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Application of CBL Teaching Method in Clinical Microbiology Laboratory Training for Residents

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Abstract: Clinical microbiology laboratory training for residents has long faced the limitations of traditional Lecture-Based Learning (LBL), which is characterized by an overemphasis on technical operations, inadequate cultivation of clinical thinking, and a disconnection between testing and diagnosis, and treatment. In this study, a case-sharing teaching model based on Case-Based Learning (CBL) was introduced, and a hierarchical and progressive teaching framework was constructed. Using common clinical infection cases as a carrier, the study implemented case screening, data collection, analysis, and reporting, stepped problem discussion, and multidimensional evaluation feedback in stages. Teaching practice has shown that the CBL model significantly improves trainees' clinical interpretation skills of test results, antimicrobial drug decision-making logic, and multispecialty collaboration awareness, while strengthening autonomous learning and evidence-based thinking skills.

Keywords: Clinical microbiology testing; Case-Based Learning (CBL); Standardized training for resident physicians; Clinical thinking

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1. Introduction

Clinical microbiology testing is a core component of infectious disease diagnosis, and its talent cultivation is directly related to the accuracy of clinical diagnosis and treatment and patient prognosis. Standardized training for resident physicians is a critical stage in the transition of medical graduates to qualified clinicians. However, due to the complexity of pathogen species, rapid iteration of testing technology, and high demands on clinical thinking, microbiology laboratory training for residents has always faced challenges such as the disconnection between theory and practice and insufficient trainee participation [1]. Traditional Lecture-Based Learning (LBL) focuses on imparting knowledge, with trainees passively receiving information, making it difficult to adapt to the dynamic and individualized diagnostic needs of pathogenic diseases in clinical scenarios. In this context, Case-Based Learning (CBL), characterized by "problem-driven, contextual immersion, and independent exploration," has gradually become an important direction for medical education reform [2].

In recent years, the application value of the CBL teaching method in the medical field has been widely validated [3–5]. Studies have shown that through deep analysis of real cases, CBL can effectively improve trainees' clinical thinking skills,

autonomous learning abilities, and team collaboration skills [6]. For example, in microbiology testing teaching, CBL uses typical infection cases as entry points to guide trainees through the entire process from collecting medical history, laboratory testing to result interpretation, transforming abstract microbiological knowledge into concrete clinical decision-making abilities. In addition, CBL emphasizes trainees actively proposing hypotheses and validating solutions in group discussions. This process not only strengthens core skills such as pathogen identification and drug sensitivity analysis but also cultivates evidence-based medical thinking and clinical communication skills [7]. Compared to traditional teaching models, the dynamic interactivity of CBL significantly enhances trainees' interest and participation in learning.

This study systematically constructs an application framework for the Case-Based Learning (CBL) teaching model in microbiology laboratory training, targeting resident trainees in the laboratory department of a top-tier hospital. By optimizing case selection criteria, designing layered and progressive question chains, integrating new technology teaching resources, and combining diversified evaluation systems, the aim is to verify the comprehensive effects of the CBL teaching method on improving trainees' clinical practice abilities, scientific research literacy, and teaching satisfaction. The research results will provide a theoretical basis and practical reference for the teaching reform of microbiology laboratory resident training, helping to cultivate a team of laboratory physicians with solid skills and innovative abilities.

2. Implementation of CBL-based case sharing teaching method

2.1. Case selection

Cases are the foundation of the case-sharing teaching method. The instructor selects appropriate cases for sharing, focusing on common clinical diseases with clear patient history, distinct symptoms and signs, relatively complete examinations, standardized treatment, and unambiguous final diagnoses.

2.2. Case data collection and reporting

The instructor uses the patient's relevant laboratory test reports as a starting point, assigns tasks ahead of time, and specifies junior trainees to collect and report case data, including patient history, symptoms, and signs. Senior trainees are assigned to analyze the case, including summarizing case characteristics, interpreting test reports, diagnosis, and differential diagnosis. Simultaneously, they are required to search relevant literature and expand their knowledge of disease-related diagnostic guidelines, clinical and laboratory aspects.

2.3. Discussion and analysis

The instructor proposes tiered questions around pathogen identification, drug sensitivity result analysis, diagnosis and treatment strategies, key points of clinical communication, and other aspects, guiding trainees to discuss in groups. The first tier discusses sample collection and transportation points and test method selection. The second tier focuses on report interpretation, including common identification points and clinical significance of detected pathogens, drug resistance mechanisms, and special phenotype analysis. The third tier discusses the patient's diagnosis and treatment process, guiding trainees to consider alternative detection methods and newer technologies for the case, and discussing potential improvements in the current diagnosis and treatment process. The fourth tier simulates clinical and laboratory dialogue scenarios, guiding trainees to consider key points and communication skills in clinical interactions.

2.4. Summary

The instructor provides comprehensive feedback and reasonable improvement suggestions on various aspects such as case report history data collection, case characteristic summarization, diagnostic thinking, slide production, and trainee expression ability. They also encourage audience members to ask questions and discuss the content.

3. Effects of CBL-based case sharing teaching

3.1. Trainee survey feedback results

Ten resident trainees who received case-sharing teaching methods in this department evaluated the courses. The results showed that most resident trainees agreed with the CBL-based case-sharing teaching method, with scores above 4 for all evaluation items (**Table 1**).

