ORIGINAL ARTICLE

Ultrasound-Guided Transmuscular Quadratus Lumbar Block Reduces Opioid Consumption after Laparoscopic Partial Nephrectomy

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Objectives Transmuscular quadratus lumborum block (TQLB) may provide postoperative analgesia in patients undergoing intraperitoneal surgeries. The purpose of this study was to examine the potential efficacy of TQLB among patients undergoing retroperitoneal procedures, such as the laparoscopic partial nephrectomy (LPN).

Methods This prospective, randomized, controlled study was conducted from August 2017 to November 2018 at Peking Union Medical College Hospital (Beijing, China). Patients who were scheduled for a LPN, aged 18-70 years old with an ASA physical status score of I - II were randomly assigned to receive either TQLB with 0.6 ml/kg of 0.5% ropivacaine plus general anesthesia (TQLB group) or general anesthesia alone (control group). Patient-controlled intravenous analgesia with morphine was initiated immediately upon surgery completion. The primary outcome was the cumulative consumption of morphine within 8 h after surgery. The secondary outcome included postoperative consumptions of morphine at other time points, pain score at rest and during activity, postoperative nausea and vomiting (PONV), and recovery related parameters.

Results Totally 30 patients per group were recruited in the study. The 8 h consumption of morphine was lower in the TQLB group than in the control group (median, 0.023 mg/kg vs. 0.068 mg/kg, $U=207.5$, $P<0.001$). No significant differences were observed in postoperative pain scores between the two groups. Patients in the TQLB group had fewer episodes of PONV (20% vs. 47%, $\chi^2=4.8$, $P=0.028$) in the first 24 h after surgery and higher scores for quality of recovery (mean, 138.6 vs. 131.9, $t=-2.164$, $P=0.035$) 120 h after surgery than the controls.

Conclusions TQLB resulted in an opioid-sparing effect during the early postoperative period following LPN, as well as a lower incidence of PONV and improved quality of recovery.

DURING quadratus lumborum block (QLB), a local anesthetic (LA) agent is deposited between the quadratus lumborum (QL) muscle and its surrounding fascia. This procedure allows the LA agent to readily spread to the paravertebral space to block the thoracic somatic nerve roots and sympathetic trunk.^[1,2] QLB is advantageous in that it can theoretically alleviate both anterior and posterior somatic/visceral pain in the abdominal region.^[1] Recent randomized controlled studies have demonstrated that QLB can effectively relieve postoperative pain in patients undergoing intraperitoneal abdominal surgeries.^[3-5] However, the analgesic effect of QLB after retroperitoneal procedures, such as renal surgery, has not been fully investigated.

First described in 2007,^[2] QLB was classified as QLB1 or QLB2, in which the injection is delivered laterally or posteriorly to the QL, respectively.^[4] In 2013, Børglum *et al.*^[6] described the transmuscular QLB (TQLB, also known as QLB3) approach, in which LA is delivered between the QL and psoas major (PM) muscles via a posterior approach.^[7] The LA injected during TQLB spreads into the thoracic paravertebral space via a pathway posterior to the arcuate ligaments to reach the somatic nerves and the thoracic sympathetic trunk.^[1]

Previous reports revealed that TQLB was effective for pain relieving after retroperitoneal renal surgeries.^[8,9] However, our literature search failed to identify randomized controlled trials that evaluated the effectiveness of TQLB among patients undergoing laparoscopic partial nephrectomy (LPN), a typical retroperitoneal procedure. Therefore, we conducted this randomized controlled clinical trial to examine if a preoperative, single-shot TQLB would improve postoperative analgesia after LPN comparing to general anesthesia alone.

PATIENTS AND METHODS

Patient recruitment

This prospective controlled randomized trial was approved by the institutional review board of Peking Union Medical College Hospital (No. ZS-1559). Written informed consents were obtained from all participants. We recruited adult patients who aged 18-70 years old, scheduled for elective LPN, and had an American Society of Anesthesiologists physical status classification of I-II. Exclusion criteria included known allergy to any of the trial medications, coagulopathy or on anticoag-

ulants, chronic opioid therapy or history of substance abuse, and inability to accurately describe postoperative pain to the investigators.

