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ORIGINAL ARTICLE

Local anesthetic spread into the paravertebral space with two types of quadratus lumborum blocks: a crossover volunteer study

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Abstract

Purpose Previous work showed that 20 mL of local anesthetic (LA) did not spread into the paravertebral space (PVS) via the intramuscular quadratus lumborum block (QLBi). If spread of LA into the PVS can be achieved by increasing the total LA volume, QLBi can be more effective. We hypothesized that a larger volume of LA for the QLBi would spread into the PVS.

Methods This crossover volunteer study included five healthy men. For comparison, both the ultrasound-guided QLB type 2 (QLB2) and QLBi were employed on opposite sides of each volunteer, and the spread of LA solution (0.7 mL/kg) mixed with contrast media in the PVS was assessed 1 h after the first injection using magnetic resonance imaging. Sensory loss was evaluated by pinprick 90 min post-injection. Each volunteer underwent both QLB types, and the same procedures were administered on opposite sides 7 days after the first experiment.

Results In total, 20 QLB blocks (10 QLB2 and 10 QLBi) were performed. LA did not spread into the PVS after the QLBi. The sensory block area included the lower abdomen after the QLB2, but not after the QLBi. The sensory block area did not extend to the upper abdominal region or the midline of the lower abdomen with either block method.

Conclusion LA administered by the QLB2 spreads into the PVS of T10–T12, resulting in lower and lateral abdominal sensory loss. In contrast, LA administered by the QLBi does not spread into the PVS and results in only lateral abdominal sensory loss.

Keywords Quadratus lumborum block · Paravertebral space · Volunteer study · Local anesthetic spread

Introduction

Nerve blocks are often used as part of multimodal analgesia for postoperative pain management. The quadratus lumborum block (QLB), which was first reported as Rafi's transversus abdominis plane (TAP) block in 2001 and later developed by Blanco in 2007 (The European Society of Regional Anesthesia annual meeting, unpublished work), is now commonly used for postoperative pain relief following abdominal surgery. Blanco showed that the QLB type 2 (QLB2) [1] effectively blocks visceral pain, and several reports indicate that the QLB is clinically effective for pain relief [2–4]. Carney and colleagues observed noncontinuous spread of local anesthetic (LA) into the thoracic paravertebral space (PVS) from the T4 to the L2 vertebral level [5].

The QLB can be administered using any of three basic approaches, known as types 1, 2, and 3 [1]. Although analgesic effectiveness is thought to be comparable among these three types of QLB, the LA injection points vary for each method. In addition, the intramuscular QLB (QLBi) [3, 6, 7] is a modified QLB approach, differing from types 1, 2, and 3, and has been reported to induce a prolonged analgesic effect. The QLB is believed to be effective for both somatic and visceral pain due to the spread of LA into the PVS, and all types of QLB are believed to achieve analgesia of the entire abdomen. However, we previously reported that the QLBi with 20 mL of ropivacaine did not provide LA spread and did not show midline abdominal sensory block [8]. However, it remains unclear whether LA spreads into the PVS when a

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higher volume of LA is used for the QLBi than was used in our previous study [8].

We hypothesized that LA administered by the QLBi would spread into the PVS if we used a larger volume of LA than was used in a previous study [8]. In this study, we investigated our hypothesis using magnetic resonance imaging (MRI) to evaluate the spread of LA into the PVS with the QLBi as the experimental procedure and the QLB2 as the control.

Materials and methods

Study design

This crossover volunteer study was approved by the Institutional Review Board of the Japanese Red Cross Nagoya Daiichi Hospital (IRB # 2016–088), and written informed consent was obtained from all subjects participating in the trial. The trial was registered prior to patient enrollment at the University Hospital Medical Information Network (UMIN000025014; principle investigator: Takahiro Tamura; date of registration: November 28, 2016). Participants with no previous medical history were recruited through public advertisements from December 1, 2016, to January 31, 2017, and all experiments were performed during this period. Each volunteer underwent a general physical examination, past history interview, blood pressure and heart rate measurement, electrocardiography, and blood tests, including a complete blood count and coagulation panel. Exclusion criteria were as follows: anatomical deformity of the thoracic or lumbar spine (determined by medical history and/or physical examination), history of surgery of the thoracic or lumbar spine or nearby muscles, claustrophobia, metal implant precluding MRI, coagulopathy, thrombocytopenia, and anti-coagulation therapy. One week prior to the first procedure, participants meeting the inclusion criteria underwent abdominal ultrasound examinations to identify the QLB2 and QLBi injection sites.

