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REPORTS OF ORIGINAL INVESTIGATIONS

Novel external oblique muscle plane block for blockade of the lateral abdominal wall: a pilot study on volunteers

Un nouveau bloc du plan musculaire oblique externe pour le bloc de la paroi abdominale latérale : une étude pilote auprès de volontaires

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Abstract

Purpose *No reports have described techniques to efficiently anesthetize the lateral cutaneous branches of the entire abdomen. The aim of this study was to investigate an effective procedure for blocking the lateral cutaneous branches in the abdominal region. We sought to describe the sensory distribution of the previously described thoracoabdominal nerve block through perichondrial approach (TAPA) and the novel costal and lateral external oblique muscle plane (EXOP) blocks in healthy volunteers.*

Methods *This was a proof-of-concept pilot study that comprised ten volunteers with an American Society of Anesthesiologists Physical Status I. The participants underwent modified TAPA (M-TAPA), injection 2 of TAPA (injection into the anterior aspect of the 10th costal cartilage: I2-TAPA), costal EXOP, and lateral EXOP blocks with injection of 20 mL of ropivacaine 0.2% for each block. A pinprick test was performed one hour after injection and repeated at 30-min intervals until the effect of the nerve block disappeared.*

Results *The M-TAPA injection anesthetized the anterior branches from T6/7 to T11/12, whereas the I2-TAPA injection had no effect. Costal and lateral EXOP injections anesthetized the lateral cutaneous branches of T7–10 and T11–12, respectively.*

Conclusion *The results of this pilot study in ten healthy volunteers indicate that novel EXOP blocks involving local anesthetic injection superficial to the external oblique muscle efficiently anesthetize the lateral cutaneous branches of the thoracoabdominal nerves. Our study shows that it may be anatomically plausible for the combined use of these blocks to anesthetize the entire abdominal wall.*

Résumé

Objectif *Aucune présentation de cas n'a décrit de techniques permettant l'anesthésie efficace des branches cutanées latérales de tout l'abdomen. L'objectif de cette étude était d'évaluer une procédure efficace pour bloquer les branches cutanées latérales de la région abdominale. Nous avons cherché à décrire la distribution sensorielle du bloc nerveux thoraco-abdominal par approche périchondrale (TAPA), décrit précédemment, et des nouveaux blocs du plan musculaire oblique externe (EXOP) costal et latéral réalisés chez des volontaires sains.*

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Méthode *Il s'agissait d'une étude pilote de preuve de concept qui comprenait dix volontaires avec un statut physique I selon l'American Society of Anesthesiologists. Les participants ont bénéficié d'un bloc TAPA modifié (M-TAPA), de l'injection 2 d'un bloc TAPA (injection dans l'aspect antérieur du 10e cartilage costal : I2-TAPA), d'un bloc EXOP costal et d'un bloc EXOP latéral avec injection de 20 mL de ropivacaïne 0,2 % pour chaque bloc. Un test cutané par piqûre d'épingle a été réalisé une heure après l'injection et répété à des intervalles de 30 minutes jusqu'à ce que l'effet du bloc nerveux disparaisse.*

Résultats *L'injection de M-TAPA a anesthésié les branches antérieures de T6/7 à T11/12, tandis que l'injection d'I2-TAPA n'a eu aucun effet. Les injections costales et latérales d'EXOP ont anesthésié les branches cutanées latérales de T7–10 et T11–12, respectivement.*

Conclusion *Les résultats de cette étude pilote chez dix volontaires sains indiquent que les nouveaux blocs EXOP avec une injection superficielle d'anesthésique local au muscle oblique externe anesthésient efficacement les branches cutanées latérales des nerfs thoraco-abdominaux. Notre étude montre qu'il peut être anatomiquement plausible de combiner ces blocs pour anesthésier toute la paroi abdominale.*

Keywords abdominal wall · anesthesia · external oblique muscle · lateral cutaneous branch

