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The Study of Ultrasound-Guided Central Venous Catheterization in the Teaching of Anesthesia Residents

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Abstract

Objective: To evaluate the application effect of ultrasound-guided central venous catheterization in the teaching of anesthesia residents. Methods: Forty anesthesia resident companions who received standardized residency training in our department from July 2018 to July 2020 were randomly divided into an ultrasound group and a control group, with 20 participants in each group. The ultrasound group was taught by ultrasound-guided central venipuncture, while the control group was taught by traditional anatomy. After ten training punctures, all trainees were assessed twice. Results: Both groups could master the technique of central venipuncture. The success rate of first puncture and the overall success rate of puncture in the ultrasound group were significantly higher than those in the control group ($p < 0.05$). The operation time and puncture complications in the ultrasound group were less than those in the control group ($p < 0.05$). Conclusion: Compared with the traditional anatomical localization teaching, the use of ultrasound-guided technology can improve the success rate of puncture, save puncture time, reduce related complications, and have a better training effect.

Keywords

Ultrasound, Central Venous Catheterization

1. Introduction

Central venous catheterization technology can be used for rapid intravenous

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infusion, rescue of critically ill patients, central venous pressure monitoring, parenteral nutrition, etc. It is a routine operation in the department of anesthesiology, and also a basic skill to be mastered by anesthesia resident training students [1] [2]. Clinically, the right internal jugular vein is often selected for central venous catheterization [3] [4]. In the past, the puncture point was mostly selected through anatomical localization. Briefly, the puncture point was located in the carotid triangle, which was the triangle formed by the sternocleidomastoid muscle and the sternal head of the clavicle and the clavicle. Specifically, the puncture can be performed at the top position of the clavicular head of the sternocleidomastoid muscle, the triangle formed by the sternal head and the clavicle, and the puncture point is 0.5 - 1cm lateral to the pulsating point of the common carotid artery. Due to the invasive operation and complicated anatomy around blood vessels, improper operation is prone to complications such as hematoma, pneumothorax, thyroid injury, and peripheral nerve injury [5], which bring harm to patients and easy to cause disputes; at the same time, it brings psychological burden to the training students and affects their learning confidence and learning effect. Therefore, it is very important to explore a teaching method that can improve the success rate of puncture and catheterization, reduce related complications and improve learning efficiency. With the update and development of medical equipment, such as ultrasound, fiberoptic bronchoscopy, video laryngoscope and other visualization equipment are widely used in the department of anesthesiology. Their safety and accuracy bring help to clinical comfortable medical treatment, and gradually become the standard equipment in the department of anesthesiology and the basic skills that anesthesiologists need to master [6] [7]. Therefore, we tried to use ultrasound localization teaching in the central venipuncture training of the residents, hoping to improve the learning efficiency and training effect of the residents.

2. Objects and Methods

2.1. Study Object

A total of 40 residents who received standardized residency training in our department from July 2018 to July 2020 were randomly divided into ultrasound group (group U) and control group (group C), with 20 people in each group. Group U was taught by ultrasound-guided central venipuncture, and group C was taught by traditional anatomy. There were no statistical differences in general characteristics such as age, gender and education between the two groups.

2.2. Research Methods

All trainees were taught the theory of central venipuncture, including anatomy, indications and contraindications. The training content included the basic knowledge of ultrasound-guided internal jugular vein puncture, the teaching video of ultrasound-guided internal jugular vein puncture, the traditional anatomical positioning method, and the complications of internal jugular vein puncture. The instructors were experienced doctors who could skillfully use ultrasound and traditional anatomical methods to perform internal jugular vein catheterization. After that, the teacher performed two operation demonstrations: one is the ultrasound-guided central venipuncture and the other one anatomical localization blind puncture. Finally, theoretical examination was conducted and the examination results were recorded. After passing the examination, the puncture operation was performed under the guidance of the tutor.