Ultrasound-guided QLB2 and QLBi

Computer generated randomization was used to determine which type of QLB volunteers would receive as the first puncture. The QLB2 and QLBi were performed on either side for each volunteer, and the procedure was repeated on the opposite sides 7 days after the first experiment. Before performing each nerve block procedure, we established intravenous access and applied standard monitoring (electrocardiography, non-invasive blood pressure monitoring, and pulse oximetry). Prior to skin puncture with the block needle, the skin was infiltrated with 4 mL of 1% lidocaine. Aseptic technique was utilized throughout the block procedures. Blocks were performed using a specialized block needle (Stimuplex D Plus, 0.71 × 80 mm, 22G × 3 1/8 in, B. Braun Aesculap Japan Co. Ltd., Tokyo, Japan) with an in-plane puncture technique under ultrasound guidance. The ultrasound system included a 50-mm, 13-MHz linear ultrasound transducer (Venous50, GE Healthcare Japan K.K., Tokyo, Japan). In the first study, we performed QLB2 or QLBi on one side after randomization. We then performed the other block type on the contralateral side. Both blocks were performed with the patient in the lateral position. Figure 1 shows the injection points for the two block methods. For the QLB2 procedure, injections were administered into the lumbar interfascial triangle along the dorsal side of the middle layer of the thoracolumbar fascia [2, 5, 9], whereas QLBi injections were administered into the quadratus lumborum muscle [3, 6, 7]. Prior to LA injection, negative aspiration was performed, and a 0.5-mL test dose of normal saline was administered to confirm the position of the needle tip. We then administered 0.7 mL/kg of 0.2% ropivacaine (Anapeine injection, AstraZeneca K.K., Osaka, Japan) mixed with gadolinium solution (Magnevist, BAYER K.K., Tokyo, Japan) using a well-established method [5, 8]. If no complications arose from the first procedure, a second round of blocks was performed 7 days later. Each successive procedure was performed on the contralateral side of the body to conduct a crossover study. A single experienced anesthesiologist carried out all nerve block procedures.

Evaluation of endpoints by MRI and the pinprick test

Volunteers remained in the supine position for 60 min after the injections and then underwent 1.5T MRI in the same

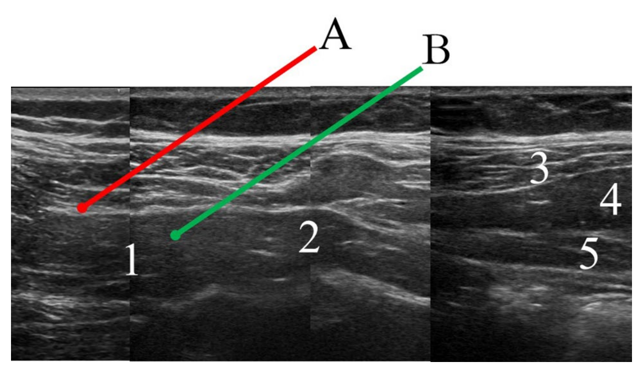

Fig. 1 Nerve block methods and injection points. This figure was modified from sonographic images of a volunteer in our study to serve as a schema to explain our methods. The labeled circles indicate the injection points. Local anesthetic consisting of 0.7 mL/kg of ropivacaine mixed with gadolinium solution was injected at **a** (QLB2, red circle) and **b** (QLBi, green circle). The circles indicate mean injection points. 1: quadratus lumborum muscle, 2: fat, 3: external oblique, 4: internal oblique, 5: transversus abdominis muscle

position (Achieva 1.5T, Philips Japan K.K., Tokyo, Japan), as reported previously [5, 8]. e-Thrive sequences, multi-planar reconstruction, 3-dimensional T1-weighted sequences with fat suppression, and gradient echo imaging were used to identify LA infiltration. The radiologist who interpreted the imaging was blinded to which block was performed on which side.