Peripheral nerve blockade is one of the key strategies for analgesia, improving the quality of postoperative recovery.[1] The transversus abdominis plane (TAP) block is a commonly used regional anesthesia technique for the abdominal region. The three primary approaches to the TAP block are subcostal,[2] lateral,[3,4] and posterior.[5] Anesthesiologists select the approach according to the surgical site because subcostal TAP block provides analgesia chiefly to the upper abdomen, whereas lateral TAP and posterior TAP blocks provide analgesia mainly to the lower abdomen.[5,6] In surgeries on the lower abdomen, the posterior TAP block is more effective than the lateral TAP block,[7–9] probably because the local anesthetic injected in the posterior area spreads centrally and affects the lateral cutaneous branches of thoracolumbar nerves before branching or anastomosing and entering the TAP.[9,10] The oblique subcostal TAP block[11] is a little difficult for beginners; it involves injecting a local anesthetic incrementally in the TAP using a long needle passing along the oblique subcostal line from the xiphoid to the anterior part of the iliac crest, providing a wide anesthetic area. These TAP blocks, excluding the posterior approach, mainly affect the anterior branches, restricting their anesthetic effect to the mid-abdomen.[12]

In 2019, Tulgar *et al.* reported the thoracoabdominal nerve block through perichondrial approach (TAPA)[13] and the modified TAPA (M-TAPA)[14] block. The TAPA block involves two injections of local anesthetic: injection 1 is between the internal oblique and transversus abdominis muscles and injection 2 is between the external oblique muscle and costal cartilage at the level of the 9th–10th costal cartilage. For the M-TAPA block, only injection 1 of the TAPA block is administered. It was shown that the TAPA/M-TAPA block anesthetized both the anterior and lateral cutaneous branches of the thoracoabdominal nerves, achieving a potent analgesic effect in a wide abdominal area. Therefore, the TAPA/M-TAPA block has been used in various abdominal surgeries.[15–20] Nevertheless, as our clinical experience increased, we questioned the analgesic area achieved by the TAPA/M-TAPA block. First, we observed that quite a few patients complained of pain in the lateral region of the abdomen or lower abdomen when we performed TAPA/M-TAPA block, especially for laparoscopic surgery or gynecological open abdominal surgery. Therefore, the area blocked by TAPA/M-TAPA may be smaller than previously reported.

Second, the lateral cutaneous branches of the thoracoabdominal nerves anatomically perforate the internal and external oblique muscles and run superficial to the external oblique muscles. We wondered if the TAPA/M-TAPA block could really affect the lateral cutaneous branches.

Several techniques of local anesthesia to block the lateral cutaneous branches have been previously reported. The external oblique fascial plane (EOFP) block[21] and the external oblique intercostal (EOI) block[22] involve local anesthetic injection deep to the external oblique muscle at the level of the sixth rib. The serratus-intercostal interfascial (SII)/serratus-intercostal plane (SIP) block[23–26] is achieved by local anesthetic injection into the fascial plane between the serratus anterior and external intercostal muscles on the mid axillary line. These techniques anesthetize the lateral cutaneous branches from the thoracic to the upper-umbilical area. To the best of our knowledge, no reports have described techniques to efficiently anesthetize the lateral cutaneous branches of the entire abdomen. Injection 2 of the TAPA block (I2-TAPA) and M-TAPA block are potential candidates of those techniques, but the analgesic area achieved by the TAPA/M-TAPA block has not yet been clarified.

In this study, we aimed to verify the analgesic effect of the TAPA/M-TAPA block by administering it to healthy volunteers. We also sought to describe a novel technique of blocking the lateral cutaneous branches of the entire abdomen via costal and lateral external oblique muscle plane (EXOP) injections. To efficiently anesthetize the lateral cutaneous branches of the entire abdominal region, we tested three EXOP approaches: one for the costal EXOP injection and two for the lateral EXOP injection.

Methods

Volunteers

This study was approved by the institutional ethics committee of Keiyu Hospital (approval number: R3-25) and registered in the UMIN Clinical Trials Registry (UMIN 000046215). Enrollment included a convenience sample of healthy adult volunteers of both sexes with an American Society of Anesthesia Physical Status I. The exclusion criteria were as follows: (1) younger than 20 yr or older than 50 yr, (2) history of allergy to local anesthetics, (3) neurologic disorder affecting the corresponding region, (4) opioid or steroid use, and (5) pregnancy. After receiving a detailed explanation of the procedure, the participants provided written informed consent for their participation. Participants were assigned to two groups (group 1 for study 1 and group 2 for study 2) in the order they were recruited. All injections were administered by a single anesthesiologist (Y. O.) under continuous ultrasound guidance.

