Original Article

The Application of Case-Based Learning (CBL) Combined with PDCA Cycle in the Clinical Teaching Practice of Breast Ultrasound in Standardized Residency Training

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ABSTRACT

Background: The integration of case-based learning (CBL) with the plan-do-check-act (PDCA) cycle has potential benefits for clinical education, yet its efficacy in ultrasound residency training, particularly for breast ultrasound, requires evaluation. **Aim:** This study aimed to assess the impact of a combined CBL and PDCA cycle teaching model on the clinical thinking and skills of ultrasound residents compared to traditional teaching methods. **Methods:** A comparative study was conducted at Sichuan Provincial People's Hospital's ultrasound medicine base, from August 2020 to June 2023, focusing on residents in training. Sixty-one trainees were randomly divided into two groups: a joint group (n = 31) taught using a PDCA cycle-based model integrated with CBL and a traditional group (n = 30) taught with conventional methods. Both groups underwent a 20-hour course and were subsequently evaluated on theoretical knowledge, clinical thinking, and skills. Comparative statistical analysis was performed to evaluate the performance differences between the two groups. **Results:** The joint group demonstrated significantly better clinical thinking and skills operation than the traditional group ($P < 0.05$). No significant difference was observed between the groups regarding theoretical knowledge ($P > 0.05$). **Conclusions:** The combined CBL-PDCA cycle teaching mode significantly enhances the clinical thinking abilities and operational skills of residents in breast ultrasound training. This innovative approach shows promise as an effective educational strategy to foster intrinsic motivation and higher order learning capabilities among ultrasound residents.

KEYWORDS: *Breast ultrasound, CBL, PDCA, residency training*

INTRODUCTION

Standardized residency training programs (RTPs) are a crucial component of postgraduate medical education, serving as a bridge between academic learning and clinical practice. In the United States, Europe, and other developed regions, RTPs have evolved into sophisticated systems that ensure high-quality clinical practice. After over two decades of evolution, China has adapted its standardized residency training to align with its unique healthcare system, creating a horizontal training model that addresses the specific needs of the country's medical institutions.[1]

Ultrasonography stands out as a discipline reliant on practical expertise and operator skill, presenting unique challenges to residency training due to its inherent subjectivity and dependency on the practitioner's judgment.[2,3] As China's medical sector grows, so does the demand for skilled specialists in ultrasonography.

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The challenge of elevating teaching quality and nurturing top-tier talent within this field is one that educators are currently striving to address.[4]

The plan-do-check-act (PDCA) cycle, also known as Deming's cycle, is a foundational model in management that emphasizes continuous improvement. Originally devised in the 1920s for total quality management, its principles have since been applied across numerous industries, including education, to enhance the quality of outcomes.[5,6]

Concurrently, case-based learning (CBL), pioneered by Harvard Medical School and Law School, has gained recognition as an engaging educational strategy that promotes deep learning through the analysis of real clinical cases in a group discussion format.[7,8]

In our study, we have innovatively amalgamated the CBL method with the PDCA cycle. We focused on breast ultrasound, a complex aspect of ultrasound residency training, to investigate the effectiveness of this integrated teaching model. We aim to evaluate the added value of the CBL-PDCA approach to standardized training for ultrasound residents, with the intent to improve both educational outcomes and clinical proficiency.

Subjects and Methods

Study participants

This study was approved by the Ethics Committee of Sichuan Provincial People's Hospital, China. All methods were conducted by related guidelines and regulations (approval no. 2021517). The participants also read and provided the informed consent form before completing the questionnaire.

This study included residents undergoing standardized training at the Ultrasound Medical Base of Sichuan Provincial People's Hospital from August 2020 to June 2023. Inclusion criteria were as follows: (1) no prior training in standardized breast ultrasound examination; (2) no experience in breast ultrasound, including no rotations in the ultrasound subspecialty group focused on superficial ultrasound. Exclusion criteria included: (1) prior participation in standardized breast ultrasound training; (2) any prior experience with breast ultrasound or related work; (3) trainees who had deferred their training or had reduced years of experience among the standardized training cohort. A total of 61 residents met these criteria and were enrolled in the study; they were junior doctors aged between 23 and 30 years, with an average age of 25.34 ± 1.76 years. The cohort consisted of seven males and 54 females, all of whom held full-time undergraduate bachelor's degrees from medical school.

Research methods

Participants were randomly assigned to two groups using ascending numerical order; those with odd numbers were placed in the combined CBL-PDCA teaching group ("combined group"), and those with even numbers were placed in the traditional teaching group, which utilized small lectures ("traditional group"). Both groups received identical theoretical and practical instruction from the same educators. The curriculum comprised 20 hours of lectures on topics including "Breast Ultrasound Guidelines," "Ultrasound Diagnosis of Common Breast Diseases," "Breast Imaging-Reporting and Data System (BI-RADS)," and "Breast Ultrasound Operation Training."

