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TEACHING INNOVATION

Effectiveness of a simulation-based practice model for training anesthesiology residents in ultrasound-guided transversus abdominis plane block

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Abstract

Objective: To evaluate the effectiveness of a simulation-based practice model for training anesthesiology residents in ultrasound-guided transversus abdominis plane (TAP) block. **Methods:** A total of 40 anesthesiology residents from the Department of Anesthesiology, Jiangsu Cancer Hospital, who participated in standardized anesthesiology residency training from June 2025 to December 2025, were enrolled and randomly assigned into a simulation group and a control group, with 20 residents in each group. TAP block training was provided through demonstration in both groups, while the simulation-based practice model was additionally applied to the simulation group. Outcome measures included total procedure duration, success rate of TAP block, skill operation scores, theoretical test scores, trainee satisfaction, training vividness, and willingness to recommend the training mode. **Results:** Compared with the control group, residents in the simulation group completed the TAP block procedure faster (10.54±3.42 min vs. 15.53±4.56 min, $P<0.05$), and achieved significantly higher scores in skill operations (25.81±1.13 vs. 22.91±1.25, $P<0.05$) and theoretical tests (92.51±2.93 vs. 85.67±1.01, $P<0.05$). Additionally, the simulation group reported significantly higher scores in trainee satisfaction (8.93±0.57 vs. 7.58±1.18, $P<0.05$), training vividness (8.98±0.67 vs. 7.33±0.82, $P<0.05$), and willingness to recommend the training mode (8.86±0.83 vs. 7.63±1.25, $P<0.05$). The success rate of TAP block performed by residents was significantly higher in the simulation group than in the control group (85% vs. 70%, $P<0.05$). **Conclusion:** The simulation-based practice model substantially improves the quality and effectiveness of TAP block training. By enabling repeated practice of both ultrasound techniques and TAP block procedures on simulators and real patients, anesthesiology residents can achieve proficiency in the relevant theoretical knowledge and technical skills before clinical application.

Keywords: Simulation-based practice, Medical training, Ultrasound-guided plane block, Transversus abdominis plane block

Highlights

- This study demonstrates the value of a simulation-based practice model for training anesthesiology residents in ultrasound-guided transversus abdominis plane (TAP) block.
- The simulation-based practice model integrates training and hands-on practice of both ultrasound techniques and TAP block procedures using simulators and real patients, enabling residents to practice repeatedly and achieve proficiency in the relevant theoretical knowledge and technical skills prior to clinical application.

1 INTRODUCTION

Transversus abdominis plane (TAP) block provides analgesia to the anterior and lateral abdominal walls by anesthetizing the nerves situated between the internal oblique and transversus abdominis muscles. It offers high efficacy in pain relief for abdominal surgeries, including laparoscopic surgery, cesarean section, colorectal surgery, gynecological surgery, and urological surgery [1-3]. TAP block is a fundamental procedure that anesthesiology residents are expected to perform proficiently [4, 5]. Conventionally, TAP block training has focused on teacher-centered knowledge explanation and demonstration of ultrasound-guided skills, an approach that may be less scientific and systematic [6, 7]. The success or failure of TAP block largely depends on the individual practitioner's experience. In clinical practice, various factors—such as abdominal obesity, complexity of abdominal anatomy, poor delineation of the abdominal muscle layers, and unclear visualization of the anesthetic needle—may complicate the performance of TAP block. Consequently, improper technique can increase the risk of complications, including local anesthetic toxicity, visceral injury, intraperitoneal injection, nerve ischemia, intravascular injection, infection, femoral nerve paralysis, and block failure [8]. Moreover, the concern over potential failure may diminish the enthusiasm of anesthesiology residents to master this technique.

Currently, the widespread application of ultrasonography has made TAP blcok easier, faster and less risky [6]. A simulation-based practice model using rubber anatomical models has emerged as a mainstream, learner-centered approach in medical education, allowing anesthesiology residents to practice skills in a realistic yet risk-free environment [9, 10].

In the present study, we applied a simulation-based practice model to train anesthesiology residents in performing TAP block and evaluated its effectiveness. Our findings are expected to provide valuable insights for standardized anesthesiology residency training.

