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ORIGINAL ARTICLE

Modified versus traditional subcostal anterior quadratus lumborum block for postoperative analgesia after laparoscopic nephrectomy: a randomized-controlled study

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Abstract

Purpose To examine the ramifications of both the modified and traditional subcostal anterior quadratus lumborum block (SQLB) on postoperative analgesia in individuals undergoing laparoscopic nephrectomy.

Methods Forty-six individuals slated for elective laparoscopic nephrectomy under general anesthesia were randomly assigned to acquire either traditional or modified SQLB using 20 mL of 0.5% ropivacaine. The primary outcome was intravenous morphine-equivalent intake during the first 24 h following surgery. Secondary outcomes included sensory block dermatomes, numerical rating scale (NRS) scores, the total number of patient-controlled analgesia (PCA) demands, rescue analgesic use, and complications related to opioids and nerve block.

Results The modified SQLB group had significantly lower morphine-equivalent consumption compared to the traditional SQLB group within the initial 24 h after surgery (23.1 ± 4.3 vs. 34.7 ± 6.8 mg, $P < 0.001$). The modified SQLB also resulted in a greater number of dermatome segments of sensory block at 5, 10, and 15 min after block ($P < 0.05$), lower NRS pain scores at rest and during coughing at 6, 24, and 48 h ($P < 0.001$), and reduced usage of rescue analgesics as well as total PCA demands ($P < 0.05$). No significant differences were observed in the incidence of complications related to opioids or the nerve block procedure between the two groups.

Conclusions Ultrasound-guided modified SQLB confers significantly superior analgesic advantages over the traditional SQLB for patients undergoing laparoscopic nephrectomy, culminating in a marked reduction in postoperative opioid consumption and more efficacious pain management.

Keywords Subcostal anterior quadratus lumborum block · Nerve block · Analgesia · Ultrasound · Postoperative pain

Introduction

Laparoscopic nephrectomies, despite being less invasive than open procedures, still involve considerable postoperative pain due to factors, such as gas distension, abdominal port placement, and retroperitoneal dissection [1]. These factors trigger both visceral and somatic pain, involving the T6–T12 somatic nerves and the extensive sympathetic innervation of the abdominal viscera and renal pelvis [2, 3]. Intravenous opioids are commonly employed to manage postoperative pain following laparoscopic surgery, often in conjunction with patient-controlled analgesia (PCA) pumps. Nevertheless, opioid administration can result in adverse effects like nausea, vomiting, pruritus, and paralytic ileus, potentially impeding the recovery process. As a result, there is a growing emphasis on reducing opioid use during the perioperative period to enhance recovery [4]. This shift has increased interest in interfascial plane blocks for analgesia strategies following both open and laparoscopic abdominal surgeries, due to their simplicity and favorable safety profile [5].

The traditional subcostal anterior quadratus lumborum block (SQLB), performed by injecting local anesthetic between the quadratus lumborum (QL) and the transversalis

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fascia (TF), has gained popularity in clinical practice for providing broad analgesic coverage from T6-7 to L1-2 [6, 7]. The traditional SQLB has emerged as a promising and efficacious method for postoperative analgesia following laparoscopic nephrectomies, its effectiveness hinges on the anesthetic's ability to diffuse into the thoracic paravertebral space via the diaphragmatic arcuate ligaments [8–10]. However, at the L1-2 level, the presence of the TF and a double layer of retro renal fascia ventral to the QL muscle complicates needle placement. Specifically, the TF may fuse with the posterior lamina of the posterior renal fascia and the blending site varies between patients [11, 12]. This complexity, particularly in elderly patients or those with muscle fibrosis, can lead to inaccurate anesthetic delivery, indicating that the precision injection is of great difficult in the traditional SQLB.