Procedures

STUDY 1: BILATERAL M-TAPA INJECTIONS

The participants were placed in a supine position. A 4–15-MHz linear probe (PX, Fujifilm Sonosite, Tokyo, Japan) was placed in the sagittal direction at the 10th costal margin, and the transversus abdominis, internal oblique, and external oblique muscles were identified. After aseptic preparation of the injection area, lidocaine 1% was used to anesthetize the skin. A needle (22G × 70 mm, Stimuplex Ultra 360, B. Braun, Tokyo, Japan) was introduced in-plane through the skin and advanced into the posterior aspect of the 10th costal cartilage, the fascial plane between the internal oblique and transversus abdominis muscles (Fig. 1, dotted arrow 1). After negative aspiration for blood, 20 mL of ropivacaine 0.2% was injected bilaterally.

STUDY 2: BLOCK OF LATERAL CUTANEOUS BRANCHES IN TWO PHASES

Study 2-1: I2-TAPA (right) and costal EXOP (left) injections The participants' position and probe orientation were the same as those of the M-TAPA injection, and a needle was introduced using the in-plane technique. The needle tip was moved to the anterior aspect of the 10th costal cartilage, the plane under the external oblique muscle for the I2-TAPA injection (Fig. 1, dotted arrow 2) and the plane superficial to the external oblique muscle for the costal EXOP injection (Fig. 1, dotted arrow 3). After negative aspiration for blood, 20 mL of ropivacaine 0.2% was administered for each injection.

Study 2-2: Bilateral lateral EXOP injections Study 2–2 was performed at least seven days later to facilitate complete recovery from study 2–1. The participants were placed in a supine position. An ultrasound probe was located on the lateral abdominal wall cephalad to the iliac crest and caudal to the costal margin. The needle tip was positioned superficial to the external oblique muscle at the level of the anterior axillary line on the left side (Fig. 1, dotted arrow 4; lateral EXOP-ant) and at the level of the posterior axillary line on the right side (Fig. 1, dotted arrow 5; lateral EXOP-post). After negative aspiration for blood, 20 mL of ropivacaine 0.2% was administered for each injection.

Sensory-level assessment

An investigator (Y. O. or S. H.) assessed the sensory levels using a pinprick test one hour after the injection. A three-point numerical scale (0 = no pain, 1 = decreased pain, 2 = normal pain) was used; values of 0 or 1 were defined as effective. To assess the duration of the block, the pinprick test was repeated at 30-min intervals until the effect of the nerve block disappeared.

Results

A total of ten participants (six for study 1 and four for study 2) were successfully recruited and completed the study. Two participants withdrew from study 2 and were excluded. The characteristics of the participants are presented in Table. All participants described areas of anesthesia demarcated by areas of normal sensation. Figure 2A shows the area of sensory block induced by the bilateral M-TAPA injections in six participants. The sensory block area was restricted to the mid-abdomen, which was innervated by the anterior branches of the thoracoabdominal nerves. The area of sensory blockade between T8 and T11 was observed on both sides of all six patients; however, further analgesia up to T7 and T6 was observed in 11 sides (92%) and seven sides (58%), respectively. In addition, the analgesia down to T12 was in seven sides (58%) (Fig. 2B). The median duration of sensory loss following the bilateral M-TAPA injections