2 MATERIALS AND METHODS

2.1 Baseline data of anesthesiology resident trainees

A total of 40 anesthesiology residents from the Department of Anesthesiology, Jiangsu Cancer Hospital, who participated in standardized anesthesiology residency training from June 2025 to December 2025, were enrolled. They were randomly assigned (1:1) into a simulation group and a control group, with 20 residents in each group, using a computer-generated random number sequence (SPSS version 22.0). Allocation concealment was achieved using sealed opaque envelopes. TAP block training was provided through teaching demonstration in both groups, while a simulation-based practice model was additionally applied to residents in the simulation group. Residents were considered eligible if they met the following criteria: held a bachelor's degree in clinical medicine or anesthesiology, passed the unified examination for standardized residency training at Xuzhou Medical University, and provided informed consent to participate in this study. Residents with non-right-handedness were excluded, as the entire training and assessment protocol—including ultrasound machine setup, transducer handling, needle manipulation, and instructor demonstration—was standardized for right-handed operators to ensure uniformity in skill acquisition and evaluation. Baseline characteristics of anesthesiology residents in the simulation and control groups are presented in **Table 1**. No statistically significant differences were observed between the two groups for any baseline variable (all $P>0.05$).

2.2 Baseline data of patients undergoing TAP block

A total of 40 adult patients undergoing elective surgery for colorectal cancer were enrolled. Eligible patients were aged 18–70 years, had an American Society of Anesthesiologists (ASA) physical status of II–III, and a body mass index (BMI) of 18.5–24.0 kg/m^2. Exclusion criteria included refusal to undergo TAP block, infection at the intended puncture site, and coagulation dysfunction.

Patients were randomly allocated into the simulation group and the control group (n=20 per group) using a computer-generated randomization sequence. During the skill operation and theoretical tests, each trainee independently performed ultrasound-guided TAP block on randomly assigned patients within the same group. In the simulation group, there were 13 male and 7 female patients, with a mean age of 55.63±5.31 years (range: 38–67 years) and a mean BMI of 21.33±1.21 kg/m^2 (range: 20.31–24.60 kg/m^2). The control group also comprised 20 patients, including 13 male and 7 female patients, with a mean age of 60.3±7.5 years (range: 28–70 years) and a mean BMI of 21.73±1.51 kg/m^2 (range: 21.11–24.63 kg/m^2). Regarding ASA physical status, 5 patients in the simulation group and 7 in the control group were classified as ASA II, while 15

Table 1. Baseline characteristics of anesthesiology residents

Characteristic	Simulation group (n=20)	Control group (n=20)	t/χ^2 value	*P*-value
Age (years, mean ± SD)	28.51±2.31	29.10±2.53	0.784	0.438
Gender (male/female, n)	12/8	11/9	0.102	0.749
Years of residency training (mean ± SD)	1.80±0.70	1.93±0.61	0.476	0.637
Prior experience with ultrasound-guided blocks (n, %)	6 (30.0)	5 (25.0)	0.125	0.723

Note: Continuous data were analyzed using the independent samples t-test; categorical data were analyzed using the chi-square test. SD, standard deviation.

Table 2. Baseline characteristics of patients undergoing TAP block

Characteristic	Simulation group (n=20)	Control group (n=20)	t/χ^2 value	*P*-value
Gender (male/female, n)	13/7	13/7	0.000	1.000
Age (years, mean ± SD)	55.63±5.31 (38–67)	60.30±7.52 (28–70)	1.876	0.068
BMI (kg/m^2, mean ± SD)	21.33±1.21 (20.31–24.60)	21.73±1.51 (21.11–24.63)	0.924	0.361
ASA physical status (n, %)			0.440	0.507
ASA II	5 (25.0)	7 (35.0)		
ASA III	15 (75.0)	13 (65.0)		

Note: Continuous data were analyzed using the independent samples t-test; categorical data were analyzed using the chi-square test. TAP, transversus abdominis plane; SD, standard deviation; BMI, body mass index; ASA, American Society of Anesthesiologists.

patients in the simulation group and 13 in the control group were classified as ASA III. No significant differences were observed between the two groups in terms of gender, age, BMI, or ASA physical status distribution (all $P>0.05$) (**Table 2**). This study was approved by the Ethics Committee of Jiangsu Cancer Hospital (approval No. KY-2025-069), and all participants provided written informed consent.

