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Anatomical characteristics of the rectus abdominis and transversus abdominis muscles related to ultrasound-guided rectus sheath block for analgesia around the umbilicus in healthy adult Japanese volunteers

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Background: The rectus abdominis muscle partially overlaps with the transversus abdominis muscle belly when following cephalad. This study aimed to evaluate the overlapping properties between the rectus abdominis muscle and the transversus abdominis muscle belly in relation to the performance of ultrasound-guided rectus sheath block for analgesia around the umbilicus.
Methods: After obtaining institutional approval and written informed consent, ultrasound examinations of bilateral abdominal walls were performed in healthy adult Japanese volunteers. The craniocaudal distance from the level of the umbilicus to the point where the rectus abdominis muscle and the transversus abdominis muscle belly begin to overlap on the ultrasound image was measured.
Results: Sixty hemi-abdominal walls were examined in 30 volunteers (15 males, 32±6 years old, and 15 females, 31±5 years old). The craniocaudal distance from the level of the umbilicus to the point where the rectus abdominis muscle and the transversus abdominis muscle belly begin to overlap on the ultrasound image (left side/right side) was 17.4±11.8/18.8±13.3 mm in male subjects and 19.5±11.5/21.2±12.4 mm in female subjects, respectively. At the level of the umbilicus, overlapping of the two muscles was observed only in 2 of 60 subjects. At 45 mm cephalad from the level of the umbilicus, the two muscles began to overlap in 58 of 60 subjects (96.7%).
Conclusions: The position where the rectus abdominis muscle and transversus abdominis muscle belly begin to overlap as detected by ultrasound imaging is approximately 20 mm cephalad to the umbilicus.

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Key words: rectus sheath block, rectus abdominis muscle, transversus abdominis muscle, ultrasound

Introduction

Rectus sheath block (RSB) is an anterior abdominal wall approach to block the terminal muscular branches and anterior cutaneous branches of the thoracic nerves that have been used to provide somatic analgesia for surgeries with midline incisions[1-3]. Recently, RSB has become commonly performed under ultrasound guidance[4] to confirm the proper needle tip position and appropriate local anesthetic spread within the target tissue plane, and to avoid inadvertent vascular puncture or organ injury[2]. The efficacy of RSB has been reported in pediatric umbilical hernia repair surgery[5,6]. In addition, there is an increasing clinical importance of RSB for adult patients undergoing laparoscopic surgery that requires an umbilical port insertion[3,7,8].

According to a previous anatomical examination, branches of the 10th thoracic nerve (T10 nerve) almost always innervate the umbilicus[9]. The T10 nerve travels superficial to the

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transversus abdominis muscle belly, then penetrates the lateral part of the posterior layer of the rectus sheath[1,9,10]. After a short course between the posterior layer of the rectus sheath and the rectus abdominis muscle, the T10 nerve enters the rectus abdominis muscle to supply skin from the midline to the mid-clavicular line[9,11] (Fig. 1). It is known that the transversus abdominis muscle consists of the muscle belly with fleshy transverse fibers that arise from the inguinal ligament, the inner lip of the iliac crest and the inner surfaces of the cartilages of the lower six ribs, and the anterior broad aponeurosis that inserts into the linea alba. In addition, the rectus abdominis muscle partially overlaps with the transversus abdominis muscle belly when following cephalad, and the overlapping width between the rectus abdominis muscle and the transversus abdominis muscle belly increases, when following cephalad from the level of the umbilicus to the xiphoid process (Fig. 1),[1,12]. Therefore, it is essential to understand the anatomical relationship between the transversus abdominis muscle, the rectus abdominis muscle, and the thoracic nerve to perform proper ultrasound-guided (USG)-RSB.