2.3. Operation Method

All patients signed the informed consent for central venipuncture, and the right internal jugular vein was chosen for puncture. Patients with contraindications to puncture were excluded. The first patient puncture was performed in the operating room, and the subsequent patients completed the relevant puncture operations in the anesthesia preparation room. The patient was given oxygen inhalation through nasal catheter and electrocardiogram monitoring. Lying flat without pillow, and the head was tilted about 30 degrees to the left. In the ultrasound group, the arteries, veins and surrounding tissues were identified by ultrasound localization, and the positioning marks were drawn along the blood vessels (**Figure 1**). The common carotid artery was marked by a solid line, and the internal jugular vein was marked by a dashed line. The larger blood vessel was selected as the puncture point, and the depth of the internal jugular vein from the skin was recorded. In the traditional anatomy teaching group, the internal jugular vein descending from the mastoid foramen, entered the chest at the jugular notch between the sternocleidomastoid muscle and the clavicular head, and was projection on the neck surface as the connection between the midpoint of the mastoid process and the mandibular Angle to the jugular notch. After positioning, the line was drawn on the body surface, and the level of the cricoid cartilage, 0.5 - 1 cm lateral to the pulsating point of the common carotid artery, was selected as the puncture point. Puncture method: conventional disinfection drape, local anesthesia before puncture and catheterization. The 7F double-lumen central venous puncture package from Shenzhen Yixinda Company was selected. In group U, the needle was perpendicular to the skin, and negative pressure was applied after puncturing the skin. The depth of the needle was determined by distance between the skin to vein by ultrasound. The direction of the needle was along the marked dashed line until the dark red blood was drawn, and the end of the needle was pressed down at an Angle of 30 degrees to the skin, so as to facilitate the smooth insertion of the guide wire. The needle was withdrawn with the right hand, and the guide wire was graduated to about 15 cm at the skin after withdrawal. After withdrawing from the expander, a central venous catheter was placed along the guide wire with a depth of 12 cm. The guide wire was pulled out, the air in the catheter was extracted, the catheter was sealed with heparin, the catheter was fixed with suture, and sterile protective film was attached. In group C, the needle was at 45 degrees from the skin, and the needle tip was inserted in the direction of the ipsilateral nipple. The needle was pulled back while inserting the needle until dark red blood appeared, then the needle was pressed down at the end of the needle. The procedures of inserting the guide wire, expanding the tube and placing the central venous catheter were the same as those of the ultrasound group. The end of all procedures was regarded as the completion of puncture.

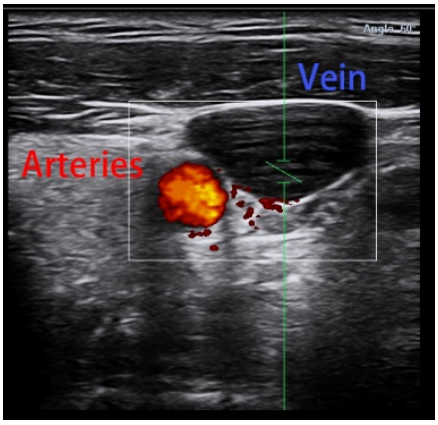

Figure 1. Ultrasound image of the internal jugular vein. The red color represents the carotid artery and the hypoechoic represents the internal jugular vein.

All the trainees completed 10 cases of puncture training and were assessed twice. The following records were recorded: 1) Success rate of first puncture; 2) The overall success rate of puncture (failure to penetrate the internal jugular vein for 3 consecutive times was regarded as puncture failure, and the puncture operation was completed by the teachers); 3) Puncture time (the time from the start of local anesthesia to the end of the operation); 4) Related complications. Documentation was performed by another attending physician who was not involved in this investigate.

2.4. Statistics

SPSS20.0 statistical software was used for statistical analysis, and the measurement data were expressed as mean ± standard deviation. The measurement data satisfying normal distribution were compared between the two groups by independent sample t test, and the non-normal measurement data were compared by Wilcoxon Rank Sum Test. Chi-square test was used for count data, and Fisher's exact test was used when a single data was less than 5. $p < 0.05$ was considered statistically significance in all analyses.