2.3 Interventions

Colorectal cancer patients received anesthesia induction prior to TAP block. With the patient in a supine position, after routine disinfection and draping, the rectus abdominis and transversus abdominis muscles were first identified using a subcostal approach on ultrasound scans. Using an in-plane technique, the needle was advanced into the fascial plane between the transversus abdominis and internal oblique muscles. Absence of blood flashback upon slow needle withdrawal indicated correct needle placement. Subsequently, a small volume (2–3 mL) of local anesthetic was injected into the plane. After separation of the internal oblique and transversus abdominis muscles, a slow injection of 20–30 mL of 0.5% ropivacaine (75 mg/10 mL; Xianju Pharmaceutical Co., Ltd., Taizhou, Zhejiang, China) was administered. During local anesthetic injection, a slow withdrawal was performed for every 5 mL injected to ensure fusiform drug diffusion and compression of the transversus abdominis muscle toward the abdominal cavity.

Anesthesiology residents in the control group received teacher-centered medical training for performing TAP block. Briefly, the teacher first described and demonstrated each step of TAP block on a rubber anatomical model. Under ultrasound guidance via a subcostal approach, the layers of the abdominal wall from the skin to the abdominal cavity could be clearly visualized. Ultrasonography enabled well-structured visualization of fat, muscles, nerves, and blood vessels, made the TAP block procedure easier to observe, and allowed real-time monitoring of needle penetration depth and local analgesic injection. This teaching method consisted of two sessions of 15 minutes each and greatly improved the success rate of TAP block. After two sessions of teaching demonstration, residents were permitted to practice on real patients undergoing TAP block for colorectal cancer under teacher supervision.

Anesthesiology residents in the simulation group first received the same teacher-centered training on a rubber anatomical model for 15 minutes, followed by an additional 15-minute training session focused on performing ultrasound-guided TAP block on the anatomical model. After repeated practice on the anatomical model, residents were allowed to perform TAP block on real patients under teacher supervision.

Skills for performing TAP block were assessed three months later in both groups.

2.4 Outcomes

Skill and knowledge assessment: Each trainee was tested on skills encompassing the entire procedure from patient positioning in the supine position to the completion of local anesthetic injection. Theoretical knowledge was assessed using a standardized written test consisting of 20 multiple-choice questions covering anatomy of the abdominal wall, ultrasound anatomy of the TAP plane, indications and contraindications for TAP block, local anesthetic pharmacology, needle visualization techniques, and recognition and management of potential com-

Table 3. Comparison of TAP block skill performance between the simulation group and control group

Variable	Simulation group (n=20)	Control group (n=20)	t/χ^2 value	*P*-value
Total procedure duration (min)	10.54±3.42	15.53±4.56	5.316	0.001
One-time puncture success rate (n, %)	17 (85.0)	14 (70.0)	0.643*	0.382
Overall puncture success rate (n, %)	18 (90.0)	15 (75.0)	0.901*	0.326
Puncture failure rate (n, %)	2 (10.0)	4 (20.0)	0.906*	0.328
Incidence of complications (n, %)	1 (5.0)	2 (10.0)	0.000*	1.000

Note: Continuous data were analyzed using the independent samples t-test; categorical data were analyzed using the chi-square test. * Value represents χ^2 statistic. TAP, transversus abdominis plane.

plications (e.g., local anesthetic toxicity, visceral injury). Each question was assigned 5 points (20 questions × 5 points = 100). A successful one-time puncture was defined as achieving TAP block on the first puncture attempt; otherwise, it was recorded as a puncture failure, and the procedure was subsequently performed by the teacher, as well as trainee satisfaction.