To address these challenges, we developed a modified SQLB technique that varies from the traditional SQLB in both probe placement and scanning approach [13]. By positioning the ultrasound probe laterally to the tip of the L1 transverse process and paramedian longitudinal scanning, the targeted injection site is the potential space between the QL muscle and the TF, located just below the lateral arcuate ligament at the diaphragm's lower edge. Real-time ultrasound guidance ensures that the anesthetic spreads correctly through the lateral arcuate ligament into the apposition zone between the QL and the diaphragm. The preliminary study has confirmed that this technique could be regarded as a modified version of the SQLB approach, with promising potential for providing effective postoperative analgesia in laparoscopic nephrectomies [13]. However, the comparison between this modified technique and the traditional SQLB has not been performed, which constitutes the primary objective of the current study.

Materials and methods

Patients and design

This research was approved by the Ethics Committee of Beijing Chaoyang Hospital, affiliated with Capital Medical University, China, on August 16, 2021 (reference number: 2021-ke-318) and was conducted in accordance with the principles of the Declaration of Helsinki. The study was officially registered with the Chinese Clinical Trial Registry (ChiCTR2100050020) on January 19, 2020. A total of 52 patients scheduled for elective laparoscopic nephrectomy under general anesthesia were assessed for eligibility at the department of anesthesiology, Beijing Chaoyang Hospital, located in China. After excluding 6 patients, 46 patients were ultimately enrolled and randomly allocated into two groups. Inclusion criteria included: (1) American Society of Anesthesiologists (ASA) physical status I–III; (2) aged 20–70 years; (3) Body Mass Index (BMI) < 30 kg/m^2; (4) normal liver function; exclusions criteria were: (1) puncture site infection; (2) anticoagulant therapy; (3) allergy to local anesthetics; (4) serious cardiovascular or endocrine system diseases, severe renal (serum creatinine > 442 μmol/L or requiring renal replacement therapy) insufficiency [14]; (5) alcohol or drugs abuse; (6) psychiatric disorders or cognitive impairments, unable to cooperate. All patients signed an anesthesia and trial informed consent and were randomly categorized into two cohorts based on the type of regional block received: the traditional SQLB group and the modified SQLB group.

Anesthesia, surgery, and analgesia techniques

Vital signs were monitored after admission, including blood pressure, pulse oxygen saturation, and electrocardiogram. A peripheral vein was cannulated for infusion of lactated Ringer's solution. Regional block was performed before induction of general anesthesia. Patients were placed in a lateral or prone position and scanned with a portable ultrasound instrument (Wisonic Huaseng, Shenzhen Wisonic Medical Technology Co., Ltd, Shenzhen, Guangdong, China) with a low-frequency convex array probe (2–5 MHz). All punctures are performed by the same team of skilled and senior attending physicians in the operating theater. After skin disinfection with chlorhexidine, sterile gloves and a sterile probe cover were used to maintain aseptic conditions during the ultrasound-guided nerve block procedure. Prior to the nerve block, 2 ml of lidocaine was administered subcutaneously at the puncture site to alleviate patient discomfort.

The sensory block plane segments were assessed at 5, 10, and 15 min post-block using the ice cube method. To ensure that the assessment of the nerve block plane was not influenced by sedation or other medications, no premedication was administered in this study.

In the traditional SQLB, the ultrasound probe was positioned posteriorly below the 12th rib in a parasagittal oblique plane at L1-2 level. The QL muscle and the TF on its anterior surface can be identified along the lateral border of the erector spinae muscle (Fig. 1a). A sterile 22 G, 10 cm echogenic puncture needle with a sharp tip (YADU Medical, Henan YADU Industrial Co., Ltd, Xinxiang, Henan, China) be progressed in a caudal-to-cranial trajectory. Once the needle tip reaches the space between the QL muscle and the TF, 3 ml of normal saline is administered to confirm the diffusion of the fluid, followed by the administration of 20 ml of 0.5% ropivacaine.