3. Result

1) There was no significant difference in gender, age and theoretical test scores between the two groups, see Table 1.

2) The one-time success rate of internal jugular vein puncture and the overall success rate of puncture in the ultrasound group were significantly higher than

those in the control group ($p < 0.05$). The operation time of the ultrasound group was significantly shorter than that of the control group ($p < 0.05$), and the complications were significantly lower than that of the control group ($p < 0.05$), see Table 2. This indicates that ultrasound-guided internal jugular vein catheterization takes less time and has a higher success rate. Compared with the traditional anatomical positioning method, ultrasound-guided internal jugular vein catheterization has a lower incidence of complications, which can provide patients with safer puncture procedures.

Table 1. The age, gender, and theoretical test scores of the two groups of living companions were compared (Mean ± SD, n = 20).

Group	Age	Gender (male/female)	Test score
Ultrasound group	25.70 ± 0.59	14/6	84.05 ± 0.84
Control group	26.30 ± 0.50	10/10	84.94 ± 1.15
Statistic	$p = 0.129$	Fisher $p = 0.333$	t = 0.729 $p = 0.471$

Table 2. The success rate of puncture, operation time and complications were compared between the two groups (Mean ± SD, n = 40).

Group	Success rate of first puncture	Overall puncture success rate	Operation time (min)	Complications
Ultrasound group	87.5%*	95%*	11.77 ± 1.45***	2*
Control group	62.5%	75%	13.58 ± 1.31	8
Statistic	$\chi = 6.667$ $p = 0.01$	Fisher $p = 0.025$	t = −4.132 $p < 0.0001$	Fisher $p = 0.044$

4. Discussion

Standardized residency training is an important part of medical students' education after graduation, and it mainly aims to cultivate students' clinical practice ability and comprehensive thinking ability through intensive specialized training [8]. The Department of anesthesiology of our hospital is the first batch of standardized training base for residents in Hubei Province, and it is the responsibility of each of our teachers to cultivate high-quality residents. Therefore, it is very important to explore some efficient and conducive teaching methods for students [9] [10].

In recent years, with the popularization and promotion of ultrasound visualization technology in the department of anesthesiology, visualization techniques are being used in an increasing number of hospitals, and familiarity with and master relevant ultrasound technology has gradually become a skill that anesthesiologists need to master [11] [12]. In the standardized training stage of residents, early exposure to and familiarity with ultrasound visualization technology can lay a good foundation for becoming an excellent anesthesiologist in the future [13] [14]. Our department has carried out ultrasound-guided various nerve blocks, arteriovenous puncture, gastric contents assessment, effective blood volume assessment and other techniques. Through our clinical work, we found that ultrasound-guided central venipuncture is relatively simple compared with other operations, and it is more conducive to the residents to quickly accept and master ultrasound visualization technology.

Most of the patients who need central venous catheterization in clinical practice have complex operations and critical physical conditions, which most of them do the urgent operation, so it requires high puncture efficiency [15]. In the past, central venipuncture was mostly taught by traditional anatomical localization. Due to the anatomical variation of blood vessels in patients, the filling of blood vessels is poor when the volume is insufficient, and the puncture is difficult for patients with obesity and short neck, which depends on the experience of the anesthetist, and is very difficult for the resident trainees, and repeated puncture will bring harm to the patients [16]. The experimental results showed that both groups of trainees could master the central venipuncture technology. The one-time success rate and overall success rate of ultrasound group were significantly higher than those of the control group (87.5% vs 62.5%; 95% vs 75%, $p < 0.05$). The puncture time of the ultrasound group (11.77 ± 1.45 min) was less than that of the control group (13.58 ± 1.31 min). There were 2 cases of complications in the ultrasound group, because the patient's blood vessel filling was poor, the puncture needle penetrated the internal jugular vein to form hematoma, and the hematoma did not further expand after withdrawing the needle to compress the bleeding, and the puncture point was successfully selected. In the control group, there were 8 cases of complications, including 6 cases of hematoma (4 cases of common carotid artery puncture, 2 cases of internal jugular vein penetrated puncture), 2 cases of abnormal sensation in the upper arm when touching the cervical nerve, and the puncture was successful after changing the puncture point. The complications in the ultrasound group were less than those in the control group. Most of the complications were local slight hematoma caused by puncture injury of blood vessels, which was relieved after compression, and no important harm was brought to the patients. Through ultrasound guidance, we can more intuitively understand the position, course, thickness, and depth of the blood vessel from the skin (see **Figure 1**). It is convenient for us to choose the most appropriate puncture point and puncture path, avoid important tissues and nerves, and reduce puncture complications [17]. It can significantly improve the success rate of puncture, improve the efficiency of puncture, and the teaching effect is good.