Randomization and blinding

Participants were randomized to TQLB group or control group at a ratio of 1:1 using a computer-generated sequence given by a professional statistician who was not otherwise involved in the study. Allocation concealment was ensured by sealed, opaque, sequentially numbered envelopes. These assignment envelopes were opened after the inclusion of the patient in the study.

TQLB and general anesthesia were conducted by a single anesthesiologist. Surgeries were performed using a standardized retroperitoneal approach by the same surgical team who were blinded to patient allocation. Postoperative assessments were carried out by a research assistant who was blinded to the group assignments.

Perioperative management and anesthesia

All patients were informed of the postoperative patient-controlled intravenous analgesia (PCIA) the day prior to surgery with a goal of maintaining pain scores <4 on an 11-point numerical rating scale (NRS; 0, no pain; 10, maximum pain imaginable).

Upon each patient's arrival at the anesthesia room, standard monitoring and peripheral venous access were established, and a bispectral index (BIS) monitor was connected to the patient. Intravenous (IV) fentanyl and midazolam were titrated based on the patient's comfort level. Patients randomized to the TQLB group were placed in the lateral decubitus position. Ultrasound-guided TQLB was performed as described previously.^[1,6] Briefly, a curved 2-5 MHz transducer (Sonosite X-port, SonoSite Inc, Bothell, WA) was placed in transverse section at posterior axillary line immediately above the iliac crest, adjusted to allow visualization of the transverse process of L4 or L3 and the three muscular structures, i.e., the QL, PM, and erector spinae, as shown in **Figure 1** (A and B). A 21-gauge needle in length of 10 cm (SonoLong Nanoline; Pajunk Inc, Geisingen, Germany) was inserted in-plane and advanced through the QL until the tip of the needle penetrated the investing fascia of the QL. After verifying correct needle placement via saline injection (1-2 mL), 0.5% ropivacaine (0.6 mL/kg) was injected at a rate of 6-7 mL/min (**Figure 1B**). Thirty minutes later, the bilateral dermatomal sensory blocks for the

anterior abdomen (between the anterior axillary and mid-clavicular lines) and thigh were assessed with the pinprick method, as utilized in an earlier study.^[10] A decrease in pinprick sensation relative to the unblocked side was interpreted as an effective block. As previous study reported that ropivacaine concentrations in arterial blood reached the peak value after TQLB with 40 mL 0.375% ropivacaine,^[3] the block was observed for at least 40 min after TQLB. Major adverse events, including anesthetic toxicity (e.g., seizure), bradycardia, hypotension, and hematoma, were recorded.

After the ultrasound-guided block, general anesthesia was induced with intravenous fentanyl (2 µg/kg), propofol (1.5–2.0 mg/kg), and rocuronium (0.6 mg/kg). All patients received endotracheal intubation. For anesthesia maintenance, sevoflurane and a mixture of O₂/N₂O were used to keep the BIS within 40–60. An additional rocuronium bolus was administered as needed and a fentanyl bolus (1 µg/kg each time) was administered to maintain the heart rate and/or systolic blood pressure below 120% of the preoperative levels. LPN was performed through three trocar ports at the posterior, middle, and anterior axillary lines. To facilitate extraction of the kidney, a port at the medial axillary line was extended to 1–2 cm. Thirty minutes prior to skin suturing, all patients received an administration of 1 µg/kg fentanyl for postoperative analgesia. Upon completion of the surgery, sevoflurane and N₂O were discontinued, and the neuromuscular blockade was reversed using neostigmine (50 µg/kg) and atropine (20 µg/kg). Extubation was performed when patients were fully awake.

PCIA was initiated immediately after extubation and delivered for 48 h. A pump (Gemstar, Hospiria Inc., USA) was set to deliver boluses of 1.5–2.0 mg of morphine with a 5-minute lockout interval and no background infusion. The maximal dosage of morphine was set at 8 mg/h.