In the modified SQLB, the probe was positioned 6–8 cm lateral to the spine midline, targeting the anterior QL muscle, with its orientation marker pointed cranially. The QL muscle, identified as a long, curved structure with its

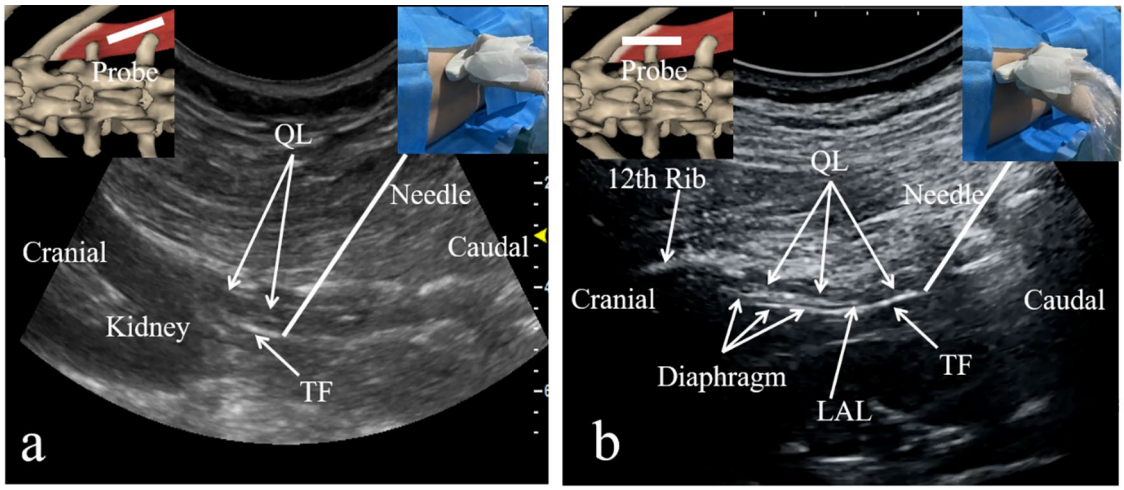

Fig. 1 Ultrasound probe positioning and corresponding images for both the traditional and modified subcostal anterior quadratus lumborum block (SQLB). **a** illustrates the traditional SQLB, in which the ultrasound probe was positioned posteriorly below the 12th rib in a parasagittal oblique plane at L1-2 level. The quadratus lumborum (QL) muscle and the transversalis fascia (TF) on its anterior surface can be identified. **b** depicts the modified SQLB, in which the probe was positioned over the tip of L1 transverse process to perform a sagittal scan. The acoustic shadows of the 12th rib and the apposition zone—specifically, the posterior pathway of the lateral arcuate ligament (LAL) between the QL and diaphragm—were visualized in the sonogram. The insets in the upper left and right corners of both Figs. 1a and 1b highlight the precise placement of the ultrasound probe (indicated by the white box) in the illustrative diagram and the real images of the human body, respectively

cranial attachment at the 12th rib, was then visualized. Subsequently, the probe was shifted medially until the tip of the L1 transverse process appeared following the identification of the 12th rib's acoustic shadow, all while maintaining consistent orientation. The ultrasound probe was then glided from cranial to caudal, centering the acoustic shadows of the 12th rib and the L1 transverse process tip within the ultrasound image. At this point, the diaphragm, a bright echogenic line on both the dorsal and ventral sides, enclosing a hypoechoic muscle layer, can be seen on the ultrasound image as a fine structure moving cranially and caudally with respiration (Fig. 1b). When the probe is subtly shifted laterally, the diaphragm can be observed gradually transitioning caudally into the thin TF on the deep surface of the QL muscle, with the transition zone representing the lateral arcuate ligament. Once the needle tip was guided into the space between the QL muscle and the TF beneath the arcuate ligament using an in-plane approach, 3 ml of saline was injected to confirm fluid diffusion in the diaphragm-QL apposition zone, as indicated by the downward displacement of the diaphragm. Subsequently, 20 ml of 0.5% ropivacaine was delivered.

