6, 12, 24, and 48 hours following the nerve block procedure.

The frequency of rescue analgesia administration, defined as the number of patients requiring rescue analgesia in first 24 hours postoperatively.

The extent of sensory block, determined by the number of dermatomes involved at 5, 10, and 15 minutes following LA administration using an ice cube.

Puncture time: recorded from the insertion of the needle into the skin until the completion of LA administration.

Number of needle insertion attempts: defined as the number of skin punctures until successful puncture was achieved.

The quality of the ultrasonic images: classified as good when the average score for both TF and QL muscle was above 4, moderate for scores between 2 and 4, and poor if the total was below 2.[18]

Adverse reactions and complications: the incidence of block-related adverse events, such as pneumothorax, renal injury, LA systemic toxicity, nerve injury, and post-puncture infection, as well as opioid-related complications, including postoperative nausea and vomiting, pruritus, respiratory depression [<10 breaths·min^{-1}] were recorded.[19] The post-operative follow-up was performed within the initial 24-hour postoperative period.

Statistical Analysis and Sample Size Calculation

The sample size was estimated based on our preliminary data concerning the block success rate. A power analysis was carried out using an online statistical calculator (https://www.cnstat.org/statx/compute.html). In a prior pilot study involving 15 patients, the block success rate was 60% in the US group and 90% in the US-NS group. To detect this difference with a statistical power of 80% ($\beta = 0.2$) and a two-sided significance level of 0.05, a minimum of 64

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participants was deemed necessary. Accounting for an anticipated dropout rate of up to 20%, the final sample size was adjusted to 80 patients (40 in each group).

All data were collected following a standardized protocol and recorded in a computerized database as either numerical or categorical variables. Statistical analyses were performed using SPSS for Windows (IBM Corp., Armonk, NY, USA). The Kolmogorov–Smirnov test was applied to assess the normality of data distribution. For normally distributed variables, results were expressed as mean ± standard deviation, and intergroup comparisons were made using independent samples t-tests. Non-normally distributed data were presented as median with interquartile range (IQR) and analyzed using the Mann–Whitney *U*-test. Categorical variables were summarized as counts and percentages, with comparisons performed using either the Chi-square test or Fisher's exact test, as appropriate. Repeated measurement data was analyzed using repeated measures analysis of variance. A two-tailed *P*-value < 0.05 was considered statistically significant.

Results

The flowchart is summarized in accordance with the CONSORT guidelines. In total, 97 patients were recruited for this study. 10 declined to participate and 3 patients were cancelled for surgery due to the preoperative hypertension. The remaining 84 patients were randomized into two groups (n=42/group). In the US group, the follow-up of 2 patients were lost due to postoperative bleeding or the intensive care unit admission with intubation. In the US-NS group, 1 patient was lost due to the postoperative bleeding and 1 patient was lost since the delirium developed after surgery. Finally, the data from 40 patients per group were collected for statistical analysis. No statistically significant differences were observed between the two groups with respect to baseline demographic or clinical characteristics ($P > 0.05$; Table 1).

The block success rate was significantly higher in the US-NS group compared to the US group (92.5% vs 62.5%, $P < 0.05$; Table 2). Furthermore, the US-NS group exhibited a significantly broader sensory block distribution at 5, 10, and 15 minutes following block administration ($P < 0.05$; Table 2).

Within the first 24 hours following surgery, total intravenous MME consumption was significantly lower in the US-NS group compared to the US group (24.3 ± 9.3 mg vs 34.7 ± 11.8 mg, $P < 0.05$; Table 2). Additionally, the requirement for postoperative rescue analgesia was significantly lower in the US-NS group compared to the US group (2.5% vs 10%, $P < 0.05$; Table 2).

A statistically significant difference in NRS scores was observed between the two groups at 6, 12, 24, and 48 hours after the blockade, with patients in the US-NS group consistently reporting lower pain scores than those in the US group, both at rest and during movement ($P < 0.05$; Table 2).

Significant disparity was also noted in terms of puncture time and the number of needle insertion attempts between the US-NS group and the US group, with the US-NS group requiring a longer duration and more attempts to complete the

Table 1 Demographic and Clinical Characteristic

	US Group (n=40)	US-NS Group (n=40)	$t/\chi^2/U$	P
Age (y)	48.2 ± 6.9	51.5 ± 8.1	−1.95	0.055
Sex (M/F)	22/18	23/17	0.05	0.823
BMI ($kg·m^{-2}$)	28.2 ± 3.3	27.8 ± 3.6	0.5	0.618
ASA status (I/II)	16/24	14/26	0.21	0.646
Intraoperative Remifentanil (μg)	2240 [1980–2540]	2080 [1760–2430]	680.0	0.216
Bleeding (mL)	40 [25–50]	35 [25–60]	780.0	0.471
Laparoscopic nephrectomy (Right/Left)	18/22	21/19	0.38	0.538
Anesthesia duration (min)	132.9 ± 21.7	129.7 ± 24.1	0.60	0.550

Notes: Values are presented as mean±standard deviation, median [interquartile range], or number (percentage).
Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index; US, Ultrasound; NS, nerve stimulation.

