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Impact of simulation-based anesthesiology training using an anesthetized porcine model for ultrasound-guided transversus abdominis plane block

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Abstract

Objective: This study was performed to assess the impact of simulation-based training for ultrasound-guided transversus abdominis plane (TAP) block using anesthetized pigs.

Methods: In this prospective study, 23 participating residents (10 in their second year, 13 in their third year) underwent simulation-based training for ultrasound-guided TAP block. The residents completed standard questionnaires comprising 10 multiple-choice questions regarding essential general knowledge of abdominal ultrasound and TAP block before and after the training session. On a 5-point Likert scale, they reported their levels of comfort with the use of ultrasound and block equipment, subject/operator positioning, proper block technique, image documentation, needle handling, anxiety, and their overall confidence with the procedure.

Results: Compared with those before training, the comfort levels of the residents significantly improved for all measures except needle handling. The participants also indicated significantly reduced anxiety regarding performance of the TAP block technique.

Conclusion: The use of anesthetized pigs in simulation-based training for ultrasound-guided TAP block improves procedural knowledge and confidence while reducing the associated anxiety in anesthesiology trainees.

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Introduction

Abdominal interfascial plane block has become more common than previously with the introduction of simple and effective techniques, such as the transversus abdominis plane (TAP) block, and the increased use of ultrasound,[1–3] which enables direct visualization of the abdominal wall layers, needle placement, and dispersion of local anesthetics. However, block procedures can be risky and result in ineffective analgesia for patients when performed by inadequately trained anesthesiologists.[4]

The traditional "see one, do one, teach one" training model for health professionals is expensive and time-consuming and produces inconsistent results for complex procedures.[5] Alternatively, hands-on simulation-based training enables trainees to gain experience in a safe and controlled environment. Practicing regional anesthesia via simulation training may improve needle handling and facilitate the localization of targets.[6–8] Simulation training can entail virtual reality, bench model simulators, human cadavers, and animal carcasses.[8]

The ultrasound appearance of the abdominal muscles and visceral organs of pigs is almost identical to that of humans, and the respiration-induced positional changes of organs and muscles are also similar. Therefore, we hypothesized that an anesthetized porcine model is ideal for simulation-based training for the TAP block. In the present study, we investigated the experiences of anesthesiology residents in simulation-based ultrasound-guided TAP block training with anesthetized pigs.

Methods

Study participants

This study was approved by the institutional review board of Severance Hospital, Korea (no. 4-2018-0208) and registered at Clinical Trials.gov (NCT 03516058). Ten second-year and 13 third-year anesthesiology residents ($n = 23$) without experience in ultrasound-guided regional block were recruited from a single academic institution to participate in a TAP block training session from June to July 2018. Participation in the study was optional, and informed consent was obtained from each trainee. This study was approved by our institutional review board.

Animal preparation

Three swine weighing 20 to 30 kg were anesthetized via inhalation of isoflurane (5%) in oxygen at 6 L/min with a standard animal mask. After intubation, anesthesia was maintained with 2% isoflurane and oxygen (2 L/min) via mechanical ventilation. The ventilator was adjusted to maintain the end-tidal carbon dioxide at 35 to 45 mmHg throughout the study. All procedures were approved by and performed in accordance with the guidelines of the local Institutional Animal Care and Use Committee and Animal and Plant Quarantine Agency of the Korean government.

Ultrasound-guided TAP block procedure and training

The 1-hour-long simulation-based TAP block training session in anesthetized pigs was led by a single fellowship-trained pain specialist (Figure 1). After a brief didactic session and demonstration, which covered needle safety, patient positioning for the block, and proper TAP block technique, the participating residents familiarized themselves with the functions of the ultrasound machine and practiced the TAP block on the swine placed in a lateral or prone position. The ultrasound probe (high-frequency linear probe, 5–10 MHz) was placed transverse to the lateral abdominal wall between the lower costal margin and iliac crest, revealing the skin (from skin to peritoneum), subcutaneous tissue, fat, external and internal obliques, and transversus abdominis. The deeper peritoneum and bowel loops were also often visualized. Needles were introduced directly under the ultrasound probe at the same plane and advanced until they reached the plane between the internal oblique and transversus abdominis muscles. Next, 2 mL of saline was injected to confirm the correct needle position (hydrolocation), and 10 mL of saline was then injected to visualize the expansion of the TAP (Figure 2). The residents performed at least three blocks and were allowed to ask questions during the training session. Feedback was provided throughout the session by the anesthesiology staff.