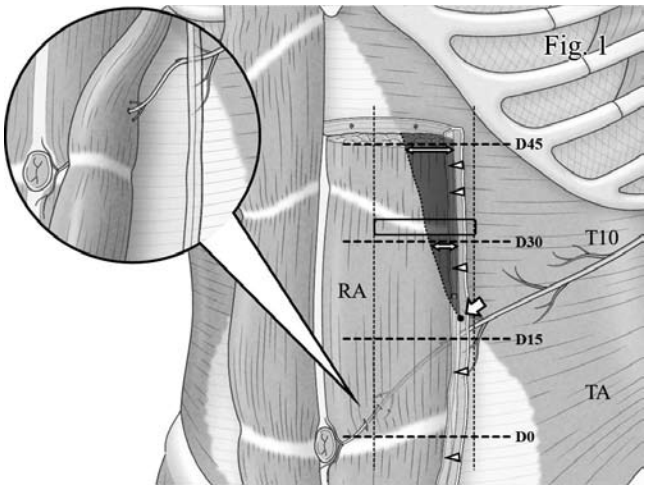

Figure 1. An illustration showing a typical example of the relationship between the rectus abdominis muscle (RA), the transversus abdominis muscle belly (TA), and the 10th thoracic nerve (T10) at the left hemi-abdominal wall and how to perform the ultrasound examination of the abdominal wall in the present study. The dotted line indicates the medial border of the TA behind the RA. A colored area on the TA indicates the overlap of the TA and RA. Cephalad portion of the left RA is truncated to directly visualize the cephalad portion of the TA. A rounded rectangle above the D30 line demonstrates an example of the ultrasound probe position that transversely visualizes the overlap of the lateral edge of RA and the medial edge of TA. In the present study, the probe was moved cephalad or caudad along with perpendicular thin dashed lines. The white asterisk indicates the position where the lateral edge of the RA and the medial edge of TA slightly overlap or a position just above the black dot that is discussed as an option of needle tip position for the ultrasound-guided rectus sheath block to obtain analgesia around the umbilicus. The black asterisks indicate the posterior layer of the rectus sheath. White arrowheads indicate the cut edge of the anterior layer of the rectus sheath. Within the balloon, the RA is reflected from a lateral to the medial direction to demonstrate the course of the peripheral part of the T10 in relation to the posterior layer of the rectus sheath and the RA. D0 indicates the horizontal line running through the center of the umbilicus. D15, D30, and D45 indicate the lines drawn at 15, 30, and 45 mm cephalad from the level of the umbilicus or D0, respectively. The width of overlap between RA and TA along with D30 and D45 are indicated by white double-headed arrows. The black dot indicated by a white arrow indicates the point where RA and TA begin to overlap.

In a recent cadaver study, we demonstrated that most T10 nerves enter the space between the posterior layer of the rectus sheath and the rectus abdominis muscle cephalad to the umbilicus (33.8 ± 14.4 mm cephalad from a horizontal line running through the umbilicus)[10]. Moreover, the position where the lateral edge of the rectus abdominis muscle and the medial border of the transversus abdominis muscle belly cross is also cephalad to the umbilicus (33.1 ± 17.1 mm cephalad from a horizontal line running through the umbilicus)[10]. Judging from the results of this cadaver study, when we perform USG-RSB to provide analgesia around the umbilicus, an appropriate needle tip position in an ultrasound image may be where the transversus abdominis muscle belly begins to underlie the lateral edge of the rectus abdominis muscle. This concept is even practical as the thoracic nerves cannot be identified by the resolution of the currently available ultrasound machine. However, the detailed sono-anatomical characteristics of the relationship between the rectus abdominis muscle and transversus abdominis muscle belly around the level of the umbilicus have not been clarified.

This study aimed to evaluate the overlapping properties between the rectus abdominis muscle and the transversus abdominis muscle belly in relation to the performance of USG-RSB for analgesia around the umbilicus.

Materials and methods

The present study was performed following approval from the Institutional Review Board of the Nagasaki University Graduate School of Biomedical Sciences (approved number: 13042681) and with written informed consent from the volunteers. Ultrasound examinations of the left and right abdominal walls were performed on 30 healthy adult Japanese volunteers in a university setting. Subjects with pathology in the anterior abdominal wall were excluded. Subjects were placed in the supine position; a high-frequency linear probe, HFL38x/13-6, was used to acquire the images (S-Nerve™;

SonoSite Japan, Tokyo, Japan). The ultrasound probe was placed in a transverse orientation to visualize the lateral aspect of the rectus abdominis muscle around the level of the umbilicus[1] (Fig. 1).