Table 1. Evaluation statistics table for standardized training and teaching case discussions of resident physicians

Evaluation content	Number of respondents	5 points	4 points	3 points	2 points	1 point
Understanding of the teaching case discussion	10	8	2	0	0	0
Suitability of teaching objectives	10	8	2	0	0	0
Instructor's classroom guidance ability	10	10	0	0	0	0
Overall gains	10	10	0	0	0	0
Preparation before class	10	10	0	0	0	0
Participant engagement	10	10	0	0	0	0
Instructor's explanation of key points and difficulties	10	10	0	0	0	0
Instructor's feedback to residents	10	10	0	0	0	0
Overall evaluation	10	9	1	0	0	0

3.2. Evaluation by supervising experts

An expert supervisor was invited to participate in the entire process of case discussion and evaluate the teaching effectiveness after the class. The feedback from the expert indicated that the teaching objectives were clear, the case selection aligned with professional training guidelines, the difficulty level matched the teaching audience, and the lesson plan was designed reasonably and in detail. Both instructors and students prepared adequately before class. Junior students collected complete case data, while senior students demonstrated independent insights in summarizing case characteristics. During the discussion, the instructor posed questions reasonably and progressively, which was conducive to cultivating the clinical diagnostic thinking of resident trainees.

3.3. Teacher self-evaluation

The case-based learning (CBL) approach to case sharing has helped improve the autonomy, enthusiasm, and participation of resident trainees. Simultaneously, during the pre-class preparation stage, resident trainees effectively enhanced their clinical diagnostic thinking ability by collecting and analyzing case data and summarizing case characteristics. In the process of preparing presentation slides, resident trainees mastered PowerPoint production methods and skills. During the presentation and discussion stages, students' oral expression skills were honed. However, it is necessary to strengthen the guidance and supervision of resident trainees during the teaching process to prevent a few students from being perfunctory in the pre-class preparation stage, which could affect the overall teaching effectiveness. Additionally, when setting discussion questions, it is important to consider the different levels of basic knowledge mastery among students of different grades. Therefore, tiered questions should be proposed to fully reflect hierarchical progression.

4. Conclusion

As the "scout" for the diagnosis and treatment of infectious diseases, the core value of clinical microbiology testing lies not only in providing accurate laboratory data but also in dynamically integrating test results with clinical diagnosis and

treatment needs to guide precision therapy and infection control [8]. As medicine transitions from "empirical medicine" to "precision medicine," the development of the clinical microbiology testing profession is no longer limited to technological advancement. Instead, there is an urgent need to cultivate clinical thinking to achieve a role transition from being a "data producer" to being a "participant in clinical decision-making [9]." Only in this way can the collaborative value of "testing guiding clinical practice and clinical practice feeding back to testing" be truly leveraged in the face of antibiotic resistance crises and emerging infectious disease threats, providing patients with a full range of precision diagnosis and treatment services. Traditional microbiology testing often falls into the dilemma of "technology for technology's sake," while clinical thinking can reshape testing logic. The essence of clinical thinking is the ability of testing personnel to systematically infer the types of pathogens, drug resistance characteristics, and infection mechanisms based on patient history, symptoms, and laboratory data [10]. For example, when faced with a positive blood culture result, it is necessary to consider the patient's immune status (such as diabetes or immunosuppression) to distinguish between contaminant bacteria and pathogenic bacteria to avoid misdiagnosis. For patients with a high clinical suspicion of pneumonia but negative sputum smears, the detection range should be expanded to include atypical pathogens (such as mycoplasma or viruses). Furthermore, clinical thinking requires testing personnel to actively participate in multidisciplinary consultations, integrating drug sensitivity results with patients' liver and kidney function and allergy history to develop individualized treatment plans. The lack of clinical thinking can easily lead to a disconnect between testing and diagnosis and treatment. Therefore, cultivating the clinical thinking of testing personnel is a critical path to enhancing the value of microbiology testing.

Traditional microbiology laboratory teaching often falls into the stereotype of being "technically operation-oriented." Although trainees can master basic operations such as Gram staining, bacterial identification, and drug sensitivity testing, they find it difficult to understand how test results affect clinical decision-making [11]. The application of the CBL-based case-sharing teaching method in clinical microbiology laboratory resident training not only meets the practical needs of infectious disease diagnosis and treatment but also reconstructs the collaborative logic between laboratory testing and clinical practice through structured cases. The teaching implementation results of this study show that this innovative model effectively breaks through the knowledge fragmentation of traditional teaching, significantly improving trainees' core competencies in clinical interpretation of microbiology test results, decision-making in antimicrobial drug selection, and multidisciplinary collaborative diagnosis and treatment. Research indicates that CBL teaching successfully achieves the logical connection between laboratory technology and clinical decision-making by constructing a dual-track parallel thinking framework of "laboratory-clinic," providing a reproducible practical paradigm for cultivating new medical laboratory talents.

However, there are still limitations in the current application of CBL in microbiology laboratory resident training. On the one hand, some teaching units' understanding of CBL remains at the level of "case presentation," lacking systematic teaching design, such as vague case selection criteria, insufficient problem setting progression, and inadequate teacher guidance. On the other hand, the rapid development of microbiology laboratory technology and the popularization of new technologies such as automated microbiology assembly lines and molecular diagnostic platforms have placed higher demands on teaching content. However, the existing CBL case library is lagging in updates, making it difficult to match the actual clinical needs. Furthermore, the cultivation of scientific research and innovation abilities of resident trainees has not been deeply integrated with CBL. How to guide trainees to conduct literature searches, data mining, and research topic selection through case analysis remains an urgent topic to explore.

The cultivation of microbiology laboratory talents is the cornerstone of discipline development [12–14]. High-quality talents not only need to master traditional detection techniques but also should possess corresponding clinical diagnostic thinking [15]. Research has confirmed that CBL can promote the transformation of microbiology laboratory talents from "data producers" to "clinical decision-making participants" through the reconstruction of dual-track thinking of "laboratory-clinic," providing a teaching reform paradigm to address the training needs of talents for drug-resistant bacteria prevention and precision diagnosis and treatment.

Disclosure statement

The author declares no conflict of interest.

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