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Table 2 Block Efficacy and Postoperative Analgesia Outcomes

	US Group (n=40)	US-NS Group (n=40)	t/χ^2/U	*P* value
Block success rate, n (%)	25 (62.5)	37 (92.5)	9.19	0.003
Dermatome coverage				
5 minutes	4 [3–5, T10-L1]	5 [4–7, T9-L1]	502.3	0.004
10 minutes	5 [3–8, T8-T12]	7 [6–9, T6-T12]	441.5	0.001
15 minutes	6 [2–9, T7-T12]	8 [6–9, T5-T12]	410.8	< 0.001
Intravenous morphine				
Equivalent consumption in first 24 h (mg)	34.7 ± 11.8	24.3 ± 9.3	4.36	< 0.001
Rescue analgesia usage, n (%)	4 (10)	1 (2.5)	4.12	0.043
Postoperative pain intensity at rest				
6 hours	2.5 ± 0.4	1.6 ± 0.3	11.78	< 0.001
12 hours	2.8 ± 0.5	1.9 ± 0.4	9.26	< 0.001
24 hours	3.0 ± 0.6	2.3 ± 0.3	7.03	< 0.001
48 hours	3.4 ± 0.8	2.8 ± 0.5	3.97	< 0.001
Postoperative pain intensity during movement				
6 hours	4.6 ± 0.8	3.8 ± 0.6	4.67	< 0.001
12 hours	4.9 ± 0.7	3.9 ± 0.7	6.15	< 0.001
24 hours	5.5 ± 0.5	4.4 ± 0.8	7.38	< 0.001
48 hours	5.1 ± 0.7	4.1 ± 0.6	6.67	< 0.001

Notes: Values are presented as mean ± standard deviation, median [interquartile range], or number (percentage).
Abbreviations: US, Ultrasound; NS, nerve stimulation.

Table 3 Block Characteristics and Adverse Reactions

	US Group (n=40)	US-NS Group (n=40)	t/χ^2/U	*P* value
Puncture time	89 ± 12	160 ± 32	13.28	<0.001
Number of needle insertion attempts	1[1–1]	1[1–2]	586.4	0.028
Ultrasonic image quality, n (%)				
Good	15 (37.5)	14 (35)	0.04	0.841
Moderate	25 (62.5)	26 (65)	0.04	0.839
Poor	0 (0)	0 (0)	NA	NA
Opioid-related complications, n (%)				
Postoperative nausea	2 (5)	2 (5)	0	1
Episodes of vomiting	1 (2.5)	0 (0)	1.01	0.315
Pruritus	0 (0)	0 (0)	NA	NA
Respiratory depression	0 (0)	0 (0)	NA	NA
Block-related adverse events, n (%)				
Pneumothorax	0 (0)	0 (0)	NA	NA
Renal injury	0 (0)	0 (0)	NA	NA
LA systemic toxicity	0 (0)	0 (0)	NA	NA
Nerve injury	0 (0)	0 (0)	NA	NA
Post-puncture infection	0 (0)	0 (0)	NA	NA

Notes: Values are presented as mean±standard deviation, median [interquartile range], or number (percentage).
Abbreviations: LA, local anesthetic. US, Ultrasound; NS, nerve stimulation. NA, not applicable.

SQLB procedure ($P < 0.05$; Table 3). Overall, no significant difference was observed with regard to in the quality of ultrasound images between the two groups ($P > 0.05$; Table 3).

There were no significant differences in the incidence of opioid-related adverse effects during the initial 24-hour postoperative period ($P > 0.05$; Table 3). Notably, no block-related complications were reported in either group, including pneumothorax, renal injury, LA systemic toxicity, nerve injury, or post-injection infection.

Discussion

To our knowledge, this is the first randomized controlled trial to evaluate the use of combined NS and US guidance for needle positioning in the setting of SQLB. Findings from this trial indicate that incorporating NS into ultrasound-guided SQLB stands out as a clinically relevant and efficient technique to improve block success rates, as well as achieving broader dermatomal coverage compared to ultrasound guidance alone. Moreover, combining the NS and US highlights additional therapeutic advantages in enhancing analgesic efficacy and optimizing opioid consumption in patients undergoing laparoscopic nephrectomy.