Sensory perception was also evaluated via a pinprick test 90 min after ropivacaine injection at the following sites: bilateral anterior abdomen, lateral abdomen, back, and hip (0 = loss off pinprick sensation, 1 = decreased pinprick sensation, 2 = normal pinprick sensation). An effective sensory block was defined as a score of 0 or 1. In the cranial and caudal areas, the sensory block area was indicated on the basis of the level of dermatomes at the midaxillary line. In the dorsal and ventral areas, the sensory block area was measured toward the body's midline such as the transverse plane. The sensory block areas were indicated on the basis of some anatomical indices (Table 2). The onset and duration of each block were not evaluated, because this study was designed to investigate the spread and the sensory block area of the LA using the two techniques. All volunteers, as well as the anesthesiologist who evaluated the sensory perception from the nerve block procedures, were blinded to the procedure type.

Complication management

If blood pressure decreased during the block procedures by more than 20% of the initial measurement, volunteers were administered both fluid therapy and repeated doses of 0.1 mg of phenylephrine. Volunteers were observed and monitored for 2 h after the blocks. They also underwent sonographic evaluation of the puncture sites to rule out puncture-related complications and were asked to report side effects up to 2 days after each procedure. The concentration of serum ropivacaine was within a safe range for all volunteers [3, 8, 10, 11].

Statistical analysis

Descriptive statistics, including frequencies, means, and standard errors, were calculated using SAS version 9.4 software (SAS Institute Inc., Cary, NC, USA). Sample size and power calculations were not performed due to the descriptive study design.

Results

A flowchart of the study participants is presented in Fig. 2. Volunteer characteristics, recorded complications, and the number of analyzed blocks are presented in

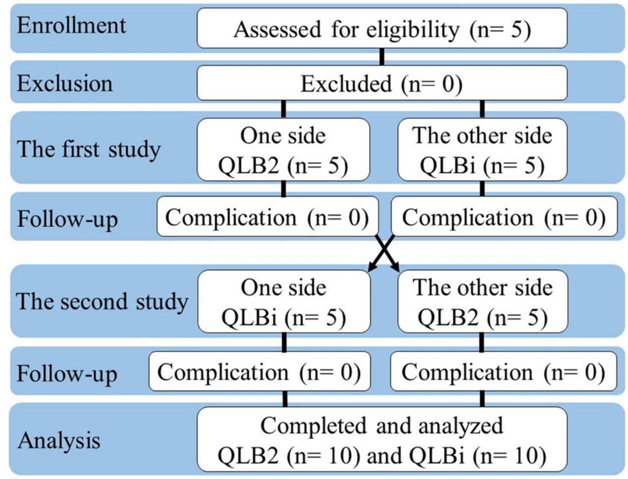

Fig. 2 Participant flow diagram

Table 1. A total of 20 blocks were performed (10 QLB2 and 10 QLBi). There were no complications in any of the volunteers.

Local anesthetic spread after the quadratus lumborum block type 2

Following the QLB2, MRI revealed LA spreading along the ribs to the PVS. The paravertebral spread was limited to the T10–T12 vertebral levels (Fig. 3a, b), and there was no detectable contrast media in the PVS, except from T10 to T12 (Fig. 3a). In addition, contrast enhancement was observed on the TAP (Fig. 3a). The widest sensory block area following the QLB2 extended from the lateral dermatome level of T10 to the proximal lateral thigh, as well as the lower abdominal area (Table 2; Fig. 4). The sensory block area did not include the umbilicus, the lower midline of the abdomen, or the upper abdomen (Fig. 4).

Local anesthetic spread after the intramuscular quadratus lumborum block

The LA spread area and the sensory block area following QLBi were observed to be the same as we had previously reported [8], despite administering a larger volume of LA. There were no images showing enhanced contrast in the PVS, and the LA remained compartmentalized in the quadratus lumborum muscle (Fig. 3a, b). The sensory block area of the QLBi included the lateral abdominal area, but not the umbilicus or the midline of the abdomen (Table 2; Fig. 4).