At present, ultrasound is only popular in the anesthesiology department of some hospitals above county level. Some students may not be able to use ultrasound after graduation. In the future, we will use the teaching model of traditional anatomical localization combined with ultrasonic localization. That is, before the puncture, the course and pre-puncture point of the common carotid artery and internal jugular vein were marked by anatomical positioning, and then the accuracy of the marked positioning was checked by ultrasound positioning, so that the positioning skills could be more comprehensively mastered through limited case training, the anatomy around the blood vessels could be understood, and the puncture accuracy and efficiency could be further improved. Our study is only a single-center and small sample study, whether it can be extended to all residents needs further large-sample and multi-center research. On the other hand, we did not analyse the influence of different teaching methods on the success rate of internal jugular vein puncture after graduation or after a long time, and further research in this regard can be done in the future.

In conclusion, the use of ultrasound-guided positioning technology in the central venipuncture training of residents in the department of anesthesiology can improve the learning efficiency of the students, the teaching effect is good, and it has high application value and is worthy of promotion.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Shin, K.W., Park, S., Jo, W., Choi, S., Kim, Y.J., Park, H., *et al.* (2024) Comparison of Catheter Malposition between Left and Right Ultrasound-Guided Infraclavicular Subclavian Venous Catheterizations: A Randomized Controlled Trial. *Critical Care Medicine*, **52**, 1557-1566. https://doi.org/10.1097/ccm.0000000000006368

[2] Schmidt, G.A. and Kory, P. (2013) Ultrasound-guided Central Venous Catheter Insertion: Teaching and Learning. *Intensive Care Medicine*, **40**, 111-113. https://doi.org/10.1007/s00134-013-3093-7

[3] Tang, J., Wang, L., Ouyang, J., Tang, X., Liu, M., Liu, H., *et al.* (2023) Modified Combined Short and Long Axis Method versus Oblique Axis Method in Adult Patients Undergoing Right Internal Jugular Vein Cannulation: A Randomized Controlled Non-Inferiority Study. *PLOS ONE*, **18**, e0295916. https://doi.org/10.1371/journal.pone.0295916

[4] Hoffman, T., Du Plessis, M., Prekupec, M.P., Gielecki, J., Zurada, A., Tubbs, R.S., *et al.* (2017) Ultrasound-guided Central Venous Catheterization: A Review of the Relevant Anatomy, Technique, Complications, and Anatomical Variations. *Clinical Anatomy*, **30**, 237-250. https://doi.org/10.1002/ca.22768

[5] Adrian, M., Borgquist, O., Kröger, T., Linné, E., Bentzer, P., Spångfors, M., *et al.* (2022) Mechanical Complications after Central Venous Catheterisation in the Ultrasound-Guided Era: A Prospective Multicentre Cohort Study. *British Journal of Anaesthesia*, **129**, 843-850. https://doi.org/10.1016/j.bja.2022.08.036

[6] Yamak Altinpulluk, E. and Turan, A. (2021) Future in Regional Anesthesia: New