Patients were placed under general anesthesia with standard tracheal intubation and mechanical ventilation for respiratory management during surgery. Anesthesia induction was achieved by 0.02 mg/kg midazolam, sufentanil 0.3–0.4 μg/kg, 1.5–2 mg/kg propofol, and 0.8 mg/kg rocuronium. Anesthesia maintenance included continuous infusion of 3–6 mg/kg/h propofol and 0.1–0.3 μg/kg/min remifentanil, with intermittent intravenous injections of and 0.15 mg/kg rocuronium, maintaining intraoperative bispectral index within a range of 40–60. At 15 min before the end of surgery, tropisetron 5 mg was administered intravenously. Upon the completion of the surgery, intravenous 40 μg/kg neostigmine was administered to neutralize the neuromuscular blockade. Individuals were subsequently moved to the post-anesthesia care unit for oxygen therapy via a face mask and routine monitoring for 60 min.

The surgical procedure we performed was laparoscopic nephrectomy, which involves several key steps to ensure the removal of the tumor with minimal invasion and optimal outcomes. Each patient was positioned in lateral decubitus with a flexed table. Transperitoneal access was initiated via a 12 mm camera port at the umbilical level, followed by placement of three 8 mm robotic trocars under direct visualization and a 12 mm midline assistant port 5–8 cm above the umbilicus. For right-sided tumors, a 5 mm midline port was added just below the xiphoid for liver retraction. Dissection proceeded to the renal hilum, with mobilization of the kidney near the tumor. The main renal artery, selective branches, or an off-clamp technique was utilized prior to tumor excision or enucleation, and the kidney was then extracted through the port incision [15, 16].

A researcher, unaware of the patient group allocations, evaluated the numerical rating scale (NRS) scores ranging from 0 (no pain) to 10 (worst imaginable pain) at rest and cough at 6, 24, and 48 h after the block. Both groups received intravenous PCA systems, which delivered

sufentanil boluses of 2 μg with a 15-min lockout interval and a steady baseline infusion of 1 μg/h. If the PCA was insufficient and NRS score at rest exceeded 4, an intravenous injection of 50 mg flurbiprofen was delivered for rescue analgesia, repeated if necessary. All of the individuals received preoperative instructions on the use of the PCA pump and the NRS. The dosage of sufentanil, the number of analgesic pump compressions, and the rescue analgesia within 24 h after operation were also recorded.

The primary outcome metric was the total morphine-equivalent consumption during the initial 24 h post-surgery. 1 mg of sufentanil is approximately equivalent to 1000 mg of morphine when comparing their analgesic potency [17]. Secondary outcomes encompassed NRS scores, sensory block plane segments, the total number of PCA demands, the incidence of rescue analgesia usage, the complications related to the block, including cases of pneumothorax, kidney injury, local anesthetic systemic toxicity, nerve injury, and post-puncture infection; opiates complications including the incidence of nausea, vomiting, and itching.

Randomization and blinding

Individuals were randomly distributed into two groups utilizing computer-generated random numbers, ensuring an equal 1:1 allocation ratio between the groups. The group assignment numbers were hidden in sealed opaque envelopes, which were opened only after the patients were enrolled. The anesthesiologist responsible for performing the nerve blocks did not participate in the preoperative or postoperative evaluation of the patients, anesthesia management, or data collection. All data were documented by another researcher that was part of the research group. All data were meticulously documented by a separate researcher who was integral to the study team. This researcher remained blinded to both the group assignments and the administration of the regional blocks. Preoperative demographic details, such as age, sex, BMI, ASA physical status, and the duration of surgery, were collected for each patient.

Statistical analysis and sample size calculation

The sample size for this study was determined based on prior observations at our institution regarding the morphine-equivalent dose required by patients during the first 24 h following nephrectomy. A power analysis was conducted using an online tool (https://www.cnstat.org/statx/compute.html). The data revealed that the morphine-equivalent dose required by patients in the traditional SQLB group and those in the modified SQLB group undergoing laparoscopic nephrectomy was 35.2 ± 13.2 mg and 24.6 ± 8.4 mg, respectively. The study power was set at 0.8, with a type I error rate of 0.05 for the null hypothesis test, indicating that approximately 38 participants were required. To mitigate the impact of potential dropouts, estimated at up to 20%, a target sample size of 46 patients (23/group) was chosen.