Outcomes and data collection

The primary outcome was the cumulative consumption of morphine via PCIA 8 h after surgery. The secondary outcomes included: morphine consumption at 0, 2, 4, 12, 24, and 48 h after surgery; pain at rest and during activity, as evaluated by the NRS (range 0–10) at 0, 2, 4, 8, 12, 24, 48, and 72 h after surgery; episodes of postoperative nausea and vomiting (PONV) during the first 24 h; patient satisfaction with anesthesia at 48 h, as assessed using a 5-point scale (5, very satis-

fied; 4, satisfied; 3, neither satisfied nor dissatisfied; 2, dissatisfied; 1, very dissatisfied); self-assessed quality of recovery, determined using the Chinese version of the Quality of Recovery-15 (QoR-15C)^[11] (0, extremely poor quality of recovery; 150, excellent quality of recovery) 72 h and 120 h after the surgery; the time lengths from the end of surgery to the first ambulation, to the resumption of bowel movements, and to the discharge (postoperative time length of hospital stay). We did not use any adjustment method for the type I error of the multiple secondary outcomes; hence, findings from the secondary outcomes were only interpreted as exploratory results.

We also documented patients' baseline characteristics and intraoperative variables. Characteristics of the TQLB including the dermatomal sensory decrease 30 min after the block, as well as adverse events attributed to the LA agent and the block (e.g., hematoma, inflammation, and infection at the administration site) were recorded.

Statistical analyses

Sample size

The sample size was calculated based on the results of a pilot study ($n = 10$) performed at our institution, in which the mean (standard deviation, SD) of cumulative morphine administration within the first 8 h after LPN was 0.069 mg/kg (0.057 mg/kg) in the control group and 0.025 mg/kg (0.026 mg/kg) in the TQLB group. To achieve 80% power for detecting differences at a level of 0.05, the calculation revealed that 27 patients were required in each group. Since 8 h morphine consumption may not follow a normal distribution, and because our sample size calculation might have underestimated the number of patients required, we planned to enroll 30 patients per group.

Variable analysis

Variables and demographics presumed to follow normal distribution were described as the mean (SD), and were analyzed using Student's *t*-test. Variables that were not normally distributed were described as the median (interquartile range, IQR), and were analyzed using Mann-Whitney U-test. Categorical data were reported as the proportion or percentage, and were analyzed using Chi-square test. $P < 0.05$ (two-tailed) was considered statistically significant. Statistical analyses were performed using SPSS (version 15.0, SPSS Inc., Chicago, IL, USA).

Figure 1. The ultrasound-guided TQLB technique in this study. (A) Ultrasound probe position of scanning at the posterior axillary line immediately above the iliac crest and the puncture point for TQLB. (B) An ultrasonic image corresponding to the ultrasound scanning in (A) showing needle trajectory and spread of local anesthetics after injection. ES, erector spinae; PM, psoas major; QL, quadratus lumborum; TP, transverse process; TQLB, transmuscular quadratus lumborum block; VB, vertebral body.

RESULTS

A total of 65 patients were assessed for eligibility from August 2017 to November 2018 at Peking Union Medical College Hospital. Three patients did not meet the inclusion criteria, and two declined to participate. No patient in either group chose to withdraw from the study. Therefore, 30 patients in each group were enrolled in the study (**Figure 2**). Patients' characteristics and intraoperative variables of the TQLB group and the control group are shown in **Table 1**.

Morphine consumption [medium (IQR)] at 8 h was significantly lower in the TQLB group than in the control group [0.023 (0, 0.051) mg/kg vs. 0.068 (0.025, 0.151) mg/kg; $U=207.5$, $P < 0.001$] with a 67% reduction (**Figure 3**). Morphine consumption was also significantly lower in the TQLB group than in the

control group at 2 h [0.005 (0, 0.027) mg/kg vs. 0.050 (0.023, 0.081) mg/kg; $U=193.5$, $P<0.001$], 4 h [0.014 (0, 0.030) mg/kg vs. 0.068 (0.024, 0.133) mg/kg; $U=188.5$, $P<0.001$], and 12 h [0.038 (0, 0.081) mg/kg vs. 0.082 (0.040, 0.189) mg/kg; $U=278.5$, $P=0.01$] after surgery; but not at postoperative 0 h, 24 h, or 48 h (**Figure 3**). No significant differences in pain scores at rest or during activity were observed between the two groups.