First, the point at which the rectus abdominis muscle crosses a horizontal line running through the center of the umbilicus was identified as the standard point 0 (D0 in Fig. 1), with cephalad to this point being considered positive, while caudal to this point being considered negative. Then, the probe was placed in transverse orientation at the level of the umbilicus (D0 in Fig. 1) to visualize the lateral aspect of the rectus abdominis muscle. Second, the probe was moved cephalad from the level of the umbilicus up until the rectus abdominis muscle and the transversus abdominis muscle belly began to overlap. If the transversus abdominis muscle belly underlay the rectus abdominis muscle at the level of the umbilicus, then the probe was first moved caudad to identify the point where the rectus abdominis muscle and the transversus abdominis muscle belly began to overlap. The width of overlap between the rectus abdominis muscle and the transversus abdominis muscle belly was measured using the caliper function of the ultrasound machine (Fig. 2) at 0, 15, 30, and 45 mm from the level of the umbilicus (D0, D15, D30 and D45 in Fig. 1, respectively). The widths at D30 and D45 were demonstrated by white double-headed arrows in Fig. 1. The craniocaudal distance from the horizontal line running through the center of the umbilicus to the point where the rectus abdominis muscle and the transversus abdominis muscle belly begin to overlap (the distance from D0 to the black dot indicated by a white arrow in Fig. 1) was also recorded. If the rectus abdominis muscle and the transversus abdominis muscle belly did not overlap at each point examined, the width of overlap was recorded as 0 mm.

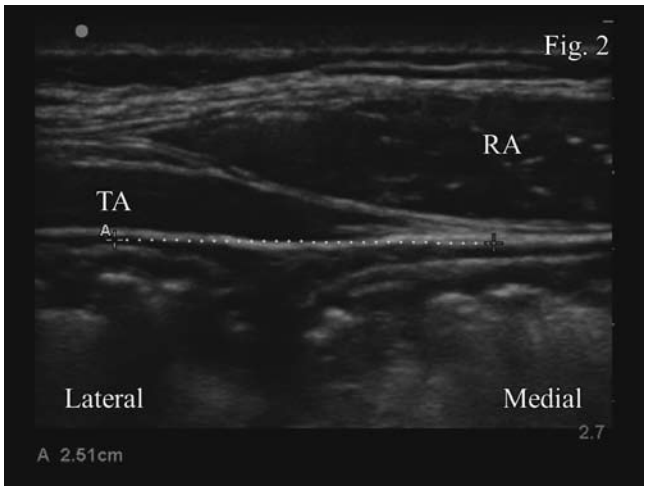

Figure 2. A transverse ultrasound image at the position corresponding to the rounded rectangle in Fig. 1. The transversus abdominis muscle belly (TA) lies deep in the rectus abdominis muscle (RA). The overlapping width of the RA and TA is measured using the caliper function of the ultrasound machine. The gray dot on the left upper corner of the image is an orientation marker provided by the ultrasound machine. Note that the lateral side of the body is visualized on the left side of the ultrasound image, on the other hand, the lateral side of the body is imaged on the right side of the illustration in Fig. 1.

Statistical analyses were performed using IBM SPSS Statistics (version 24.0) software for Windows (IBM Japan, Tokyo, Japan). For the data comparison between males and females, the normal distribution of data was checked using the Shapiro-Wilk test. Welch's *t*-test and Mann-Whitney *U* test were applied for normal distribution data and non-normal distribution data, respectively. Paired-samples *t*-test was used to perform an intragroup comparison regarding laterality. The collected data were shown as means ± standard deviation, summarized by gender distinguishing laterality. Statistical significance for all tests was defined by a two-tailed P value of < 0.05.

Results

Sixty hemi-abdominal walls were examined in 30 subjects (15 males, 32 ± 6 years old, and 15 females, 31 ± 5 years old), and all subjects completed the study (Table 1). The mean craniocaudal distance from the horizontal line running through the center of the umbilicus (D0 in Fig. 1) to the point where the lateral edge of the rectus abdominis muscle and the medial edge of the transversus abdominis muscle belly cross on the ultrasound image in male and female subjects (left side/right side) was 17.4 ± 11.8/18.8 ± 13.3 and 19.5 ± 11.5/21.2 ± 12.4 mm, respectively (Table 2).