Figure 1. Ultrasound-guided transversus abdominis block simulation training in the anesthetized porcine model

Procedure questionnaire

Each resident's training level was recorded, and they were given questionnaires to

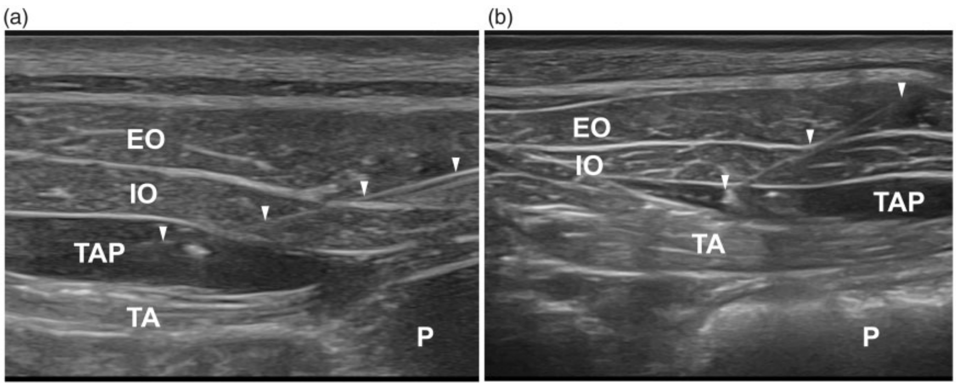

Figure 2. Ultrasound images demonstrating needle placement and injectate spread of TAP block. (a) Lateral and (b) posterior approaches in an anesthetized porcine model. EO, external oblique muscle; IO, internal oblique muscle; TA, transversus abdominis muscle; TAP, transversus abdominis plane; P, peritoneum

anonymously assess their overall knowledge and confidence of the procedure before and after the training session. The participants rated each of the following questions according to a 5-point Likert scale (1 = very low, 2 = low, 3 = moderate, 4 = high, and 5 = very high):

1. I know the anatomical basis, clinical indications, and procedure of the TAP block (basic knowledge).
2. I can handle the ultrasound machine, including selection of the probe type and control of image depth, gain, and focus (ultrasound machine functionality).
3. I know the correct positions of the subject and operator to facilitate the procedure (subject/operator positioning).
4. I can prepare the devices and materials for TAP block (block equipment preparation).
5. I can distinguish the three muscle layers of the abdominal wall and peritoneum in an ultrasound image (image documentation).
6. I can manipulate the needle safely and skillfully during TAP block (needle manipulation).
7. I know the estimated trajectory of the needle and the optimal needle tip position for successful TAP block (optimal needle tip position).
8. I can confirm the correct injectate spread within the TAP (hydrolocation) in an ultrasound image (confirmation of injectate spread).
9. I am confident in my ability to perform TAP block for patients in the future (overall confidence level).
10. I am worried about performing TAP block (overall anxiety level).

Statistical analysis

The mean scores from the questionnaires were compared before and after the training session via the Wilcoxon signed rank test. McNemar's test was used to compare the scores for each question. SPSS software, version 23.0 (IBM Corp., Armonk, NY, USA), was used for all analyses. Results with a P value of <0.05 were considered statistically significant.

Results

Compared with the scores obtained before the training session, those reported after the training were significantly higher ($P < 0.05$) for all questions concerning the level of comfort with the procedure except for that pertaining to the optimal needle tip position, for which the mean Likert score indicated moderate knowledge of the appropriate trajectory before training (Table 1). Before the training session, most residents (22/23 [96%]) cited low to very low confidence in their ability (scores of 1 or 2 on the Likert scale) and high to very high anxiety (scores of 4 or 5) with regard to performing ultrasound-guided TAP block.

Unfamiliarity with nerve blocks because of lack of practice (21 of 23 residents) and lack of foundational knowledge (15 of 23 residents) were the two main factors that contributed to trainee anxiety in performing ultrasound-guided TAP block. Moreover, 22 of the 23 residents (96%) chose simulation-based training over apprenticeship methods such as demonstration videos, lectures, and observing faculty members to learn procedural skills. In addition, 20 of the 23 residents (87%) marked the educational value of the nerve block training session as high or very high (score of 4 or 5, respectively), and 100% added that a simulation-based training session on performing TAP block should be included in the residency curriculum.

Discussion

The results of this study indicate that simulation-based training for ultrasound-guided TAP block using an anesthetized

Table 1. Likert scale scores for trainee confidence before and after simulation-based training

Category	Pre-training	Post-training	*P* value
Comfort level			
Basic knowledge	1.83 (0.58)	3.35 (0.49)	<0.001
Ultrasound machine functionality	2.79 (0.80)	3.61 (0.58)	<0.001
Subject/operator positioning	2.04 (0.64)	3.61 (0.50)	<0.001
Block equipment preparation	1.52 (0.79)	2.74 (0.81)	<0.001
Image documentation	1.57 (0.84)	3.87 (0.92)	<0.001
Needle manipulation	2.22 (1.13)	2.91 (0.85)	0.023
Optimal needle tip position	3.13 (0.76)	3.52 (0.73)	0.081
Confirmation of injectate spread	1.87 (0.81)	3.70 (0.97)	<0.001
Overall confidence level	1.22 (0.52)	2.44 (0.90)	<0.001
Overall anxiety level	4.52 (0.73)	3.22 (0.90)	<0.001

Likert scale scores are expressed as mean (standard deviation): 1 = very low, 5 = very high.

porcine model reduced anesthesiology trainees' anxiety and improved their knowledge and confidence in performing the procedure. The three basic requirements for ultrasound-guided regional block training are (i) pattern recognition, (ii) probe handling and scanning, and (iii) manual dexterity to align the needle with the ultrasound beam.[9] The latter two requirements are challenging for residents with no experience in regional block using ultrasound.[10] Correct identification of the needle tip on ultrasound during regional block, particularly as the tip proceeds to abdominal muscle layers without a bony landmark, is important for patient safety and determines block success.