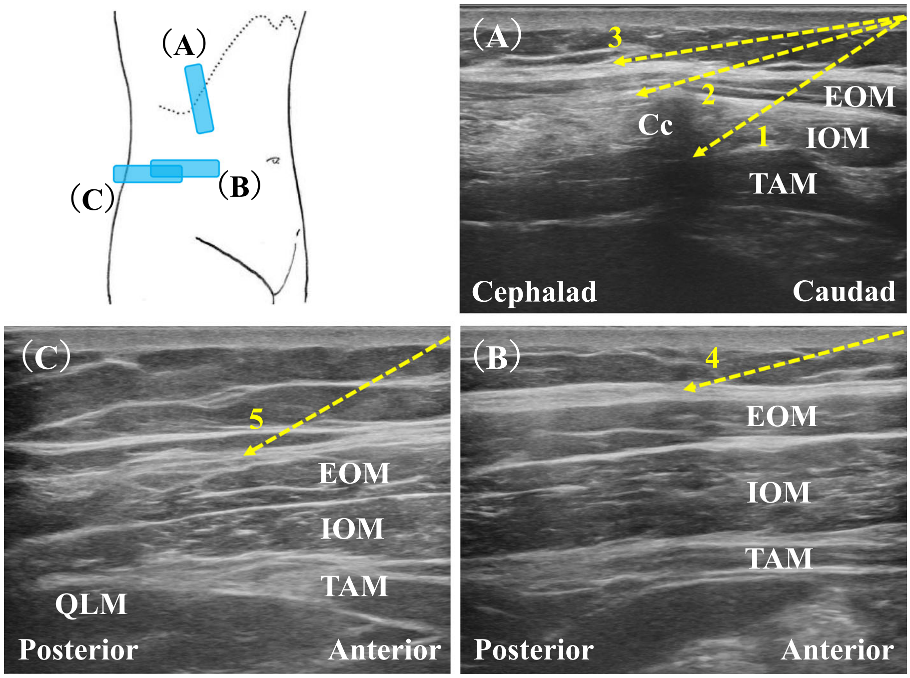

Fig. 1 Ultrasonographic view showing the injection point of the local anesthetic in the volunteer study. (A) Ultrasonographic sagittal view visualized at the 10th costal margin. (B, C) Ultrasonographic transversal view visualized at the lateral abdominal wall cephalad to the iliac crest and caudal to the costal margin, at the anterior axillary line (B) and posterior axillary line (C). The dotted arrows show the position of the needle tip for administering the (1) M-TAPA, (2) I2-TAPA, (3) costal EXOP, (4) lateral EXOP-ant, and (5) lateral EXOP-post blocks. M-TAPA = modified thoracoabdominal nerve block through perichondrial approach; I2-TAPA = injection 2 of TAPA block; costal EXOP = costal external oblique muscle plane injection; lateral EXOP2-ant = lateral EXOP injection at the level of the anterior axillary line; lateral EXOP2-post = lateral EXOP injection at the level of the posterior axillary line; Cc = 10th costal cartilage; EOM = external oblique muscle; IOM = internal oblique muscle; QLM = quadratus lumborum muscle; TAM = transversus abdominis muscle

Table Participant characteristics

Characteristic	Study 1	Study 2
Sex (M/F)	1(17%)/5(83%)	2(50%)/2(50%)
Age (yr)	39 (5)	38 (5)
	[30–46]	[31–44]
Height (cm)	162 (5)	165 (7)
	[154–169]	[154–172]
Weight (kg)	55 (9)	57 (11)
	[47–74]	[42–70]
BMI ($kg \cdot m^{-2}$)	20.9 (2.8)	20.9 (2.5)
	[17.5–25.9]	[17.7–24.2]

Data are shown as *n* (%) or mean (SD) [range]

F = female; M = male; SD = standard deviation

was 870 min (range, 660–1,200 min). Figure 3 shows the area of sensory block after administration of the I2-TAPA, costal EXOP, lateral EXOP-ant, and lateral EXOP-post injections. The costal EXOP injection anesthetized the lateral cutaneous branches of T7–10, whereas the I2-TAPA injection had no effect on the abdominal wall (Fig. 3A, C). The median duration of sensory loss after costal EXOP injection was 510 min (range, 450–720 min). In the lateral EXOP-ant injection, analgesia of the lateral cutaneous branches of T11–12 was obtained in all four volunteers. In