Skill assessment: Each trainee was tested on skills encompassing the entire procedure from patient positioning in the supine position to the completion of local anesthetic injection. A successful one-time puncture was defined as achieving TAP block on the first puncture attempt; otherwise, it was recorded as a puncture failure, and the procedure was subsequently performed by the teacher. Any complications of TAP block—including local anesthetic toxicity, visceral injury, intraperitoneal injection, nerve ischemia, intravascular injection, infection, and femoral nerve paralysis—were recorded and managed by the teacher. The following parameters were recorded: The following parameters were recorded: total procedure duration, one-time puncture success rate, overall puncture success rate, puncture failure rate, and complication rate. Overall puncture success rate was defined as the proportion of patients in whom TAP block was successfully achieved by the resident within the allotted training session, regardless of the number of puncture attempts (including cases where the teacher provided guidance or repositioning but did not take over the procedure). In contrast, one-time puncture success rate referred to successful block achievement on the first puncture attempt without any needle withdrawal or redirection. TAP block skills were scored on a 30-point scale based on the *Standard Graduation Program for Clinical Practice of Standardized Training for Residents* (*2020 Edition in Anesthesiology*) [5]. The scoring items were as follows: procedure preparations (2 points), patient positioning (2 points), landmark identification (2 points), disinfection and draping (2 points), anesthesia (1 point), puncture technique (14 points), post-puncture procedures (4 points), humanistic care (1 point), and aseptic technique (2 points).

Trainee satisfaction: After the skill and knowledge tests, trainees self-rated their satisfaction using a questionnaire. Three items were scored on a scale from 0 (lowest satisfaction) to 10 (highest satisfaction): overall trainee satisfaction, training vividness, and willingness to recommend the training mode.

2.5 Statistical analysis

Statistical analysis was performed using SPSS version 22.0 (IBM Corp., Armonk, NY, USA). Continuous data were expressed as mean ± standard deviation and compared using the independent samples t-test. Categorical data were represented as counts (n) and percentages (%) and analyzed using the chi-square test. A *P*-value of less than 0.05 was considered statistically significant.

3 RESULTS

3.1 The simulation-based practice model shortens the procedure duration of ultrasound-guided TAP block

Two cases of puncture failure in the simulation group and four in the control group were reported, all attributed to non-visualization of the needle bevel on ultrasound scans. A complication of hypotension (≥20% decrease in blood pressure from baseline, potentially related to local anesthetic toxicity or sympathetic blockade) was observed in one case in the simulation group and two cases in the control group. The total procedure duration of ultrasound-guided TAP block was significantly shorter in the simulation group than in the control group (P<0.05) (**Table 3**). No significant differences were observed between the two groups in one-time puncture success rate, overall puncture success rate, puncture failure rate, or incidence of complications (all P>0.05).

3.2 The simulation-based practice model enhances mastery of skills and knowledge of ultrasound-guided TAP block

Compared with the control group, the simulation group achieved significantly higher scores in both skill operations and theoretical knowledge of ultrasound-guided TAP block (both P<0.05) (**Table 4**).

3.3 Trainees show high satisfaction with the simulation-based practice model

Compared with the control group, anesthesiology residents in the simulation group gave significantly higher scores for trainee satisfaction, training vividness, and willingness to recommend the training mode (all P<0.05) (**Table 5**).

Table 4. Comparison of skill operation and theoretical test scores between the simulation group and control group

Outcome	Simulation group (n=20)	Control group (n=20)	t value	*P*-value
Skill operation scores	25.81±1.13	22.91±1.25	3.863	<0.001
Theoretical test scores	92.51±2.93	85.67±1.01	4.542	<0.001

Note: Data are presented as mean ± standard deviation. The maximum possible score for theoretical test scores is 100.

Table 5. Comparison of trainee satisfaction scores between the simulation group and control group

Outcome	Simulation group (n=20)	Control group (n=20)	t value	*P*-value
Trainee satisfaction	8.93±0.57	7.58±1.18	3.902	<0.001
Training vividness	8.98±0.67	7.33±0.82	5.890	<0.001
Willingness to recommend the training mode	8.86±0.83	7.63±1.25	3.267	<0.001

Note: Data are presented as mean ± standard deviation. All scores are based on a 0–10 scale, with 10 indicating the highest level of satisfaction, vividness, or willingness to recommend.

