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Exploring the Implementation Pathway for Point-of-Care Ultrasound-Guided Basic Clinical Puncture Procedures in Practical Teaching

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Abstract: The present study aims to explore the implementation pathway for practical teaching of basic clinical puncture procedures under the guidance of point-of-care ultrasound (POCUS). The goal of the study is twofold: firstly, to address the shortcomings of the current medical education model and, secondly, to enhance medical students' independent thinking abilities and clinical diagnostic skills. The study enrolled 87 clinical medicine interns rotating at Jiangning Hospital in Nanjing from January to December 2024, dividing them into an experimental group (receiving ultrasound-guided puncture procedure training) and a control group (receiving conventional puncture procedure training). It was evident that both groups had successfully completed the requisite two-hour comprehensive course training program. A subsequent analysis of the teaching outcomes was then conducted through intergroup comparison. The findings indicated that the experimental group exhibited lower DOPS assessment scores in comparison to the control group (4.91 ± 1.01 vs. 5.84 ± 1.22, $p < 0.05$). However, the satisfaction levels of the experimental group with the teaching method reached 95.45%. This finding indicates that ultrasound-guided puncture techniques may offer a substantial advantage in terms of pedagogical approaches. However, it should be noted that students in the experimental group faced challenges such as high operational complexity and the need to pay attention to numerous details during actual procedures, leading to lower assessment scores. Conducting a systematic analysis of these issues can provide clear directions for the optimization of teaching methods in the future, thereby enhancing students' learning outcomes and clinical application capabilities.

Keywords: Point-of-care ultrasound; Puncture; Practical training

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1. Introduction

With the continuous improvement of material life, the average life expectancy and medical conditions have seen significant enhancements and improvements. However, this progress has been accompanied by a scarcity of

medical resources and an uneven distribution across regions. To cope with the dynamic and complex healthcare environment, medical education needs to intensify its efforts in cultivating medical students with strong comprehensive abilities. The "Guiding Opinions of the General Office of the State Council on Accelerating the Innovative Development of Medical Education" [1] issued in 2020 explicitly proposed promoting the interdisciplinary integration of medical engineering, medical science, and medical humanities, and strengthening the cultivation of innovative and outstanding talents with a multidisciplinary background of "Medicine + X". However, traditional medical education faces issues such as disciplinary barriers, fragmented knowledge, a disconnect between basic and clinical education, and outdated teaching methods. Therefore, curriculum system reform has become a crucial aspect of cultivating innovative and interdisciplinary medical talents.

As an interdisciplinary technology, ultrasound is widely applied in imaging diagnosis and clinical operations. For clinicians, ultrasound serves as a "visual stethoscope" and is increasingly utilized in multidisciplinary collaborations [2]. Due to its advantages of no ionizing radiation, low cost, and non-invasiveness, ultrasound has become an attractive teaching tool for medical students. It can fully integrate basic medical knowledge with clinical applications, helping students deepen their understanding of foundational medical subjects such as systemic anatomy, physiology, pathology, and diagnostics, enhance their practical operational skills, and foster direct interaction between students, teachers, and patients [3]. Furthermore, as a non-invasive and real-time examination tool, ultrasound plays a significant role in the clinical education system of Western countries. Early exposure to ultrasound technology training can promote the development of competency [4–6].

The WFUMB (The World Federation of Ultrasound in Medicine and Biology) consensus on ultrasound education for medical students state that ultrasound is becoming a fundamental diagnostic tool in most medical specialties and an innovative tool for teaching anatomy, physiology, and pathophysiology to both undergraduate and postgraduate students [7]. Extensive research on ultrasound instruction has been conducted worldwide, revealing significant diversity in training methods, equipment, and curriculum design. Opportunities for ultrasound education at both undergraduate and postgraduate levels continue to expand, with increasingly diverse project concepts and teaching formats [8–10]. This study aims to explore the practical implementation path of ultrasound-guided clinical basic skills training during the medical student training phase, addressing deficiencies in the existing medical training model and enhancing medical students' independent thinking and clinical diagnostic abilities.

Ultrasound has a wide range of clinical applications [11]. In the 1990s, European medical schools began incorporating ultrasound into their teaching and recommended the development of undergraduate curricula. Subsequently, developed countries and regions successively applied ultrasound training to anatomy and physiology courses, integrated it into physical examinations and problem-based learning, and ultimately utilized it in clinical rotations [12,13]. Germany began requiring the inclusion of point-of-care ultrasound courses in the undergraduate curriculum for all medical students in 2015 [14]. In contrast, China started relatively late, with most medical schools lacking professional ultrasound training courses at the undergraduate level. Currently, clinical specialists in China often receive professional ultrasound technology training only after encountering specific practical issues in their clinical work [15]. Therefore, through this study, we aim to explore the implementation path of practical teaching for bedside ultrasound-guided basic clinical puncture procedures during the medical student training phase, with the goal of popularizing fundamental ultrasound knowledge and basic ultrasound skills.

2. Materials and methods

2.1. Research design

This study selected 87 clinical medicine interns rotating at Jiangning Hospital in Nanjing from January 2024 to December 2024 as the research subjects. The 87 students were randomly divided into an experimental group of 44 and a control group of 43. The experimental group consisted of 24 males and 20 females, while the control group had 24 males and 19 females, with no statistically significant difference in general demographic data between the two groups. The experimental group received ultrasound-guided puncture procedure training, while the control group underwent conventional puncture procedure training. After the teaching sessions, a unified clinical skills assessment (using the DOPS evaluation form) and a questionnaire survey (using the Likert scale) were conducted. Data entry and statistical analysis were performed using SPSS 23.0 statistical software to evaluate the effectiveness of the two different practical teaching implementation paths.