For the combined group, the PDCA cycle was segmented into four phases: Plan, Do, Check, and Act. In the Plan phase, breast ultrasound training goals were established in alignment with the "Content and Standards of Standardized Training for Residents (2022 Edition)" and the "Guidelines for Teaching Activities of Standardized Training for Residents (2022 Edition)." Relevant clinical cases from the picture archiving and communication system (PACS) system were selected for CBL, and senior faculty provided instruction. In the Do phase, pre-class materials were distributed, interactive case-based theoretical teaching was conducted, and hands-on skill training was emphasized. In the Check phase, an assessment team evaluated the residents, with scores ≥80 considered satisfactory. In the Act phase, feedback was provided on deficiencies, and corrective action plans were developed for the subsequent PDCA cycle.

The traditional group followed a more conventional approach, with brief pre-class reviews and comprehensive didactic lectures, alongside standard skill training led by senior instructors.

All participants provided informed consent, understanding that participation would not influence their academic evaluation or certification outcomes.

Evaluation indicators

The assessment was designed according to Bloom's taxonomy of educational objectives and included three indices: basic theoretical knowledge, clinical thinking analysis, and skill operation.[9] Each assessment had a maximum score of 100 points, with clinical thinking analysis utilizing the PACS system to retrieve preoperative ultrasound images for BI-RADS classification. Skill operation was divided into machine operation and report writing, with each section worth 50 points.

Statistical methods

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 21.0 statistical

software. Skill assessment results were expressed as mean ± standard deviation, while categorical data were presented as ratios. Chi-squared tests were employed for ratio comparisons, and independent-sample t-tests were used to compare means between the two groups. A P value of < 0.05 was considered statistically significant.

Results

Participant characteristics and demographics

From August 2020 to June 2023, 71 trainees were scheduled to receive training at the base. Among them, one trainee was deferred, one had significantly shorter years of working experience than other participants, and eight had prior experience with breast ultrasound or related training, resulting in their exclusion from the study. Consequently, 61 trainees were eligible and included in the study: 31 were assigned to the combined group and 30 to the traditional group. The participants were categorized as social trainees (referred to as "socials"), unit-appointed trainees (referred to as "units"), and postgraduate trainees (referred to as "postgraduates"). The distribution of trainees by type and grade was statistically similar across both groups [Table 1].

Basic theoretical knowledge acquisition

Before the initiation of training, a pre-course assessment was administered to both groups. The combined group had an initial average score of 54.71 ± 6.61, while the traditional group scored 52.70 ± 6.08 on average, with no significant difference in baseline knowledge between the groups ($P = 0.222$) [Table 2]. Post-training, the average scores increased significantly to 85.43 ± 4.53 for both groups, demonstrating a substantial improvement from the pre-course assessment ($P < 0.001$). This indicated that trainees from both groups were capable of acquiring theoretical knowledge through the educational activities. However, a comparison of the post-training results revealed no significant difference in basic theoretical knowledge between the combined and traditional groups ($P = 0.549$).

Table 1: Basic characteristics of the trainees

Project	Combined group (n)	Traditional group (n)	χ^2	P
Types of trainees	31	30	0.370	0.831
Socials	9	10		
Units	7	5		
Postgraduate	15	15		
Student grade	31	30	0.135	0.935
First grade	13	12		
Second grade	8	9		
Third grade	10	9		
Gender			0.126	0.772
Male	4	3		
Female	27	27		
Age	25.55±1.823	25.19±1.697	0.920	0.361

Clinical thinking and analytical skills

The combined group had an average score of 85.81 ± 3.88, while the traditional group scored 76.67 ± 5.02, with the combined group outperforming the traditional group. The difference in clinical thinking and analysis capabilities between the two was statistically significant ($P < 0.001$). Notably, in cases involving certain types of breast cancer, ultrasonographic features can be non-typical, often leading to a lower BI-RADS classification of the lesion. Through the iterative PDCA cycle, the combined group demonstrated superior clinical analysis of breast masses and higher accuracy in BI-RADS classification compared to the traditional group [Figure 1a and b].

The skills operation assessment of the two groups of trainees

The skills operation assessment was divided into two components: on-camera operation and report writing. Post-training, the combined group achieved a higher

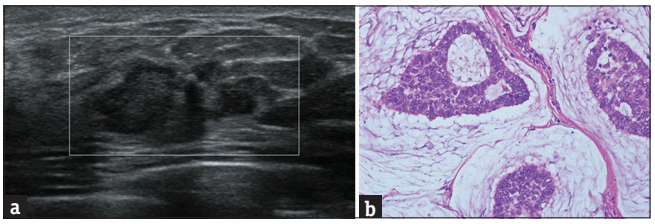

Figure 1: A 49-year-old woman presents with right breast mucinous carcinoma. After the training, BI-RADS classification was performed, and the correct rate of the trainees in the traditional group was 36.67%, and the correct rate of the trainees in the combined group was 64.52%. (a): Ultrasound image of the breast mass, (b): postoperative pathology (HE: ×400)

Table 2: Pre-course and post-course tests of the two groups of participants

Project	Combined group (n=30)	Traditional group (n=31)	P of t-test
Pre-course test (100 out of all)	54.71±6.61	52.70±6.08	0.222
After-class test (100 out of all)	86.13±4.49	85.43±4.53	0.549
Clinical thinking (100 out of all)	85.81±3.88	76.67±5.02	<0.001
Skill assessment (100 out of all)	80.26±6.29	74.80±7.35	0.03
Operation (50 out of all)	37.84±3.07	37.77±3.90	0.936
Report (50 out of all)	42.43±4.02	37.03±4.14	<0.001

average score (80.26 ± 6.29) in skill operation compared to the traditional group (74.80 ± 7.35), with the observed difference being statistically significant ($P = 0.03$).