A standardized protocol was employed to gather all initial data, which were subsequently entered into a computer as numerical or categorical variables. Data analyses were performed using SPSS for Windows (IBM; IBM Corp., Armonk, New York, USA). The Kolmogorov–Smirnov test was utilized to evaluate the normality of the data distributions. For data exhibiting a normal distribution, the mean and standard deviation were reported, and comparisons between groups were conducted using the independent sample t test. In contrast, data that did not follow a normal distribution were expressed as median (interquartile range), with intergroup differences assessed using the Mann–Whitney U test. Categorical variables were presented as frequency (%), and their analysis was performed using the Chi-square test or Fisher's exact test. A P value of less than 0.05 was considered indicative of statistical significance.

Results

The flowchart according to the Consolidated Standards of Reporting Trials (CONSORT) statement is summarized in Fig. 2. In total, 52 patients were recruited for this study, of whom 4 elected not to participate and 2 exhibited coagulation disorders. The remaining 46 patients were then randomly allocated into two groups and received the nerve block procedure. There were no significant differences between the groups in any demographic characteristics, such as age, sex, BMI, ASA physical status, or total surgery duration ($P > 0.05$) (Table 1).

The dosage of morphine-equivalent consumption administered in the modified SQLB group was 23.1 ± 4.3 mg, compared to 34.7 ± 6.8 mg in the traditional SQLB group, with a significant difference between the groups ($P < 0.001$) (Table 2). Furthermore, there was a substantial reduction in the total number of PCA demands required in the modified SQLB group compared to the traditional SQLB group ($P = 0.012$). Additionally, the incidence of postoperative rescue analgesic usage was significantly decreased in the modified SQLB group relative to the traditional SQLB group ($P = 0.047$).

The study identified a statistically significant disparity in NRS scores between the two groups at 6, 24, and 48 h after the blockade, with patients receiving the traditional SQLB exhibiting higher scores ($P < 0.001$) (Table 3). The ultrasound images were optimally visualized, allowing for precise identification of all relevant anatomical structures. The anticipated pattern of local anesthetic diffusion was uniformly achieved across all participants. Sensory block assessments conducted 15 min post-injection revealed