Table 1. Demographic data of the subjects examined.

	Male (n = 15)	Female (n = 15)
Age (year)	32 ± 6	31 ± 5
Height (cm)	172 ± 6	161 ± 8
Weight (kg)	64 ± 8	48 ± 10
Body mass index (kg/m^2)	22 ± 2	19 ± 2

Data are presented as mean ± standard deviation.

Table 2. Cranio-caudal distance from the horizontal line running through the center of the umbilicus to the point where the lateral edge of the rectus abdominis muscle and the medial edge of the transversus abdominis muscle belly cross on ultrasound images.

Male (n = 15)		Female (n = 15)	
Left	Right	Left	Right
17.4 ± 11.8	18.8 ± 13.3	19.5 ± 11.5	21.2 ± 12.4

Data are presented as mean ± standard deviation [mm].

Table 3. The width of overlap between the rectus abdominis muscle and the transversus abdominis muscle belly measured on transverse ultrasound images and the number of subjects with overlap.

	Male (n = 15)		Female (n = 15)	
	Left	Right	Left	Right
0 mm cephalad to the umbilicus (At the level of the umbilicus = D0)	0.2 ± 0.9 (1)	0.0 ± 0.0 (0)	0.0 ± 0.0 (0)	0.2 ± 0.6 (1)
15 mm cephalad to the umbilicus (D15)	3.0 ± 4.1 (6)	3.5 ± 4.0 (8)	2.9 ± 3.6 (7)	1.7 ± 3.6 (3)
30 mm cephalad to the umbilicus (D30)	10.1 ± 6.8 (13)	8.9 ± 6.1 (13)	8.9 ± 6.0 (11)	8.1 ± 6.5 (12)
45 mm cephalad to the umbilicus (D45)	18.0 ± 8.5 (14)	14.8 ± 5.8 (14)	15.4 ± 4.7 (15)	13.7 ± 7.7 (15)

Data are presented as mean ± standard deviation [mm] or (n).

The width of overlap between the rectus abdominis muscle and the transversus abdominis muscle belly measured on transverse ultrasound images of male subjects at 0, 15, 30, and 45 mm cephalad from the level of the umbilicus (left side/right side) were 0.2 ± 0.9/0.0 ± 0.0, 3.0 ± 4.1/3.5 ± 4.0, 10.1 ± 6.8/8.9 ± 6.1, and 18.0 ± 8.5/14.5 ± 5.8 mm, respectively. Likewise, the width of overlap between the rectus abdominis muscle and the transversus abdominis muscle belly measured on transverse ultrasound images of female subjects at 0, 15, 30, and 45 mm cephalad from the level of the umbilicus (left side/right side) were 0.0 ± 0.0/0.2 ± 0.6, 2.9 ± 3.6/1.7 ± 3.6, 8.9 ± 6.0/8.1 ± 6.5, and 15.4 ± 4.7/13.7 ± 7.7 mm, respectively (Table 3). There were no significant differences in the measurements for intergroup comparison regarding gender and intragroup comparison regarding laterality.

The number of subjects with an overlap of the rectus abdominis muscle and the transversus abdominis muscle belly increased monotonically from a caudal to cephalad direction in each group (Table 3). In each hemi-abdominal wall, the width of overlap also increased monotonically from a caudal to cephalad direction within the scope of the investigation (data not shown). At the level of the umbilicus, overlapping of the rectus abdominis muscle and the transversus abdominis muscle belly was observed only in 2 of 60 hemi-abdominal walls (3.3%). The points where the lateral edge of the rectus abdominis muscle and the medial edge of the transversus abdominis muscles belly cross were 5 mm caudal to the level of the umbilicus in the left side abdominal wall of a male volunteer and 4 mm caudal to the level of the umbilicus in the right side abdominal wall of a female volunteer, respectively. At D45, the rectus abdominis muscle and the transversus abdominis muscle belly overlapped in 58 of 60 hemi-abdominal walls (96.7%). The remaining two hemi-abdominal walls were from a volunteer. In the subject, the points where the lateral edge of the rectus abdominis muscle and the medial edge of the transversus abdominis muscle belly cross (left/right) were 48/55 mm cephalad to the level of the umbilicus, respectively.