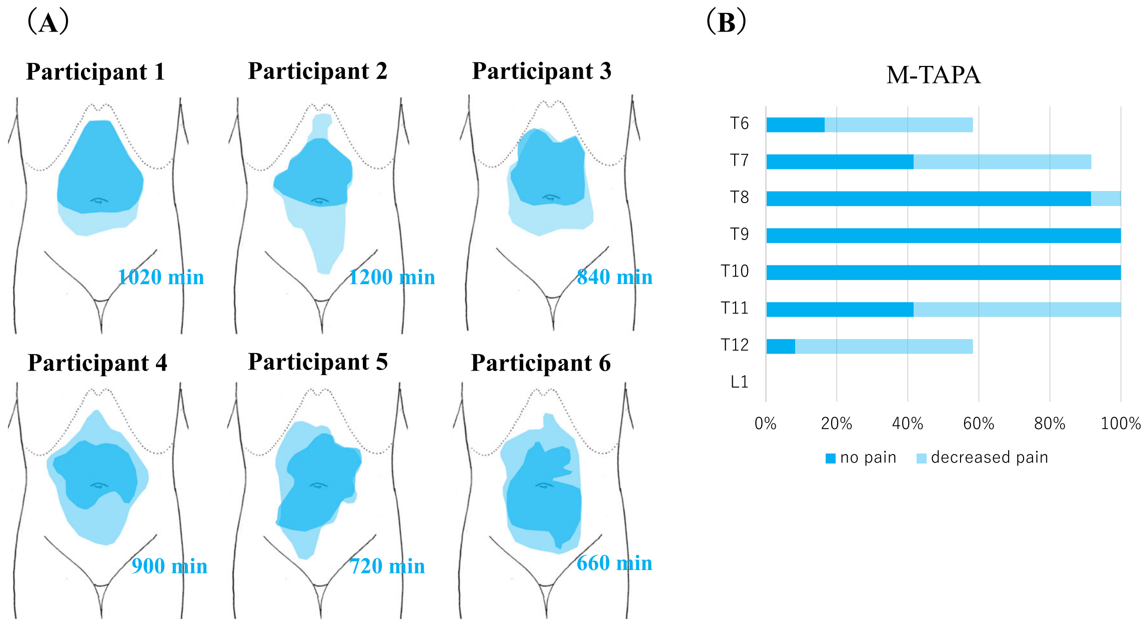

Fig. 2 (A) Area of sensory loss following the bilateral M-TAPA blocks. The dark- and light-colored regions represent areas of no pain and decreased pain, respectively. The numbers represent the duration of action of the M-TAPA block. (B) Percentages of successful blocks in each dermatome. M-TAPA = modified thoracoabdominal nerve block through perichondrial approach; min = minutes.

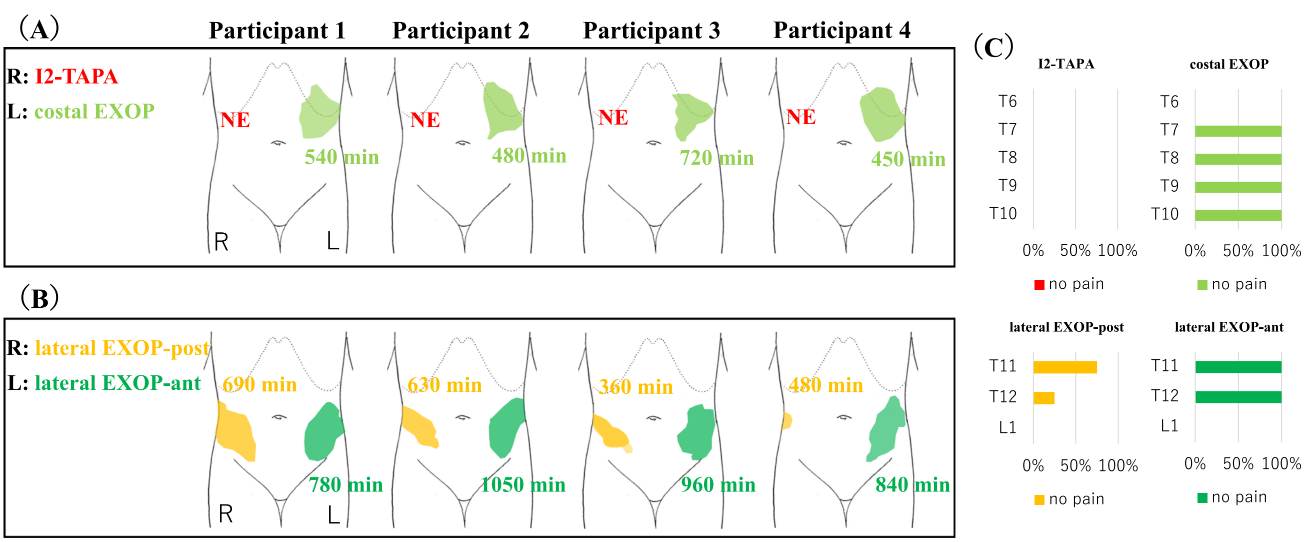

Fig. 3 (A, B) Areas of sensory loss after the (A) I2-TAPA (right side) and costal EXOP (left side) blocks, and (B) lateral EXOP-post (right side) and lateral EXOP-ant (left side) blocks. The numbers represent the duration of action of the block. min = minutes; NE = no effect. (C) Percentages of successful blocks in each dermatome. I2-TAPA = injection 2 of thoracoabdominal nerve block through perichondrial approach; costal EXOP = costal external oblique muscle plane injection; lateral EXOP2-post = lateral EXOP injection at the level of the posterior axillary line; lateral EXOP2-ant = lateral EXOP injection at the level of the anterior axillary line.

the lateral EXOP-post injection, analgesia was in both T11 and T12 in one patient (1/4, 25%), limited to T11 in two patients (2/4, 50%), and completely absent in one patient (1/4, 25%) (Fig. 3B, C). The median durations of sensory loss following the lateral EXOP-ant and lateral EXOP-post injections were 900 min (range, 780–1050 min) and 555 min (range, 360–690 min), respectively. Figure 4 shows the merged image describing the area of sensory loss obtained by nerve blocks in this study.