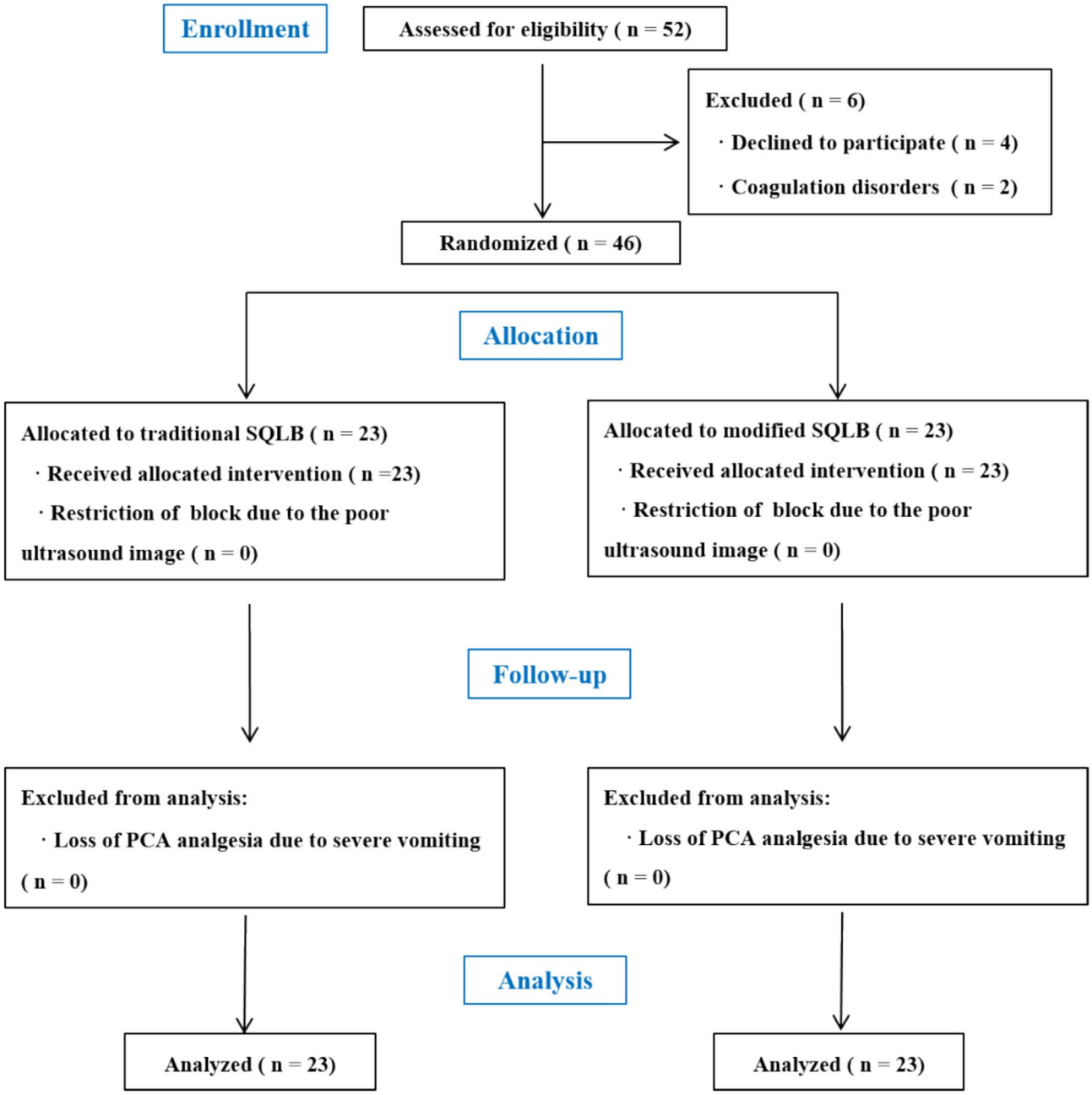

Fig. 2 Patient flow diagram

dermatomal coverage spanning from T5 to L2 in both groups, with the incidence of blockade varied across individual segments (Fig. 3). Notably, at 15 min post-injection, the traditional SQLB exhibited a significantly lower incidence of blockade across segments T6–T9 compared to the modified SQLB ($P < 0.05$), while no significant differences were observed between the two groups across segments T5 and T10 to L2 ($P > 0.05$). Additionally, the modified SQLB group demonstrated a significantly greater number of block plane segments at 5, 10, and 15 min post-block compared to the traditional SQLB group ($P < 0.05$).

The nerve block procedure was performed smoothly and successfully in both groups. The overall incidence of opioid-related side effects, such as nausea, vomiting, and pruritus, did not differ significantly between the two groups during the initial 24 h following surgery ($P > 0.05$). Furthermore, no complications related to the nerve block procedure were observed, including serious conditions, such as

Table 1 Patient characteristics and surgical data

	Traditional SQLB ($N=23$)	Modified SQLB ($N=23$)
Age (y)	49.5 ± 7.2	52.1 ± 7.9
Sex (M/F)	12/11	13/10
BMI (kg/m^2)	27.4 ± 2.6	28.6 ± 2.1
ASA physical status class (I/II/III)	12/11/0	14/9/0
Surgical duration (min)	126.1 ± 16.3	116.2 ± 12.9

Values are presented as mean ± standard deviation, or number

ASA American Society of Anesthesiologists, *BMI* Body mass index, *SQLB* Subcostal anterior quadratus lumborum block

pneumothorax, kidney injury, local anesthetic toxicity, nerve damage, or post-puncture infection.

Discussion

The findings from this randomized-controlled trial indicate that the modified SQLB emerges as a practical and effective approach for enhancing postoperative pain management in patients undergoing laparoscopic nephrectomy, as it provided a 33.4% decrease in morphine-equivalent consumption during the first 24 h after surgery relative to the traditional SQLB. This reduction underscores the clinical effectiveness of the modified technique in enhancing opioid-sparing effects and providing more comprehensive analgesia for patients undergoing laparoscopic nephrectomy.