Patients who received TQLB had less episodes of PONV during the first 24 h (20% vs. 47%, $\chi^2=4.8$, $P=0.028$) and increased QoR-15C scores at 120 h [138.6 ± 1.7 vs. 131.9 ± 12.7 ; mean difference (95% CI): -6.73 (-12.98 to -0.49), $t=-2.164$, $P=0.035$] after surgery (**Table 2**). No significant differences were observed between the two groups in the time lengths to the first ambulation and to the resumption of bowel movements, patient's satisfaction to anesthesia, QoR-15C scores 70 h after surgery, or time length of postoperative hospital stay. No adverse events attributed to the TQLB procedure or the LA agent were reported in the TQLB group.

Among the 30 participants who received TQLB, the dermatomal sensory decrease was evident at T12 in 30 (100%) patients, at T10 in 25 (83%) patients, at T4 in 15 (50%) patients, at T2 in 7 (23%) patients, at L1 in 29 (97%) patients, and at L4 in 2 (7%) patients (**Figure 4**). Analysis of the intraoperative variables revealed that the intraoperative use of fentanyl was significantly lower in the TQLB group than in the control group [1.80 ± 0.76 $\mu\text{g/kg}$ vs. 2.39 ± 0.71 $\mu\text{g/kg}$, mean difference (95% CI): 0.19 (0.20 to 0.97), $t=3.088$, $P=0.003$]. No significant differences in the other intraoperative variables were observed between the groups.

Figure 2. Flow diagram of patient recruitment and enrollment. TQLB, transmuscular quadratus lumborum block.

Table 1. Patient characteristics and intraoperative variables

Patient characteristics	Control (<i>n</i> = 30)	TQLB group (<i>n</i> = 30)	Statistics	<i>P</i>
Age [yrs, mean (SD)]	55.5 (14.5)	51.5 (9.0)	1.284 [*]	0.204
Sex, male [<i>n</i> (%)]	22 (73)	19 (63)	0.693 [†]	0.405
Height [cm, mean (SD)]	168.2 (8.2)	168.3 (10.2)	-0.042 [*]	0.967
Weight [kg, mean (SD)]	71.7 (16.3)	73.8(15.0)	-0.523 [*]	0.603
ASA PS classification I/II (<i>n</i>)	12/18	10/20	0.287 [†]	0.592
Baseline HR [bpm, mean (SD)]	74.7 (6.0)	75.6 (7.2)	-0.547 [*]	0.587
Baseline MBP [kPa mean (SD)]	12.5 (1.1)	12.7 (1.3)	-0.359 [*]	0.721
Baseline NRS [median (IQR)]	0 (0,0)	0 (0,0)	449.5 [#]	0.981
intraoperative HR [bpm, mean (SD)]	66.5 (7.7)	65.9 (10.4)	0.273 [*]	0.785
intraoperative MBP [kPa, mean (SD)]	11.9 (1.2)	11.9 (0.0)	-0.059 [*]	0.953
Duration of surgery [min, mean (SD)]	109.5 (24.9)	117.1 (32.9)	-1.013 [*]	0.315
Hilar clamping time [min, median (IQR)]	18.0 (7.0, 23.0)	17.0 (2.5, 31.0)	298.5 [#]	0.628
Blood loss [mL, median (IQR)]	200 (100, 300)	225 (150, 502)	347.0 [#]	0.100
Urine output [mL, median (IQR)]	200 (100, 300)	225 (150, 503)	362.5 [#]	0.188
Crystalloid fluid [mL, mean (SD)]	1,383.3 (387.8)	1,441.4 (324.6)	-0.631 [*]	0.531
expired isoflurane concentration [% , mean (SD)]	1.3 (0.2)	1.2 (0.2)	0.385 [*]	0.702
Intraoperative fentanyl [μg/kg, mean (SD)]	2.4 (0.7)	1.8 (0.8)	3.088 [*]	0.003
Intraoperative ephedrine [mg, median (IQR)]	0 (0, 7.5)	1.5 (0, 6.0)	444.0 [#]	0.923

ASA PS, American Society of Anesthesiologists physical status; TQLB, transmuscular quadratus lumborum block; MBP, mean blood pressure; HR, heart rate; NRS, numerical rating scale.