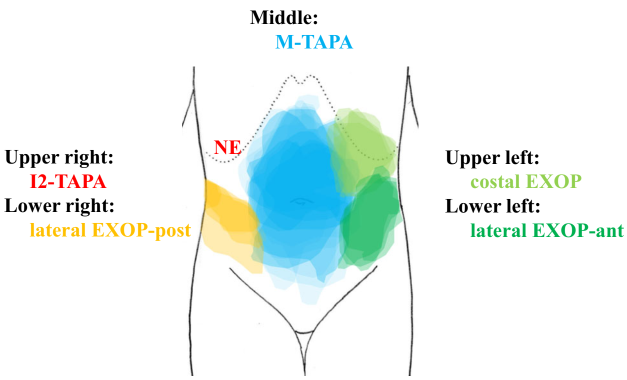

Fig. 4 Merged image describing the area of sensory loss after the M-TAPA, I2-TAPA, costal EXOP, lateral EXOP-ant, and lateral EXOP-post injections. M-TAPA = modified thoracoabdominal nerve block through perichondrial approach; I2-TAPA = injection 2 of TAPA block; costal EXOP = costal external oblique muscle plane injection; lateral EXOP2-ant = lateral EXOP injection at the level of the anterior axillary line; lateral EXOP2-post = lateral EXOP injection at the level of the posterior axillary line

Discussion

This report of our pilot study in ten healthy volunteers verifies the analgesic efficacy in the abdominal area induced by the TAPA/M-TAPA block and describes novel EXOP injections that could provide anesthesia to the area innervated by the lateral cutaneous branches of the thoracoabdominal nerves. Our study shows that the anesthesia induced by the bilateral M-TAPA blocks was restricted to the area innervated by the anterior branches of the thoracoabdominal nerves, and their analgesic effect was especially potent in the T7–T11 region (Fig. 2). The I2-TAPA injection had no analgesic effect (Fig. 3A), probably because both the anterior and lateral cutaneous branches did not run along the plane between the external oblique muscle and costal cartilage. These findings provide clinically important information that the effect of TAPA/M-TAPA blocks was less than previously reported. Aikawa *et al.* evaluated the sensory loss achieved by M-TAPA in patients undergoing gynecological laparoscopic surgery.[27] They reported that the M-TAPA block could provide analgesia to the lateral area. Our findings are distinct from the findings of their study. They evaluated the lateral cutaneous branches at a vertical line 3–5 cm from the midaxillary line. As seen in Figs. 2 and 3, the area innervated by the anterior branches is relatively broad, and the boundary line between the area innervated by the anterior and lateral cutaneous branches is approximately on the midclavicular line (probably around the semilunar line),[28] with the areas presumably partially overlapping. Therefore, the vertical line of pinprick may vary considerably depending on the body size. Furthermore, as Aikawa *et al.*[27] indicated in their discussion, the potential residual effect of opioids may affect the results of the pinprick test. Our study in healthy volunteers did not need to consider these confounding factors, and the area of sensory loss was coincident with the anatomical distribution of the thoracoabdominal nerves.

Our study also described novel costal and lateral EXOP blocks. Local anesthetic injection superficial to the external oblique muscle effectively blocked the lateral cutaneous branches of the thoracoabdominal nerves. Interestingly, the costal EXOP injection anesthetized the lateral cutaneous branches of T7–10, whereas the lateral EXOP-ant anesthetized the lateral cutaneous branches of T11–12 (Fig. 3A and B). We suggest that an unknown factor prevented the injectate from spreading over the costal arch. Therefore, both costal and lateral EXOP injections are required to block the lateral cutaneous branches on the entire abdomen. Additionally, since the lateral cutaneous branches depart from their respective anterior rami near the angle of the rib,[11,28,29] we tested two approaches for the lateral EXOP block: injection at the level of the anterior or posterior axillary line. The analgesic effect of the lateral EXOP-post injection was unstable and less effective than that of the lateral EXOP-ant injection. This is probably associated with the location of the lateral cutaneous branches that penetrate through the external oblique muscle to supply the skin. The local anesthetic should be administered at the level of the anterior axillary line for an effective lateral EXOP block. We believe that the combined use of the M-TAPA and EXOP blocks to anesthetize the entire abdominal wall may be anatomically plausible (Fig. 4).