Discussion

Our study revealed that the lowest point where the rectus abdominis muscle and the transversus abdominis muscle belly begin to overlap on the ultrasound image is approximately 20 mm cephalad to the umbilicus (Table 1). In our previously performed cadaver study, the craniocaudal distance from the level of the umbilicus to the lowest end of the area of overlap between the rectus abdominis muscle and the transversus abdominis muscle belly, which corresponds to the distance from D0 to the black dot indicated by a white arrow in Fig. 1, was approximately 33 mm[10]. This finding is considered similar to that observed in the present study. Because formalin-fixed cadavers were examined in our previous study[10], a concern remained whether the measurements were influenced by the preservation status of the cadavers. The data of the present study support the previous data obtained in the cadaver study to apply to the clinical situation.

We also demonstrated that the point where the lateral edge of the rectus abdominis muscle and the medial edge of the transversus abdominis muscle belly cross ranged from the level of the umbilicus to approximately 5 cm cephalad to the umbilicus in most of the hemi-abdominal walls in adult healthy Japanese volunteers. To perform USG-RSB for analgesia around the umbilicus, it has been reported that local anesthetic is injected at the level of the umbilicus[3, 13], just superior to the umbilicus[1] or 1 to 5 cm cephalad to the umbilicus[6, 14]. Thoracic nerves cannot be identified on the ultrasound image,

therefore, the needle tip is advanced by visualizing the lateral aspect of the posterior layer of the rectus sheath with the ultrasound probe placed in a transverse orientation and local anesthetic is injected superficial to the posterior layer of the rectus sheath during USG-RSB[1,3]. Unfortunately, there have been no clinical or anatomical reports that prove the rationale for performing USG-RSB at the above-mentioned positions. Thus, we examined the relationship between the course of the T10 nerve, the rectus abdominis muscle, and the transversus abdominis muscle belly from the viewpoint of performing USG-RSB using cadaver[10] and healthy volunteers (the present study) to support the clinical technique that has been performed on an empirical basis. As we demonstrated in the cadaver study[10], the lateral edge of the rectus abdominis muscle and the medial border of the transversus abdominis muscle belly cross adjacent to the position where the T10 nerve emerges onto the surface of the posterior layer of the rectus sheath. As the overlap status of the two muscular structures can be identified clearly on the ultrasound image, the technique used in the present study can easily be applied to clinical practice.

No studies have demonstrated the advantage of ultrasound guidance to reduce the risk of complications for patients receiving RSB[1]. If the transversus abdominis muscle belly does not underlie the rectus abdominis muscle, the abdominal cavity exists immediately deep to the posterior edge of the rectus abdominis muscle. Although the transversus abdominis muscle belly is very thin[15], its interposition between the posterior surface of the rectus abdominis muscle and the abdominal cavity may contribute to a safe USG-RSB procedure. The needle tip position for USG-RSB is deep to the lateral edge of the rectus abdominis muscle[1], and only a slight overlap between the two muscles can be enough to act as a "buffer zone" to prevent inadvertent needle insertion into the abdominal cavity. As we confirmed in the present study, the width of overlap monotonically increased from a caudal to cephalad direction from the level of the umbilicus to approximately 5 cm cephalad to the level of the umbilicus. Therefore, an ultrasound image obtained slightly cephalad to the position where the lateral edge of the rectus abdominis muscle and the medial edge of the transversus abdominis muscle belly begin to overlap (the white asterisk in Fig. 1) may be another option to perform USG-RSB for analgesia around the umbilicus from the standpoint of safety.

The present study has several limitations. First, the data presented here were obtained from the ultrasound images of younger adult healthy volunteers. Property of the relationship of the rectus abdominis muscle and the transversus abdominis muscle belly may be different in the elderly whose body habitus is quite different from younger adults. Second, we only examined the anatomical relationship between the rectus abdominis muscle and the transversus abdominis muscle belly. This study did not directly show any clinical benefits. Further studies are warranted to demonstrate the best needle tip position or best local anesthetic injection point during USG-RSB for analgesia around the umbilicus.