Our study revealed that all patients attained sensory blockade with dermatomal coverage spanning from T5 to L2 at 15 min post-injection, in concordance with prior findings [10, 13]. This consistency underscores the rigor of our methodology and reinforces the reliability of our observations. In the modified SQLB group, all patients achieved full blockade in the T8 to L1 segments at 15 min, with substantial blockade observed in the T6 to T9 segments. Conversely, the traditional SQLB group attained complete blockade only from T12 to L1, with limited efficacy in the T6 to T9 segments. Furthermore, at 5, 10, and 15 min post-injection, the traditional SQLB group exhibited a markedly lower count of blocked segments relative to the traditional SQLB group, accentuating the reduced efficacy of the traditional SQLB technique.

Table 2 Analgesic medication consumption within the first 24 h post-operation

	Traditional SQLB ($N=23$)	Modified SQLB ($N=23$)	*P* value
Intravenous morphine-equivalent consumption (mg)	34.7 ± 6.8	23.1 ± 4.3	< 0.001
Total number of PCA demands	11[9–12]	5[4–7]	0.012
Rescue analgesia usage (%)	7(30.4%)	1(4.3%)	0.047

Values are presented as mean ± standard deviation, median [interquartile range], or number (percent)

PCA Patient-Controlled Analgesia, *SQLB* Subcostal anterior quadratus lumborum block

Table 3 Postoperative pain intensity and dermatome coverage at different time points after blockage

	Traditional SQLB ($N=23$)	Modified SQLB ($N=23$)	*P* value
Postoperative pain intensity at rest			
6 h	2.5 ± 0.7	1.6 ± 0.5	< 0.001
24 h	3.1 ± 0.5	2.3 ± 0.4	< 0.001
48 h	3.3 ± 0.6	2.5 ± 0.8	< 0.001
Postoperative pain intensity during movement			
6 h	5.6 ± 0.8	3.7 ± 0.6	< 0.001
24 h	4.5 ± 0.7	3.4 ± 0.4	< 0.001
48 h	4.2 ± 0.6	3.2 ± 0.7	< 0.001
Dermatome coverage			
5 min	4[2–6]	6[4–8]	0.031
10 min	6[2–9]	8[6–9]	0.013
15 min	6[2–9]	8[6–9]	0.022

Values are presented as mean ± standard deviation, or median [interquartile range]