Techniques and Technological Advancements. *Minerva Anestesiologica*, **87**, 85-100. https://doi.org/10.23736/s0375-9393.20.14791-6

[7] Imai, E., Kataoka, Y., Watanabe, J., Okano, H., Namekawa, M., Owada, G., *et al.* (2024) Ultrasound-Guided Central Venous Catheterization around the Neck: Systematic Review and Network Meta-Analysis. *The American Journal of Emergency Medicine*, **78**, 206-214. https://doi.org/10.1016/j.ajem.2024.01.043

[8] Su, W., Yang, C., Yang, L. and Li, J. (2023) Current Situation Analysis and Improvement Measures of Anesthesia Teaching in Standardized Training of Non-Anesthesia Residents. *Asian Journal of Surgery*, **46**, 977-978. https://doi.org/10.1016/j.asjsur.2022.10.064

[9] Wang, S., Chen, W., Ma, J. and Zhan, J. (2024) Thoughts on Teaching Ward Round in the Standardized Training of Anesthesiology Residents. *Asian Journal of Surgery*, **47**, 2788-2789. https://doi.org/10.1016/j.asjsur.2024.02.068

[10] Houben, K.W., van den Hombergh, C.L.M., Stalmeijer, R.E., Scherpbier, A.J. and Marcus, M.A.E. (2011) New Training Strategies for Anaesthesia Residents. *Current Opinion in Anaesthesiology*, **24**, 682-686. https://doi.org/10.1097/aco.0b013e32834c8842

[11] Harmon, D.J., Boscardin, C.K., Cohen, N.H. and Braehler, M.R. (2023) The Efficacy of an Anatomy and Ultrasonography Workshop on Improving Residents' Confidence and Knowledge in Regional Anesthesia. *BMC Medical Education*, **23**, Article No. 665. https://doi.org/10.1186/s12909-023-04653-y

[12] Mcgraw, R., Chaplin, T., Mckaigney, C., *et al.* (2016) Development and Evaluation of a Simulation-Based Curriculum for Ultrasound-Guided Central Venous Catheterization. *Canadian Journal of Emergency Medicine*, **18**, 405-413.

[13] Ball, R.D., Scouras, N.E., Orebaugh, S., Wilde, J. and Sakai, T. (2012) Randomized, Prospective, Observational Simulation Study Comparing Residents' Needle-Guided vs Free-Hand Ultrasound Techniques for Central Venous Catheter Access. *British Journal of Anaesthesia*, **108**, 72-79. https://doi.org/10.1093/bja/aer329

[14] De Cassai, A., Geraldini, F., Pasin, L., Boscolo, A., Zarantonello, F., Tocco, M., *et al.* (2021) Safety in Training for Ultrasound Guided Internal Jugular Vein CVC Placement: A Propensity Score Analysis. *BMC Anesthesiology*, **21**, Article No. 241. https://doi.org/10.1186/s12871-021-01460-0

[15] Rando, K., Castelli, J., Pratt, J.P., *et al.* (2014) Ultrasoundguided Internal Jugular Vein Catheterization: A Randomized Controlled Trial. *Heart, Lung and Vessels*, **6**, 13-23.

[16] Yoon, H., Hur, M., Cho, H., Jeong, Y.H., Lee, H., Yang, S., *et al.* (2021) Effects of Practitioner's Experience on the Clinical Performance of Ultrasound-Guided Central Venous Catheterization: A Randomized Trial. *Scientific Reports*, **11**, Article No. 6726. https://doi.org/10.1038/s41598-021-86322-y

[17] Koh, J., Xu, Y., Yeo, L., Tee, A., Chuin, S., Law, J., *et al.* (2014) Achieving Optimal Clinical Outcomes in Ultrasound-Guided Central Venous Catheterizations of the Internal Jugular Vein after a Simulation-Based Training Program for Novice Learners. *Simulation in Healthcare: The Journal of the Society for Simulation in Healthcare*, **9**, 161-166. https://doi.org/10.1097/sih.0000000000000010