4 DISCUSSION

Ultrasound-guided TAP block is an important component of multimodal analgesia that significantly reduces postoperative opioid requirements after abdominal surgery and accelerates the recovery of gastrointestinal function, thereby aligning with the concept of enhanced recovery after surgery [11, 12]. However, this procedure is technically demanding due to several challenges: blurred layering of the abdominal muscles and difficulty in identifying fascial compartments in obese patients; risk of accidental peritoneal penetration and intra-abdominal injury caused by poor visualization of the needle shaft and bevel on ultrasound; and suboptimal nerve block outcomes resulting from uneven local anesthetic deposition [13-16]. These technical challenges contribute to a steep learning curve for resident physicians to in mastering TAP block, highlighting the need for improved training models.

In the present study, the simulation-based practice model demonstrated superior efficacy and quality in training anesthesiology residents to perform ultrasound-guided TAP block. Compared with conventional teacher-centered training, TAP block training using the simulation-based practice model reduced the procedure duration by approximately 5 minutes (10.54±3.42 min vs. 15.53±4.56 min, P<0.001). Furthermore, residents in the simulation group achieved significantly higher scores in both skill operations and theoretical tests than those in the control group. Beyond the statistical findings, these results hold substantial clinical significance. First, a shorter TAP block procedure directly enhances operating room efficiency by reducing operating room turnover time and patient waiting time, as well as improving operating room utilization. More importantly, prolonged anesthesia procedures may increase patient anxiety and cause local skin discomfort due to extended probe pressure. The ability of trainees in the simulation group to complete TAP block more rapidly reflects their greater familiarity with anatomical structures, smoother hand-eye coordination, and more standardized operating procedures. Second, simulation-based practice on anatomical models greatly improves the safety of clinical procedures by reducing medical errors. In this study, both the overall puncture success rate (90.0% vs. 75.0%) and one-time puncture success rate (85.0% vs. 70.0%) were higher in the simulation group than in the control group. Although these differences did not reach statistical significance, the higher success rates underscore the value of the simulation-based practice model in training anesthesiology residents. Additionally, fewer puncture failures (2 cases in the simulation group vs. 4 in the control group) and complications (1 case vs. 2 cases) were reported in the simulation group, indicating the advantage of this training model in improving the safety of ultrasound-guided TAP block. Generally considered a safe procedure, TAP block nonetheless carries potential risks including intraperitoneal injection, nerve damage, and local anesthetic toxicity. The simulation-based practice model allowed residents to make and correct mistakes—such as inappropriate puncture angle or depth, poor visualization of the needle shaft and bevel on ultrasound, and incorrect local anesthetic injection levels—while practicing on anatomical models. After repeated simulation training, residents became more confident and relaxed when performing TAP block on real patients. Third, the simulation-based practice model effectively enhanced trainees' self-confidence and satisfaction. Compared with the control group, residents in the simulation group gave significantly higher scores for trainee satisfaction, training vividness, and willingness to recommend the training mode (all P<0.001). Consistent with previous findings, the simulation-based practice model effectively alleviated the anxiety and fear of anesthesiology residents when performing TAP block, thereby fostering positive psychological expectations [17-20]. Self-confidence is a critical driver of performance, enabling successful medical procedures and proactive decision-making. Moreover, residents who developed genuine professional composure through simulation-based training were better able to manage unexpected challenges during TAP block (e.g., blurred anatomical layering in obese patients or poor ultrasound visualization) independently and in accordance with standard protocols.

Overall, this study provides valuable insights for standardizing anesthesiology residency training. First, we recommend integrating the simulation-based practice model into the routine TAP block training curriculum. The traditional surgical training model—"See one, do one, teach one"—carries high risks in modern medicine. Our findings validate the high efficacy and safety of the simulation-based practice model for training anesthesiology residents in ultrasound-guided TAP block. Second, the simulation-based practice model is economically affordable, as it does not require expensive medical instruments. Rubber anatomical models and bedside ultrasound equipment are highly accessible and cost-controllable across medical institutions at all levels. Third, the timing of trainee assessment is crucial. In our study, residents were tested three months after training, allowing evaluation of the long-term effectiveness of the simulation-based practice model. The superior performance of the simulation group over the control group suggests that this training model benefits both short-term memory retention and long-term skill internalization.