*Compared with Student's t-test. # Compared with Mann-Whitney U-test. † Compared with Chi-square test.

Figure 3. Comparison of cumulative postoperative morphine consumption between TQLB group and the control group. Each box extends from the upper quartile to the lower quartile and is marked by a thick black line at the median. Whiskers reflect the upper and lower values after excluding outliers (>1.5 box lengths), which are represented by filled dots. TQLB, transmuscular quadratus lumborum block. * *P* < 0.001; # *P* = 0.01.

DISCUSSION

The major finding of the current study was the significant opioid-sparing analgesic effect of unilateral

TQLB 8 h after LPN surgery. In addition, the TQLB group was associated with less episodes of PONV and better postoperative quality of recovery as patient reported.

Compared with open procedures, LPN has numerous advantages, including a smaller surgical incision site and faster postoperative recovery.^[12] However, postoperative somatic pain of trocar sites, as well as visceral pain caused by surgical manipulation and pneumoperitoneum should not be neglected. It is important to optimize postoperative pain control to minimize the associated physiological and psychological consequences.^[13] The proposed analgesic mechanism of TQLB was that the injectate spread cranially to the thoracic paravertebral space to infiltrate the ventral rami of thoracic spinal nerves and the sympathetic trunk. Henceforth, TQLB seems to be a solution for postoperative LNP analgesia because it could simultaneously provide somatic analgesia and visceral pain relief. In addition, it could avoid the risk of pneumothorax, puncture of vessel or dura, and intrathecal spread associated with the thoracic paravertebral block (TPVB).^[14]

In the current study, the opioid-sparing effect of

Table 2. Postoperative recovery-related data comparison between the TQLP patients and the controls

Postoperative recovery-related features	Control group (n = 30)	TQLB group (n = 30)	Statistics	P value
24 h PONV (episode) [n (%)]	14 (46.7)	6 (20.0)	4.800 [†]	0.028
Time to first ambulation [h, mean (SD)]	46.8 (18.6)	53.3 (19.1)	-1.345 [*]	0.184
Time to resumption of bowel movements [h, mean (SD)]	35.6 (16.9)	34.9 (17.5)	0.164 [*]	0.870
Patients' satisfaction with anesthesia (very satisfied + satisfied) [n (%)]	27 (90.0)	29 (96.7)	1.071 [†]	0.301
QoR-15C score [mean (SD)]				
72 h post-op	123.9 (13.3)	126.8 (12.4)	-0.815 [*]	0.419
120 h post-op	131.9 (12.7)	138.6 (10.3)	-2.164 [*]	0.035
Post-op hospital stay [days, mean (SD)]	6.3 (1.8)	6.2 (1.7)	0.149 [*]	0.882

TQLB, transmuscular quadratus lumborum block; PONV, postoperative nausea and vomiting; QoR-15C, Chinese version of the Quality of Recovery-15 questionnaire; post-op, postoperative.

*Compared with Student's t-test. †Compared with Chi-square test.

Figure 4. Number of patients who presented reduced sensation upon pinprick at each dermatomal level 30 min after TQLB (n=30). TQLB, transmuscular quadratus lumborum block. T2-T12 represent thoracic vertebrae, L1-L4 represent lumbar vertebrae.

TQLB was prominent during the intraoperative period and last until 12 h after surgery. This effect might also contribute to the reduced incidence of PONV, one of the side effects of opioid administration during the first 24 h after surgery. However, this effect did not last since 24 h after surgery, as both groups had a similar level of morphine consumption at the 24 h and 48 h time points. This phenomenon may likely be attributed to the 'rebound pain' following regional blockade.^[15,16] Single-shot peripheral regional blocks with ropivacaine have been reported to be able to provide pain relief for 8-24 h after surgery.^[3-5,10,16,17] When the analgesic effect of the single-shot TQLB wore off, 'rebound pain' might have occurred and induced 'rebound' opioid consumption requirements, as shown in this study. Therefore, strategies to prolong the analgesic effect of TQLB, such as using adjuvants^[18] or continuous infusion,^[19] should be considered in future to profoundly reduce opioid consumption and the related side effects.