Several techniques for blockade of the lateral cutaneous branches have been previously reported. The EOFP[21] and EOI[22] blocks are similar. The EOFP block involves the injection of the local anesthetic at the T6 level, superficial or deep to the external oblique muscle, around the midclavicular line, while the EOI block involves the injection of the local anesthetic deep to the external oblique muscle, at the level of the sixth rib, just medial to the anterior axillary line. These blocks can anesthetize the lateral cutaneous branches approximately from T6/7 to T10. Intriguingly, the level of the lateral cutaneous branches anesthetized by the costal EXOP injection is almost the same as that of these blocks, but the area of sensory loss is restricted to the abdominal wall. Furthermore, the plane of local anesthetic injection of the EOFP and EOI blocks, deep to the external oblique muscle, is substantially equivalent to that of the I2-TAPA. Nevertheless, the current study showed that I2-TAPA had no analgesic effect. This finding suggests that a local anesthetic administered into the plane deep to the external oblique muscle does not easily spread to the site of the lateral cutaneous branches piercing the intercostal and external oblique muscles when injected at the costal margin. The current study shows that local anesthetic injection superior to the external oblique muscle at the costal margin is more effective for blocking the lateral cutaneous branches in the abdominal area. Moreover, the costal EXOP injection may be a practical procedure because it can be performed with the same probe orientation and motion as the M-TAPA block, but with the needle angled superior to the external oblique muscle. On the other hand, the SII/SIP block[23–26] can also block the lateral cutaneous branches of the thoracoabdominal nerves from T7 to T11. It involves local anesthetic injection into the fascial plane between the serratus anterior and external intercostal muscles on the mid axillary line. The block is achieved by single injection at the level of the 8th rib[23] or by multiple injections of a small dose (3 mL) for each target dermatome.[24–26] These blocks, including the EOFP and EOI blocks, are performed on the chest wall, so the anesthesia extended from the thoracic to the upper-umbilical area. We believed that the costal and lateral EXOP blocks are reasonable procedures for abdominal surgery because the anesthetized area is restricted to the abdominal region after the EXOP blocks.

This study had several limitations. First, it was a pilot study with a small number of healthy volunteers. All participants who volunteered in this study were younger than 50 yr, whereas abdominal surgery is applicable for all age groups. The spread of the local anesthetic may vary with age and body size because of multiple factors, including muscular degeneration and other anatomical changes. Therefore, cadaver and clinical studies are warranted to evaluate the injectate spread and clinical effectiveness of EXOP blocks. Furthermore, we used 20 mL of ropivacaine 0.2% for each injection in this volunteer study. Since 60 mL is required for each side (total of 120 mL) when performing the bilateral M-TAPA and EXOP blocks to anesthetize the entire abdominal wall in accordance with our protocol, attention should be paid to local anesthetic systemic toxicity and the need to reduce the concentration of local anesthetics. More studies evaluating the optimal volume and concentration of local anesthetics will be informative.

In this proof-of-concept pilot study, we showed two things: 1) The M-TAPA block anesthetized only the anterior branches from T6/7 to T11/12, and 2) the costal and lateral EXOP blocks anesthetized the lateral cutaneous branches of T7–10 and T11–12, respectively. This study shows that the combined use of these blocks to anesthetize the entire abdominal wall may be anatomically plausible. Further clinical study is warranted to optimize the volume, concentration, and type of local anesthetic. We believe that blocking the lateral cutaneous branches of thoracoabdominal nerves may offer increased analgesia in abdominal surgeries.

Author contributions *Yuichi Ohgoshi* contributed to the study design, performance of blocks, data collection, and manuscript preparation and approved the final manuscript. *Izumi Kawagoe* oversaw the project and manuscript composition and approved the final manuscript. *Aki Ando*, *Maria Ikegami*, and *Sayako Hanai* contributed to the study execution and data collection and approved the final manuscript. *Koichiro Ichimura* contributed to the study design and approved the final manuscript.

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