In conclusion, the position where the lateral edge of the rectus abdominis muscle and the medial border of the transversus abdominis muscle belly begin to overlap as detected by ultrasound image is approximately 20 mm cephalad to the umbilicus in healthy adult Japanese volunteers, regardless of gender, and ranges approximately 0-5 cm cephalad to the umbilicus in most subjects. If the needle is advanced to the postero-lateral border of the rectus abdominis muscle at the level where the transversus abdominis muscle belly underlies the rectus abdominis muscle, the USG-RSB procedure to provide analgesia around the umbilicus may be much safer.

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Conflict of interest

None declared.

References

1. Chin KJ, McDonnell JG, Carvalho B, Sharkey A, Pawa A, Gadsden J. Essentials of our current understanding: Abdominal wall blocks. *Reg Anesth Pain Med* 42(2): 133-183, 2017
2. Dolan J, Lucie P, Geary T, Smith M, Kenny GN. The rectus sheath block: Accuracy of local anesthetic placement by trainee anesthesiologists using loss of resistance or ultrasound guidance. *Reg Anesth Pain Med* 34(3): 247-250, 2009
3. Cho S, Kim YJ, Jeong K, Moon HS. Ultrasound-guided bilateral rectus sheath block reduces early postoperative pain after laparoscopic gynecologic surgery: A randomized study. *J Anesth* 32(2): 189-197, 2018
4. Abrahams MS, Horn JL, Noles LM, Aziz MF. Evidence-based medicine: Ultrasound guidance for truncal blocks. *Reg Anesth Pain Med* 35(2 Suppl): S36-42, 2010
5. Willschke H, Bosenberg A, Marhofer P et al. Ultrasonography-guided

rectus sheath block in paediatric anaesthesia--a new approach to an old technique. *Br J Anaesth* 97(2): 244-249, 2006
6. Gurnaney HG, Maxwell LG, Kraemer FW, Goebel T, Nance ML, Ganesh A. Prospective randomized observer-blinded study comparing the analgesic efficacy of ultrasound-guided rectus sheath block and local anaesthetic infiltration for umbilical hernia repair. *Br J Anaesth* 107(5): 790-795, 2011
7. Chung W, Yoon Y, Kim JW et al. Comparing two different techniques of rectus sheath block after single port laparoscopic surgery in benign adnexal mass patients: Surgical versus ultrasonography guidance-a randomized, single-blind, case-controlled study. *Eur J Obstet Gynecol Reprod Biol* 217: 29-33, 2017
8. Hoyuela C, Juvany M, Carvajal F. Single-incision laparoscopy versus standard laparoscopy for colorectal surgery: A systematic review and meta-analysis. *Am J Surg* 214(1): 127-140, 2017
9. Rozen WM, Tran TM, Ashton MW, Barrington MJ, Ivanusic JJ, Taylor GI. Refining the course of the thoracolumbar nerves: A new understanding of the innervation of the anterior abdominal wall. *Clin Anat* 21(4): 325-333, 2008
10. Sakai-Tamura A, Murata H, Ogami-Takamura K et al. Course of the thoracic nerves around the umbilicus within the posterior layer of the rectus sheath: A cadaver study. *J Anesth* 34(6): 953-957, 2020
11. Rozen WM, Ashton MW, Murray AC, Taylor GI. Avoiding denervation of rectus abdominis in diep flap harvest: The importance of medial row perforators. *Plast Reconstr Surg* 122(3): 710-716, 2008
12. Hebbard PD, Barrington MJ, Vasey C. Ultrasound-guided continuous oblique subcostal transversus abdominis plane blockade: Description of anatomy and clinical technique. *Reg Anesth Pain Med* 35(5): 436-441, 2010
13. Courreges P, Poddevin F, Lecoutre D. Para-umbilical block: A new concept for regional anaesthesia in children. *Paediatr Anaesth* 7(3): 211-214, 1997
14. Smith BE, Suchak M, Siggins D, Challands J. Rectus sheath block for diagnostic laparoscopy. *Anaesthesia* 43(11): 947-948, 1988
15. Sugaya T, Abe Y, Sakamoto M. Ultrasound evaluation of muscle thickness changes in the external oblique, internal oblique, and transversus abdominis muscles considering the influence of posture and muscle contraction. *J Phys Ther Sci* 26(9): 1399-1402, 2014