Table 1 Volunteer demographics and post-study recordings

Demographics	$n=5$[a]		
Age (years)	27.6 (6.8)[b]		
Sex (male:female)	5:0		
Height (cm)	171.4 (1.9)[b]		
Body weight (kg)	64.0 (10.8)[b]		
Body mass index (kg/m^2)	21.8 (3.8)[b]		
Complications	$n=10$		
Nausea	0		
Vomiting	0		
Hypotension	0		
Hematoma	0		
Nerve disorder	0		
Puncture site pain	0		
Number of analyzed blocks	$n=20$[c]		
QLB2	10		
QLBi	10		
MRI evaluation results	Paravertebral spread	Main area of affect	Upper abdominal sensory block
QLB2	Yes ($n=3/10$)	Inferior and lateral abdomen	No
QLBi	No ($n=0/10$)	Lateral abdomen	No

QLB2 quadratus lumborum block type 2, *QLBi* intramuscular quadratus lumborum block, *MRI* magnetic resonance imaging

[a]Total number of volunteers

[b]The data is the mean (standard deviation)

[c]Total number of nerve block procedures

Discussion

This crossover volunteer study analyzed the LA spread and sensory block area of after the QLBi, in which we used a larger volume of LA than was used in our previous study [8]. Evaluating LA spread is necessary to clarify the mechanisms of these methods and to improve the efficacy of these procedures in clinical practice.

The results of this study do not support our hypothesis; however, three main conclusions can be drawn from these results. First, LA administered by the QLBi does not spread into the PVS. Second, LA administered by the QLB2 spreads into the PVS, but only at the T10–T12 vertebral levels. Lastly, the sensory block area of the QLBi includes only the lateral abdominal area, whereas the sensory block area of the QLB2 includes the lateral and lower abdominal regions.

Carney and colleagues [5] reported that LA spreads non-continuously into the upper thoracic PVS. During the prescanning MRI for this study, we found that it was difficult to distinguish the contrast media from the lumbar artery, lymph node, and pleural effusion near the PVS. We adjusted the MRI settings for each volunteer to clarify the images, which resulted in more accurate results. We employed the QLB2 as the control; however, we did not observe LA dissemination into the PVS in the upper thoracic vertebral levels. Our results do indicate that LA spreads along the ribs into the PVS following the QLB2. A recent cadaveric study also reported that there was no dye spread along the intercostal nerves into the PVS of T6–T9 [12]. Our results are consistent with the cadaveric study, as we also did not observe LA spread into the PVS of T6–T9.

The results of our previous study showing that LA delivered via the QLBi does not spread into the PVS can be explained by the anatomy of the thoracolumbar fascia [8]. It remained unclear; however, whether LA would spread into the PVS if a higher volume of LA was administered. Several anatomical reports have indicated that the thoracolumbar fascia is strongly connected to the transverse processes [13–16]. Both previously published results and those of the current study suggest that the QLBi cannot provide paravertebral LA spread, even if a large volume of LA is used.

We determined the sensory block area of the QLB2 and QLBi in volunteers who had never experienced umbilical or upper abdominal sensory loss. We found that the main