2.2. Teaching implementation

A teaching research group consisting of six instructors from clinical departments, the ultrasound department, and the skills center was established. An in-depth investigation was conducted into the learning abilities and practical needs of medical students. Taking into account the actual clinical requirements, the characteristics of ultrasound technology, and the feasibility of simulation-based teaching, a two-hour teaching content was determined that integrates basic procedures such as thoracentesis and deep venous catheterization with ultrasound technology.

2.2.1. First class hour: Theoretical knowledge explanation

(1) Basic principles of ultrasound (15 minutes)
Utilizing videos from the MOOC platform, PowerPoint presentations, and animated demonstrations, the fundamental concepts of ultrasound imaging and equipment structure are introduced. The PBL (Problem-Based Learning) teaching method is employed to present misdiagnosis cases, stimulating students' interest in learning about ultrasound principles.

(2) Traditional thoracentesis and internal jugular vein puncture procedures (45 minutes)
Employing the CBL (Case-Based Learning) teaching method, real clinical cases are introduced to provide a detailed explanation of indications, contraindications, and procedural steps. Live demonstrations using human models are conducted, emphasizing key precautions.

2.2.2. Second class hour: Video learning and discussion

Video Learning of Ultrasound-Guided Thoracentesis and Internal Jugular Vein Puncture (45 minutes): High-definition operation videos are played to demonstrate in detail the real-time application of ultrasound images during the puncture process. The video is paused at appropriate times to provide detailed explanations of key steps.

2.2.3. Group discussion and summary (15 minutes)

Organize students into groups for discussion, allowing them to share their insights, questions, and experiences. The teacher will summarize the key points of the course and re-emphasize the importance of ultrasound-guided puncture techniques.

3. Results

3.1. Student skill assessment results

After the course implementation, DOPS evaluation scales were collected from 87 interns. The experimental group scored 4.91 ± 1.01, while the control group scored 5.84 ± 1.22, with a statistically significant difference ($p < 0.001$), as shown in **Table 1**.

Table 1. Scores on the DOPS evaluation scale for the experimental and control groups

Group	Sample size	Excellent [n (Score)]	Qualified [n (Score)]	Failed [n (Score)]	Mean score	*p*-value
Experimental group	44	2 (7.65 ± 0.43)	37 (4.94 ± 0.54)	5 (3.58 ± 0.11)	4.91 ± 1.01	< 0.001
Control group	43	8 (7.69 ± 0.46)	33 (5.52 ± 0.85)	2 (3.85 ± 0.07)	5.84 ± 1.22	

3.2. Questionnaire survey results

The satisfaction survey on this course training covered five dimensions: teaching content, teaching methods, teacher performance, training effectiveness, and overall evaluation, with a total of 18 sub-items. A total of 44 questionnaires were distributed, and 44 valid questionnaires were collected, resulting in a 100% effective response rate. See **Table 2**.

Table 2. Overview of satisfaction ratings across dimensions in the experimental group

Survey dimension	Satisfied (Count)	Dissatisfied (Count)	Satisfaction rate	Dissatisfaction rate
Teaching content	38	6	86.36%	13.64%
Teaching methods	42	2	95.45%	4.55%
Instructor performance	35	9	79.55%	20.45%
Training effectiveness	32	12	72.73%	27.27%
Overall satisfaction & willingness to recommend	38	6	86.36%	13.64%

4. Discussion

The lower scores in the experimental group during the implementation of this teaching approach were primarily attributed to the inherent characteristics of ultrasound operation. Ultrasound operation requires students to master a wide range of skills, including the operation of ultrasound equipment, interpretation of ultrasound images, and real-time monitoring of puncture needles. Moreover, prolonged operation can easily lead to student fatigue, thereby increasing the likelihood of errors and affecting assessment scores. However, it cannot be denied that ultrasound-guided puncture technique has extensive clinical application scenarios and significant clinical value. In the future, it is necessary to further increase simulation training sessions and optimize assessment criteria. Meanwhile, we also need to strengthen teacher training to ensure that students receive more professional guidance.

This study has some limitations, such as a small sample size and a short research period, which failed to comprehensively evaluate the effectiveness of ultrasound-guided puncture technique in long-term clinical practice. The core challenge currently faced by ultrasound puncture teaching is the lack of a unified assessment system [16]. The design of the DOPS assessment form may not fully cover all the details of ultrasound operation, affecting the

comprehensiveness of the assessment results. Although medical educators are committed to optimizing ultrasound teaching procedures based on practical experience, there are still the following methodological disagreements: whether traditional experimental methods derived from biomedical research (such as randomized controlled trials) are suitable for evaluating ultrasound teaching processes that are highly context-dependent and multifactorial. Therefore, whether teaching interventions can be effectively validated and improved in the form of medical research remains an unresolved issue [17].

5. Conclusion

This study explores a practical teaching implementation path for guiding basic clinical puncture procedures with bedside ultrasound, aiming to address issues such as the reliance on surface landmarks in traditional puncture teaching, the long learning curve for junior physicians, and the high incidence of complications [18]. Although students in the experimental group scored lower in the DOPS assessment, they expressed higher satisfaction with the teaching methods and content. Through reasonable adjustments and improvements, this teaching path is expected to enhance students' learning outcomes in puncture procedures and enable ultrasound-guided puncture techniques to play a greater role in clinical teaching. In the future, students' clinical practical abilities can be further enhanced by increasing simulated training sessions, optimizing assessment criteria, and strengthening teacher training.

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Disclosure statement

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