For effective analgesia, the needle should be placed between the internal oblique and transversus abdominis muscles. TAP blocks were historically performed in a blind manner, but current clinical trends show a reliance on ultrasound to check the needle tip and thus prevent possible damage to internal organs.[4] Although needle handling and optimal positioning may still be difficult after a single training session, residents gain realistic practice and confidence with this hydrodissection technique. To strengthen resident training, simulation-based training programs should be further incorporated for both skill retention and familiarity for trainees.

Water, gelatin, meat, cadavers, and animal carcasses have been used for ultrasound training.[11–13] However, water and gelatin are more suitable for spine models, and fascial plane blocks are difficult to reproduce with these materials. A meat phantom provides tactile feedback from the needle, with echogenicity resembling that of human tissue.[14] Cadaver phantoms are similar in this regard. However, these materials are expensive and not readily available. Additionally, these models are fixed and do not incorporate movement, such as that of the abdominal wall caused by respiration of the patient, which can interfere with the TAP block. For this reason and because of their similar anatomy, live pigs are superior for practicing the TAP block. Indeed, most (87%) of the residents surveyed for this study reported that the experience was closer to that with real patients.

In our institution, the anesthetized porcine model has been incorporated for educating residents about other regional anesthesia techniques and anatomy. Notably, this model provides vivid sonoanatomies of the ribs, intercostal muscle layers, and most importantly, the sliding pleura sign, all of which are helpful for performing intercostal nerve blocks. Because the sonoanatomy of the porcine lumbar spine is similar to that of humans, this model can be used to practice block techniques, including facet joint injection, medial branch block, and psoas compartment block. Blocks in the thoracic region, such as paravertebral blocks, have a risk of pneumothorax, and a living porcine model with breathing patterns can provide an opportunity to practice avoiding such complications. Nevertheless, the use of live pigs for nerve blocks involves general anesthesia requiring veterinarian assistance and equipment. In addition, training can only occur while the pigs are anesthetized, which limits training time and space. Regardless of the extra effort, a live porcine model provides a clinical and anatomical environment similar to that of real patients as a desirable option for training in various ultrasound-guided regional block techniques.

This study has some limitations. First, we surveyed a relatively small sample of residents from a single institution. Second, the residents had no opportunity to perform the TAP block on actual patients; thus, we could not directly assess the outcome of the nerve block training. Third, the efficacy of the training performed in this study was not compared with that of other simulation-based training models. Finally, no objective parameters were evaluated, such as inter-evaluator reliability, internal consistency, convergent validity, or error reduction. Although a typical process validation of such a technical simulation-based scenario should include data derived from both subjective and objective parameters, we only addressed subjective parameters in this study.

In conclusion, the results of the present study suggest that simulation-based ultrasound-guided TAP block training using an anesthetized porcine model positively impacts ultrasound knowledge and block technique education. After the training session, residents expressed higher levels of comfort and confidence with the technical aspects of the TAP block as well as reduced anxiety regarding performance of the procedure. Our findings are in line with those of prior studies that demonstrated improved confidence levels in performing ultrasound-guided regional blocks after simulation-based training.

Future direction

Practicing on actual patients will become more difficult over time with patients' increasing concerns regarding medicolegal issues. Anesthetized pigs represent an appropriate model for training in various interfascial plane blocks, such as the erector spinae plane block, quadratus lumborum block, serratus plane block, and many others, and should be considered an effective tool in regional anesthesia education. Anesthetized pigs are also expected to be used for training in advanced pain interventions such as introduction of spinal cord stimulation or intrathecal drug delivery systems for pain specialist.

Author contributions

KYL and SHK designed the study. All authors contributed to the literature search. TH, HJ, and SHK collected the data. SJP, H-MY, KBY, HJK, KYL, HJ, and SHK analyzed the data. SJP, H-MY, KBY, KYL, TH, HJ, and SHK prepared the manuscript. SJP, H-MY, KBY, HJK, KYL, TH, and SHK reviewed the manuscript.

Availability of data and materials

The datasets generated and analyzed during the present study are available from the corresponding author on reasonable request.

Consent for publication

Not applicable.

Declaration of conflicting interest

The authors declare that there is no conflict of interest.

Ethics approval and consent to participate

This study was approved by the institutional review board of Severance Hospital, Korea (no. 4-2018-0208). Each patient read and signed a consent form before enrolling in the study. All procedures using swine were approved by the local Institutional Animal Care and Use Committee (no. MIC-IACUC 201801) and Animal and Plant Quarantine Agency of the Korean government.

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