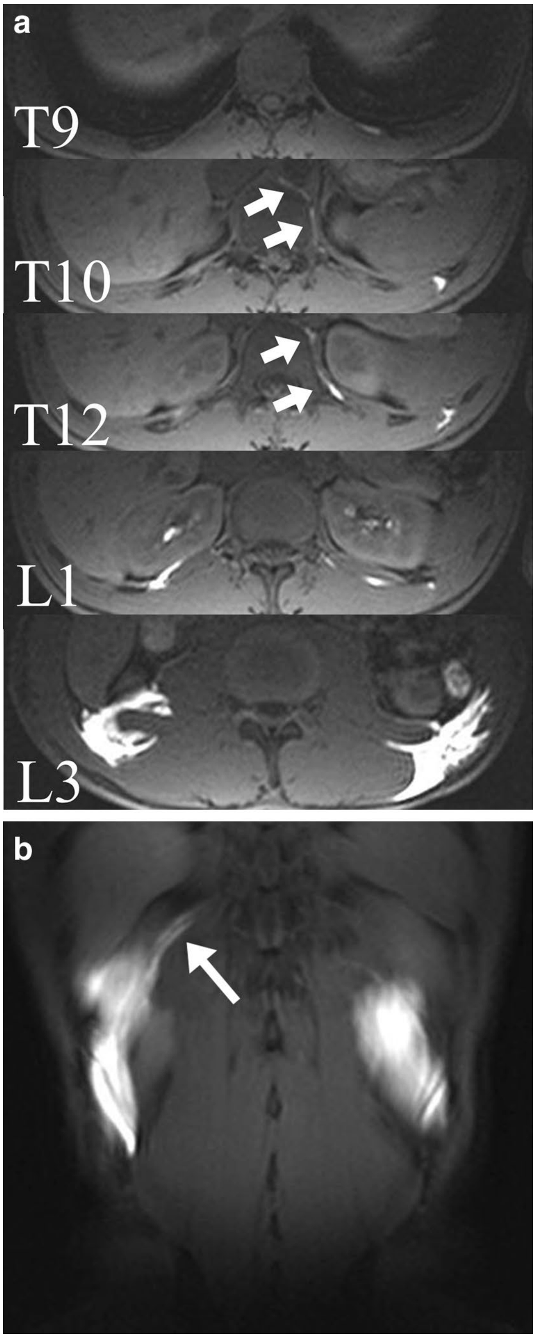

Fig. 3 Magnetic resonance imaging (MRI) of local anesthetic (LA) spread into the paravertebral space (PVS) after QLB2 and QLBi. **a** LA spread into the PVS was detected by MRI following QLB2 (white arrows). The volunteer imaged in this figure underwent left-sided QLB2 (right side of each image). In contrast, MRI did not show LA spread into the PVS following QLBi. The volunteer in this image underwent right-sided QLBi (left side of each image). Top image: Level of the T9 vertebral body. Second image from the top: Level of the T10 vertebral body. Third image from the top: Level of the T12 vertebral body. Second image from the bottom: Level of the L1 vertebral body. Bottom image: Level of the L3 vertebral body. All images are from the same volunteer. **b** Coronal section from a volunteer different from the one shown in Fig. 3a. LA spread into the PVS along the ribs after QLB2 administration (white arrow). The volunteer underwent right-sided QLB2 (left side of image). In contrast, QLBi resulted in a maximum cranial spread that reached the T12 rib. The volunteer in this image underwent left-sided QLBi (right side of image)

Table 2 Volunteers' dermatomes and sensory block area

Volunteer	Cranial	Caudal	Dorsal	Ventral
QLB2				
1	T10	L1	Lateral than S[a]	Lateral than L[c]
2	T11	L1	Lateral than P[b]	Lateral than L
3	T10	L1	Lateral than S	Lateral than M[d]
4	T11	T12	Lateral than P	Lateral than L
5	T10	L1	Lateral than S	Lateral than M
6	T11	L1	Lateral than P	Lateral than L
7	T11	T12	Lateral than P	Lateral than L
8	T11	L1	Lateral than S	Lateral than M
9	T10	L1	Lateral than S	Lateral than L
10	T10	L1	Lateral than S	Lateral than L
QLBi				
1	T9	L1	Lateral than S	Lateral than L
2	T9	L1	Lateral than S	Lateral than L
3	T8	L2	Lateral than S	Lateral than L
4	T9	L1	Lateral than S	Lateral than L
5	T10	T12	Lateral than P	Lateral than L
6	T9	L1	Lateral than S	Lateral than L
7	T9	T12	Lateral than S	Lateral than L
8	T9	L1	Lateral than S	Lateral than L
9	T8	L2	Lateral than S	Lateral than L
10	T10	L1	Lateral than P	Lateral than L

In the cranial and caudal areas, the sensory block area was indicated on the basis of the level of dermatomes at midaxillary line. In the dorsal and ventral areas, the sensory block area was measured toward the body's midline, and was indicated on the basis of the following anatomical indices. Dorsal side anatomical index: [a]S, scapular line; [b]P, posterior axillary line. If the sensory block area is over P toward the spinal process, it is indicated as S. Ventral side anatomical index: [c]L, linea semilunaris; [d]M, middle line between the linea semilunaris and median line of the body; A, anterior axillary line. If the sensory block area is over L, it indicated as M

sensory block area following the QLB2 included the lateral and lower abdominal area, while the sensory loss following the QLBi included only the lateral abdominal area. In fact, the contrast media was observed on the TAP following the QLB2 in our current study, but there was no contrast media observed on the plane in which the intercostal nerves innervate the upper abdomen. This result can be explained by several anatomical studies that have reported that the injection point for the QLB2 is connected to the TAP [13, 14].