Several limitations of this study should be acknowledged. First, this was a single-center study with a relatively small sample size. Our conclusions should be further validated in multi-center, large-scale studies. Second, we did not assess long-term prognostic outcomes in patients undergoing ultrasound-guided TAP block. Comprehensive evaluation of postoperative pain at 24 hours, opioid consumption, and length of hospital stay would further highlight the benefits of the simulation-based practice model in training anesthesiology residents to perform high-quality TAP block. Third, the potential impact of individual patient characteristics (e.g., degree of obesity, surgical history) on TAP block procedural outcomes should be explored in future stratified analyses.

5 CONCLUSION

The simulation-based practice model adopted in the training of anesthesiology residents significantly improves the efficiency, quality, and safety of ultrasound-guided TAP block, while also enhancing trainee satisfaction. The rubber anatomical models and bedside ultrasound equipment used in this model are highly accessible and cost-effective, facilitating widespread adoption in standardized residency training. Future efforts should focus on exploring the applicability of the simulation-based practice model in training anesthesiology residents to perform other regional blocks beyond the transversus abdominis plane. The efficacy and safety of this training model could be more comprehensively assessed by integrating clinical outcome measures.

DECLARATIONS

Author contributions

Lili Ma and Yongyi Chen designed the study. Yongyi Chen, Miao Zhou, and Lianbing Gu performed the experiments and collected the data. Yuxian Liu, Lei Hu, Chengzhen Wang, and Jiahui Chen analyzed and interpreted the data. Zhiyan Wang and Gang Xiao provided administrative and technical support. Yongyi Chen drafted the manuscript. Lili Ma critically revised the manuscript for important intellectual content. All authors read and approved the final manuscript.

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Data availability

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Ethics approval and consent to participate

This study was approved by the Ethics Committee of Jiangsu Cancer Hospital (Approval No. KY-2025-069). Written informed consent was obtained from all participating anesthesiology residents and from all patients undergoing transversus abdominis plane block. The study was conducted in accordance with the Declaration of Helsinki.

Consent for publication

All authors have reviewed and approved the final manuscript and consent to its publication.

Competing interests

The authors declare that they have no competing interests.

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REFERENCES

[1] Salmonsen CB, Lange KHW, Kleif J, Krøijer R, Bruun L, Mikalonis M, et al. Transversus abdominis plane block in minimally invasive colon surgery: A multicenter three-arm randomized controlled superiority and non-inferiority clinical trial. Reg Anesth Pain Med. 2026 May 5;51(5):558-567. https://doi.org/10.1136/rapm-2024-105712

[2] Tran DQ, Bravo D, Leurcharusmee P, Neal JM. Transversus abdominis plane block: A narrative review. Anesthesiology. 2019 Nov;131(5):1166-1190. https://doi.org/10.1097/aln.0000000000002842

[3] Zako J, Kevorkov A, Jeffries SD, Ramirez-Garcia Luna JL, Daccache N, Song K, et al. Transversus abdominis plane block for postoperative pain management and opioid sparing: A systematic review and meta-analysis of randomised controlled trials. Br J Anaesth. 2026 Jan;136(1):266-282. https://doi.org/10.1016/j.bja.2025.10.033

[4] Chinese Medical Doctor Association. The Notice from the Chinese Medical Doctor Association on the release of the “Guidelines for Teaching Programof the Standardized Training for Residents (2021 Edition)”. Letter for Medical Association. 2021 No. 2021 883.

[5] Health Human Resources Development Center N H C, P.R. China. A standard graduation program for clinical practice of standardized training for residents. Edition in Anesthesiology. 2020.

[6] Bayaca K, Falyar CR, Pitman JD, Simmons VC. The development and validation of an objective assessment tool for performing ultrasound-guided transversus abdominis plane blocks. AANA J. 2024 Aug;92(4):271-278.