When evaluating on-camera operation, parameters, such as the duration of breast ultrasonography (indicative of proficiency), continuity and completeness of sweeps, the absence of missed diagnoses, and proper image storage, were considered. Although the combined group demonstrated better performance in on-camera operation compared to the traditional group (37.03 ± 4.14), this difference did not achieve statistical significance ($P = 0.936$).

For report writing, the difference between the combined group and the traditional group was statistically significant ($P < 0.001$), with the combined group showing superior results.

Discussion

The standardized training of residents in China plays a pivotal role in the continuum of medical education, bridging the gap between academic learning and ongoing professional development. Its significance extends to shaping the caliber of the nation's medical workforce, which is, unsurprisingly, a focal point of national inspections.[10] Since 2008, our institution has embarked on this journey of standardized training, earning recognition as a premier national training base for residents in ultrasound by 2014. Over the years, we have cultivated over 200 ultrasound specialists, who now serve across the province and the nation, a testament to our commitment to excellence in this field.

Traditional lectures, while cost-effective for imparting theoretical knowledge,[11] fall short in equipping ultrasound residents with the requisite clinical acumen and practical skill set.[12] The potency of CBL in medical instruction has been well-documented.[12,13] Our study illustrates that integrating CBL in breast ultrasound training significantly enhances the trainees' abilities to identify, collate, and synthesize information, fostering deeper cognitive processes, such as application, analysis, evaluation, and creativity. This, in turn, invigorates students' intrinsic motivation and catalyzes the development of higher order thinking.[14,15]

The focus of our study on breast ultrasound within the CBL and PDCA framework stems from its criticality in diagnosing breast conditions.[16] The BI-RADS system,[17] pivotal in lesion classification,[18] served as a benchmark for evaluating the residents' clinical judgment in our research. Feedback and evaluation are cornerstones of a successful educational experience, paving the way for enhanced outcomes. Our approach parallels the PDCA cycle's ethos in quality management, applying it innovatively to our teaching methodology, albeit its application in educational settings has been scant.[19] The CBL-PDCA model we devised underwent scrutiny across theoretical knowledge, clinical thinking, and procedural skills, affirming its efficacy in bolstering clinical reasoning and technical proficiency, particularly in diagnosing atypical breast tumors, such as mucinous carcinoma, where the PDCA-trained group excelled. The absence of a significant difference in procedural skills between the groups suggests that such competencies may hinge more on the duration and focus of hands-on practice rather than the teaching strategy employed.[20]

This study has several strengths. Firstly, the integration of CBL with the PDCA cycle in ultrasound training is novel and shows a significant enhancement in clinical thinking and technical skills, setting a precedent for future educational frameworks. Secondly, the study evaluates theoretical knowledge, clinical thinking, and procedural skills, providing a holistic view of training effectiveness. Thirdly, the focus on breast ultrasound, particularly the use of BI-RADS for lesion classification, ensures that the training is aligned with clinical necessities and improves diagnostic accuracy for complex conditions. However, some weaknesses should be considered when interpreting the results of this study. The non-blind nature of the course and assessments could introduce bias, potentially affecting the objectivity of the results. The relatively small sample size limits the generalizability of our findings and precludes a stratified analysis by trainee grade level. In addition, this study does not provide long-term follow-up data, which is necessary to determine the sustainability of the observed benefits.

PDCA is a robust quality control framework in breast ultrasound instruction, enabling dynamic corrections and problem identification and fostering continuous teaching improvement.[20,21] It also facilitates the accrual of invaluable teaching insights for educators. Future research should aim for multicenter randomized trials with larger cohorts and long-term follow-up to validate and extend our conclusions. In addition, incorporating blind assessments and stratifying analysis by trainee grade levels could further enhance the robustness of the findings.

Conclusions

In conclusion, the CBL methodology synergized with the PDCA cycle substantially enhances the clinical reasoning and practical skills of residents in breast ultrasound training. It fosters intrinsic motivation and advanced learning capabilities while providing a platform for educators to refine their instructional strategies. This innovative approach holds promise as a progressive model in the standardized training of medical residents.

Key Messages

CBL-PDCA integration significantly boosts clinical skills in ultrasound residents, marking an innovative leap in residency training effectiveness.

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Conflicts of interest

There are no conflicts of interest.

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