We were unable to evaluate visceral pain in this volunteer study. The splanchnic nerves arise from the thoracic spinal cord and run through the PVS to the celiac plexus on the ventrolateral side of the vertebral body, and these nerves show some variation in origin and course [17–19]. In this study, we observed only a small quantity of LA in the PVS following the QLB2, which would likely be insufficient to block the splanchnic nerves in some cases. Furthermore, the splanchnic nerves are not blocked following the QLBi,

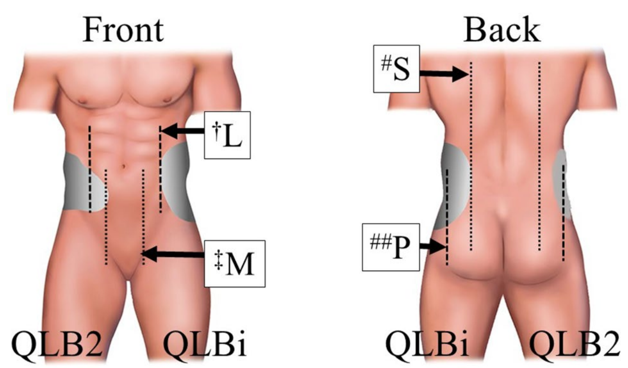

Fig. 4 Typical sensory block area induced by QLB2 and QLBi among all study participants. The gray areas that showed a pinprick score of less than 1 are indicated. The right side of the body schema shows the sensory block area induced by QLB2, while the left side of the body schema shows the sensory block area induced by QLBi. Dorsal side anatomical index: #S, scapular line; ##P, posterior axillary line. Ventral side anatomical index: †L, linea semilunaris; ‡M, middle line between the linea semilunaris and median line of the body; A, anterior axillary line

because this procedure does not result in LA spreading into the PVS.

This study has some limitations that should be addressed. First, although we were able to detect LA spread 1 h after ropivacaine injection, the spread could not be assessed several hours after injection. One previous study investigated LA spread following regional nerve blocks using a greater time interval and was able to identify contrast media in the PVS 1 h after ropivacaine injection [5]. The time period chosen before MRI was based on this previous study. Second, there were no muscle relaxants administered in our study, which differs from the methods of general anesthesia. This may have caused the LA to spread among muscles easily in the QLB2 procedure. Third, to inject a larger volume of LA than was used in our previous study [8], we used a lower concentration of ropivacaine than has been used in previous studies. Fourth, in a previous study, the sensory block caused by the thoracic paravertebral block was significantly larger compared to the spread of LA noted on MRI [20]. However, this observation may not be applicable for the blocks used in the present study, as there was no sensory block at the upper abdomen in both QLBi and QLB2. Thus, it was difficult to determine the sensory block area and any changes in our results that might have occurred if a higher concentration of ropivacaine had been used. In addition, our study design did not evaluate differences due to anatomical variation.

In conclusion, LA administered by ultrasound-guided QLB2 spreads along the ribs into the PVS of T10–T12, resulting in lateral and lower abdominal sensory block. LA administered by ultrasound-guided QLBi does not spread into the PVS and only results in a lateral abdominal sensory block. Neither the QLB2 nor the QLBi provides sensory blockade to the entire abdomen. The amount of LA in the PVS administered by the QLB2 is likely insufficient to block visceral pain. Further studies are necessary to evaluate the analgesic effectiveness of the various QLB methods [21].

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Compliance with ethical standards

Conflict of interest None of the authors has any conflicts of interest to declare in relation to this work.

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