From an anatomical perspective, the enhanced block success in the US-NS group can be attributed to the more precise deposition of LA within the fascial plane between the QL muscle and the TF. It is noteworthy that, at the anatomical level of the superior lumbar triangle, the subcostal, iliohypogastric, and ilioinguinal nerves are situated posterior to the TF.[20,21] Therefore, even in cases where the LA is not precisely deposited between the TF and the QL muscle, it may still diffuse dorsally to achieve blockade of these nerves. However, such diffusion appears to be insufficient for consistent spread into the thoracic paravertebral space, which may partly explain the lower block success rate observed in the US group compared to the US-NS group.[22]

Furthermore, findings from this study revealed that at 5, 10, and 15 minutes post-block, the sensory dermatome coverage in the US group was significantly less extensive compared to the US-NS group. This finding further suggests that, in certain cases, the LA administered via SQLB may not have consistently reached the thoracic paravertebral space, potentially limiting the extent of sensory blockade. Additionally, within-group comparison showed no notable variation in the range of sensory block between 10 and 15 minutes after administration, indicating that maximal spread had been achieved by the 10-minute mark.

From a clinical practice perspective, the enhanced block success and dermatomal coverage in the US-NS group translated into tangible postoperative benefits. In the present study, the 24-hour postoperative intravenous sufentanil consumption in the US group was 34.7 µg, aligning with values reported in prior investigations.[23] Importantly, patients in the US-NS group exhibited an additional 30% reduction in MME usage within the first 24 hours following surgery compared to those in the US group. This reduction is clinically meaningful, especially given that intravenous sufentanil consumption exceeding 10 µg is considered to have substantial analgesic relevance.[24,25] The observed opioid-sparing benefit may be attributed to the higher success rate and broader sensory blockade achieved through the dual guidance approach, which likely facilitates improved spread of the LA and enhances the overall quality of analgesia.

In addition, we assessed postoperative pain intensity at 6, 12, 24, and 48 hours after the blockage both at rest and during movement in subjects who underwent laparoscopic nephrectomy. The analysis revealed significant differences in NRS scores between the two groups at these time points, with the US-NS guided SQLB group consistently reporting lower pain scores both at rest and during coughing. These findings suggest that the US-NS guided SQLB offers superior analgesic effects compared to the traditional US-guided SQLB. Moreover, the need for rescue analgesics was significantly lower in the US-NS guided SQLB group, further underscoring the enhanced and more satisfactory pain relief provided by this novel technique.

In this study, the nerve block procedures were performed uneventfully in both groups, supported by comparable ultrasound image quality. However, the puncture time in the US-NS group was significantly longer than that in the US group, likely due to the additional procedural steps required for nerve stimulation. Precise localization of the subcostal nerve involved repeated needle adjustments in response to stimulation feedback, as well as calibration of electrical parameters. In contrast, the US group did not employ nerve stimulation, which may have streamlined the procedure and reduced the number of needle insertion attempts.

No block-related complications were reported throughout the perioperative period. In particular, there were no occurrences of serious adverse events such as visceral injury, pneumothorax, systemic LA toxicity, neurological deficits, or post-procedural infections, supporting the safety and technical reliability of both procedure evaluated in this trial.[26,27] In addition, the incidence of opioid-related adverse effects within the first 24 hours postoperatively did not differ significantly between the US and US-NS groups, indicating comparable profiles in terms of opioid-related tolerability and similar effectiveness in mitigating common opioid-associated discomforts.

Several limitations of this study should be considered. First, the results may not be generalizable to obese populations, as the study exclusively enrolled participants with a BMI below 30 $kg \cdot m^{-2}$. This selection criterion was primarily due to the dependence of both block techniques on optimal ultrasound image quality, which may be compromised in individuals with higher BMI. Second, sensory block assessment was conducted using the ice cube test to determine the extent of temperature sensation loss. However, temperature perception is inherently subjective and may vary between individuals, potentially introducing variability in the evaluation of sensory blockade levels, a more objective and reproducible method for assessing the extent and accuracy of the nerve block plane is warranted. In addition, the relatively small sample size may have limited the ability to identify infrequent or rare adverse events. Finally, postoperative renal function was not specifically evaluated, despite the use of anesthetic agents with minimal renal metabolism and low nephrotoxicity.[28,29]

Conclusions

In summary, the SQLB guided by the combined use of NS and US demonstrated superior block success rates, along with broader dermatomal coverage and improved postoperative analgesia compared to ultrasound guidance alone in patients undergoing laparoscopic nephrectomy. These findings suggest that US-NS–guided SQLB is a promising and clinically valuable regional anesthesia technique.

Data Sharing Statement

The data of this study are available from the corresponding author, Yun Wang, upon reasonable request.

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Disclosure

The authors report no conflicts of interest in this work.

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