[7] Wannatoop T, Ratanalekha R, Wongkornrat W, Keorochana K, Piyaman P. Efficacy of a perfused cadaver model for simulated trauma resuscitation in advanced surgical skills training. BMC Surg. 2022 Aug 8;22:306. https://doi.org/10.1186/s12893-022-01754-1

[8] Desai N, El-Boghdadly K, Albrecht E. Peripheral nerve blockade and novel analgesic modalities for ambulatory anesthesia. Curr Opin Anaesthesiol. 2020 Dec;33(6):760-767. https://doi.org/10.1097/aco.0000000000000928

[9] Song W, Dong Z, Zheng S, Zhao B. Impact of simulation model and gel model for the training of ultrasound-guided transversus abdominis plane block. Chin J Grad Med Educ. 2024;8(11):862-866. https://doi.org/10.3969/j.issn.2096-4293.2024.11.014

[10] Jiang X, Wang L, Zhang M, Jin R. Discussion on teaching effect of light wand induction tracheal intubation combining simulation and clinical practice. Chin Contin Med Educ. 2024;16(18):152-155. https://doi.org/10.3969/j.issn.1674-9308.2024.18.033

[11] Johns N, O’Neill S, Ventham NT, Barron F, Brady RR, Daniel T. Clinical effectiveness of transversus abdominis plane (TAP) block in abdominal surgery: A systematic review and meta-analysis. Colorectal Dis. 2012 Oct;14(10):e635-e642. https://doi.org/10.1111/j.1463-1318.2012.03104.x

[12] Walter CJ, Maxwell-Armstrong C, Pinkney TD, Conaghan PJ, Bedforth N, Gornall CB, et al. A randomised controlled trial of the efficacy of ultrasound-guided transversus abdominis plane (TAP) block in laparoscopic colorectal surgery. Surg Endosc. 2013 Jul;27(7):2366-2372. https://doi.org/10.1007/s00464-013-2791-0

[13] Chen X, Trivedi V, AlSaflan AA, Todd SC, Tricco AC, McCartney CJL, et al. Ultrasound-guided regional anesthesia simulation training: A systematic review. Reg Anesth Pain Med. 2017 Nov-Dec;42(6):741-750. https://doi.org/10.1097/aap.0000000000000639

[14] Aggarwal R, Grantcharov TP, Darzi A. Framework for systematic training and assessment of technical skills. J Am Coll Surg. 2007 Apr;204(4):697-705. https://doi.org/10.1016/j.jamcollsurg.2007.01.016

[15] Clark CA, Mester RA, Redding AT, Wilson DA, Zeiler LL, Jones WR, et al. Emergency subglottic airway training and assessment of skills retention of attending anesthesiologists with simulation mastery-based learning. Anesth Analg. 2022 Jul 1;135(1):143-151. https://doi.org/10.1213/ane.0000000000005928

[16] Burnett GW, Shah AS, Katz DJ, Jeng CL. Survey of regional anesthesiology fellowship directors in the USA on the use of simulation in regional anesthesiology training. Reg Anesth Pain Med. 2019 Sep 16;rapm-2019-100719. https://doi.org/10.1136/rapm-2019-100719

[17] Zhao J, Wei X, Wang T, Wang L, Fang J, Yang B, et al. Investigation on the mode of teaching ward round instandardized training for residents of anesthesiology. Chin Contin Med Educ. 2023;15(18):171-174. https://doi.org/10.3969/j.issn.1674-9308.2023.18.039

[18] Li P, Jin G, Li P, Jin R, Chen J, Wang Z, et al. Discussion on teaching effect of combination of simulated and clinical training in internal jugular vein puncture. Chin Contin Med Educ. 2024;16(21):125-130. https://doi.org/10.3969/j.issn.1674-9308.2024.21.027

[19] Blackmore C, Austin J, Lopushinsky SR, Donnon T. Effects of postgraduate medical education “boot camps” on clinical skills, knowledge, and confidence: A meta-analysis. J Grad Med Educ. 2014 Dec;6(4):643-652. https://doi.org/10.4300/jgme-d-13-00373.1

[20] Malekzadeh S, Malloy KM, Chu EE, Tompkins J, Battista A, Deutsch ES. ORL emergencies boot camp: Using simulation to onboard residents. Laryngoscope. 2011 Oct;121(10):2114-2121. https://doi.org/10.1002/lary.22146