SQLB Subcostal anterior quadratus lumborum block

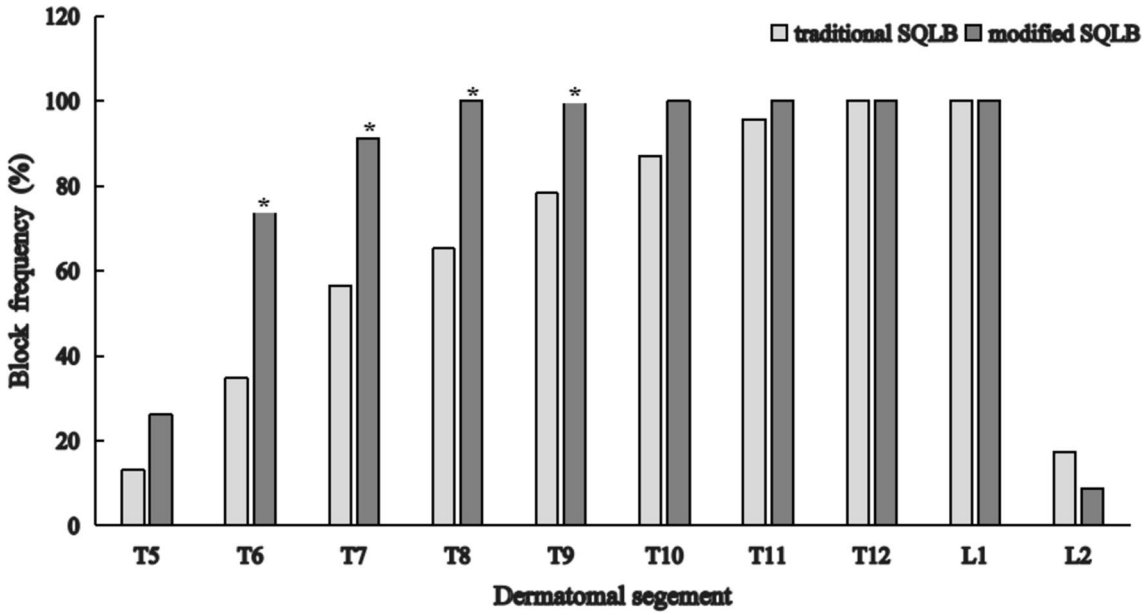

Fig. 3 The sensory block of dermatomes in patients at 15 min after injection

This discrepancy suggests that, in some patients, the local anesthetic in the traditional SQLB did not consistently reach the thoracic paravertebral space. Notably, at the level of the superior lumbar triangle, the subcostal, iliohypogastric, and ilioinguinal nerves lie dorsally to the TF [18, 19]. Even without direct injection between the TF and QL, the anesthetic can still diffuse to block these nerves. However, this diffusion is less effective in reaching the thoracic paravertebral space, which likely explains the less-extensive block achieved with the traditional SQLB compared to the modified SQLB. In addition, the intra-group analysis revealed no significant changes in sensory dermatome coverage between 10 and 15 min, implying that the sensory block was basically fixed at 10 min after blockage. This observation aligns with the previous research findings, indicating that a 15-min interval is sufficient for gauging the efficacy of the nerve block [11, 13].

In this study, the intravenous morphine-equivalent consumption within 24 h post-surgery was 34.7 mg in the traditional SQLB group, consistent with findings from previous research [20]. Notably, patients who received the modified SQLB experienced a further 33.4% reduction in morphine-equivalent consumption during the same period compared to those who underwent the traditional SQLB. This observation underscores the clinical significance, particularly considering that intravenous morphine-equivalent consumption exceeding 10 mg is deemed of substantial clinical importance [21]. Additionally, the total number of PCA demands required by patients in the traditional SQLB group was notably higher than those in the modified SQLB group. These findings, coupled with the decreased consumption of intravenous morphine-equivalent consumption in the modified SQLB group, strongly indicate that the modified SQLB technique markedly improves postoperative opioid management in patients undergoing laparoscopic nephrectomy. This opioid-sparing effect is likely attributed to the enhanced block coverage provided by the modified SQLB, which delivers more comprehensive and effective analgesia.

In this study, the puncture process for both patient groups was carried out smoothly, with no reported complications related to the nerve block procedure. Specifically, there were no incidents of organ injury, pneumothorax, local anesthetic toxicity, nerve damage, or post-puncture infection, which underscores the safety profile of both techniques used in the study. We also monitored opioid-related side effects, including nausea, vomiting, and pruritus, as secondary outcomes. Interestingly, the study found no significant differences between the two groups regarding the incidence of opioid-related side effects within the first 24 h following surgery. This suggests that both techniques were equally effective in managing postoperative symptoms.

This study has several limitations that must be acknowledged. First, the findings cannot be extrapolated to obese patients, as the study only included individuals with a BMI of less than 30 kg/m^2. This limitation arises from the reliance of both traditional and modified SQLB techniques on high-quality ultrasound imaging. Additionally, the ice cube method was used to identify the temperature perception plane as the block plane for this technique. However, since temperature perception is a subjective measure that can vary among individuals, a more objective and reliable method for evaluating the nerve block plane is needed [22].

Furthermore, the relatively limited sample size might restrict the capacity to detect uncommon adverse events.

In summary, the ultrasound-guided modified SQLB provides superior analgesic effects relative to the traditional SQLB in individuals undergoing laparoscopic nephrectomy. This technique not only reduces the need for postoperative analgesic drugs but also effectively alleviates postoperative pain, indicating that the modified SQLB is a compelling and optimistic block technique for these patients.

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Data availability Access to the data that supports the finding of this study is provided upon request.

Declarations

Conflict of interest All of the authors have no conflict of interest.

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