Our study did not show significant differences between groups in postoperative pain either at rest or during activity. This may be explained by the fact that all patients were informed about maintaining postoperative NRS pain scores below 4 with PCIA. Similar levels of patient satisfaction were also observed in this study, which was consistent with earlier studies showing that patient's satisfaction with anesthesia was correlated with the severity of acute postoperative pain.^[10,20]

TQLB is advantageous in that the anesthetic agent spreads from the QL to the higher paravertebral spaces, thus covering a greater range of dermatomal segments.^[1,21] However, controversy regarding the conduciveness of TQLB to thoracic spread still exists.^[21,22] In our study, the dermatomal sensory reduction due to TQLB was observed from L4 to T2, which confirmed the wide thoracic spread. In addition, this result suggests that the sympathetic trunk between T12 and L3, which has previously been found to mediate renal visceral pain,^[23] could also be blocked. At the same time, we also noticed a sensory reduction in the lower L2-L4 dermatomes in a few cases, which reflected lumbar nerve root spread of the LA. Børglum and colleagues^[6] developed the TQLB procedure based on the assumption that LA injected in the fascia plane between QL and PM muscles can spread to the paravertebral space without spreading to the lumbar plexus. However, they also emphasize that piercing of the PM muscle by the needle tip must be avoided because this can easily facilitate spread to the lumbar plexus,^[1] as reported by other cadaveric studies.^[21,22] We performed all procedures in strict accordance with the technique described by Børglum *et al.*^[1,6] Nonetheless, as described in other reports,^[24,25] inadvertently injecting into PM muscle

may lead to LA distribution to the lumbar plexus, which then likely cause unexpected lower limb weakness, though we did not measure lower limb strength in this study. This phenomenon have potential side effects, including prolonging the motor block, delaying mobilization, and postponing hospital discharge,^[24] which we assumed might offset the analgesic benefit of TQLB in reducing ambulation time and hospital stay time, as observed in this study. Consequently, the overall effect of TQLB on the mobilization of patients undergoing abdominal surgeries requires further study.

The volume of ropivacaine used in our study was based on the findings of a radiological study by Carney *et al.*^[26] who reported that 0.6 mL/kg of contrast solution administered posteriorly near the lateral border of QL spread in a posterior-cranial fashion to the paravertebral space from L2 to T4. It is noteworthy that we defined the level of dermatomal blockade based on reductions in pinprick sensation rather than the absolute level of spread as observed during magnetic resonance imaging or cadaveric dissection.^[4,22,26] Because all thoracolumbar nerves that innervate the anterior abdominal wall travel as multiple conjoined segmental nerves that branch and communicate widely,^[27] the segments to which the LA spread in the current study may have been more restricted than those observed using the pinprick test. The total dosage of ropivacaine used in this study was 3 mg/kg, which was below the suggested dose of 4 mg/kg for a single shot block.^[28] No cases of systemic toxicity were observed in the current study. The relatively sparse vascularity of the inter-myofascial plane may also have contributed to this safety profile.^[3,29] However, as with all regional anesthesia techniques, the risk of LA toxicity should always be considered. In order to minimize the risk of toxicity, further studies are needed to determine the minimum dosage of LA that produces the maximum beneficial clinical effects.

This study possesses noteworthy limitations. Given that controversy remains regarding whether TQLB is conducive to thoracic spread, the level of sensory blockade should be confirmed following TQLB. However, this would have prevented blinding in the current trial. In addition, the current study did not include a placebo control group due to ethical reasons. Furthermore, our study included patients with a unique demographic profile from a single center, which may limit the generalizability of our findings. Further large-scale studies are required to evaluate the effect

of TQLB on clinically important outcomes in patients undergoing LPN, including lower extremity strength after the block, serum ropivacaine level, incidence of postoperative complications, and postoperative recovery parameters.

In conclusion, the ultrasound-guided preoperative single-shot TQLB in patients undergoing LPN, a representative retroperitoneal procedure, reduced early postoperative morphine consumption with reduced PONV and improved patient perceived quality of recovery.

Conflict of interests disclosed

None.

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