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Innovations in Neurology Education: A Case-Based Learning Approach

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ABSTRACT
The purpose of this study is to investigate the application of Case-Based Learning (CBL) in neurology education and to design an effective framework for its implementation. This study systematically examines five key dimensions of CBL application: case design and selection, learning objectives and outcomes, student engagement and group dynamics, instructor facilitation and guidance, and assessment and evaluation. Through practical exploration, the study demonstrates how each dimension contributes to enhancing critical thinking, diagnostic reasoning, and problem-solving skills among medical students. However, the teaching reflection identified three main areas for improvement. First, the complexity of cases did not always match students' learning levels, leading to challenges in understanding or lack of depth. Second, group dynamics were sometimes uneven, with some students dominating while others remained passive. Third, assessment methods did not adequately capture essential communication and teamwork skills, which are crucial in clinical practice. This study provides valuable insights into optimizing CBL in neurology education, offering a structured approach to bridge theoretical knowledge and practical skills.

KEYWORDS
Case-based learning; neurology education; teaching application; teaching reflection; educational innovation

1 Introduction

Neurology is a complex medical specialty that focuses on the diagnosis and management of disorders affecting the nervous system (Moeller & Salas, 2023). Given the intricate nature of neurological conditions, which often present with diverse and overlapping symptoms, traditional didactic teaching methods that rely heavily on lectures and rote memorization are insufficient for developing students ' clinical reasoning and problem-solving skills (van der Meulen & Wijnenga, 2024). To bridge the gap between theoretical knowledge and clinical practice, there is a growing need for more interactive, student-centered teaching approaches (Rigby et al., 2012). Case-Based Learning (CBL) has emerged as an effective pedagogical method in medical education, characterized by the use of real or simulated patient cases as the foundation for instruction. CBL encourages active learning, critical thinking, and collaborative problem-solving, allowing students to analyze patient histories, interpret examination findings, and apply theoretical knowledge to diagnose and manage neurological conditions. In this context, exploring the application of Case-Based Learning in neurology education is essential to enhance students' diagnostic accuracy and clinical competence, making it a critical focus of this study.

2 Literature review

CBL originated as an educational approach within medical training, evolving from Problem-Based Learning (PBL) as a more structured method of teaching (Rigby et al., 2012). Unlike traditional didactic methods that focus on passive knowledge transfer, CBL emphasizes active learning through the analysis of real or simulated clinical cases (Sunde et al., 2018). In CBL, students are presented with patient scenarios that they must analyze, discuss, and solve under the guidance of an instructor. This method encourages students to integrate theoretical knowledge with practical skills, develop critical thinking, and enhance clinical reasoning. By simulating real-world scenarios, CBL helps bridge the gap between classroom learning and clinical practice, making it an essential tool in medical education.

CBL has been widely applied in various aspects of medical education, including improving diagnostic skills, enhancing clinical decision-making, fostering teamwork through group discussions, promoting self-directed learning, and integrating basic science with clinical practice (Tolchin et al., 2015). These applications allow students to engage with complex patient scenarios, explore differential diagnoses, discuss management plans, and receive instructor feedback (Berkowitz & Chang, 2024). Despite its broad application, the use of CBL in neurology education has received relatively less attention. Given the complexity of neurological disorders, which require precise diagnostic skills and strong clinical reasoning, there is a pressing need to explore how CBL can be effectively implemented in neurology training to enhance students' learning outcomes.

This study is significant because it focuses on the application of CBL in neurology education, a field characterized by

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diagnostic challenges and complex patient presentations. By exploring how CBL can be effectively used in neurology teaching, this study aims to enhance students' clinical reasoning, diagnostic accuracy, and problem-solving abilities. It also seeks to provide educators with insights into the design and implementation of CBL in neurology, including the selection of appropriate cases, effective instructor guidance, and strategies for maximizing student engagement. Ultimately, this research contributes to improving the quality of neurology education and better preparing medical students for clinical practice.

3 Application for Case-Based Learning in Classroom Teaching

3.1 Case Design and Selection

Effective CBL begins with the careful design and selection of cases, which are the cornerstone of the learning process (Li et al., 2024). Cases should be authentic, reflecting real-world clinical scenarios that students are likely to encounter in practice. In neurology, this means incorporating a wide range of cases covering conditions such as stroke, epilepsy, migraine, multiple sclerosis, and myasthenia gravis. Each case should include a complete patient profile, with detailed medical history, clinical findings, diagnostic test results, and potential management options. These cases must not only be accurate and realistic but also be carefully crafted to stimulate critical thinking and clinical reasoning. By providing well-documented cases, educators can ensure that students are exposed to the complexities of neurological diagnosis and treatment. The cases should also present varying levels of difficulty, ranging from straightforward diagnoses to complex scenarios involving overlapping symptoms, multiple diagnoses, and comorbid conditions. This variety helps maintain student interest while gradually building their diagnostic skills.

The complexity of cases should match the students' level of training to ensure an effective learning experience (Williams et al., 2012). For beginners, cases may focus on basic symptom recognition, allowing them to build confidence in identifying common neurological signs, such as headache patterns in migraine or motor weakness in stroke. As students progress, cases should become more complex, introducing multiple symptoms that require differential diagnosis. Advanced students can be challenged with cases involving complex diagnostic puzzles, comorbidities, and ethical dilemmas, such as whether to prioritize aggressive treatment for elderly patients with multiple health issues. Regularly updating and diversifying the case library ensures that students encounter a wide spectrum of neurological conditions, from common disorders to rare syndromes. Additionally, incorporating emerging conditions, such as autoimmune encephalitis, keeps the content current and relevant. Such a dynamic approach not only maintains student interest but also strengthens their diagnostic and clinical reasoning skills, providing a solid foundation for clinical practice.

3.2 Learning Objectives and Outcomes

Clear learning objectives are essential for the successful implementation of CBL, providing students with a well-defined focus for their learning activities (Alrawdhan et al., 2025). In neurology education, these objectives should encompass core competencies, such as recognizing and describing key symptoms of neurological disorders, applying theoretical knowledge to establish differential diagnoses, interpreting diagnostic test results, and developing effective management plans. For instance, in a case of stroke, students should be able to identify the signs of ischemic and hemorrhagic stroke, differentiate between transient ischemic attacks and full-blown strokes, and understand the importance of rapid intervention. Such objectives ensure that students approach each case with a clear understanding of what they are expected to achieve. These objectives should be communicated to students at the beginning of each CBL session, allowing them to focus their attention on critical aspects of the case. This structured approach not only enhances learning efficiency but also encourages active participation, critical thinking, and the application of theoretical knowledge to clinical scenarios.

Learning outcomes should be measurable and directly aligned with the defined objectives, providing a clear standard for evaluating student performance (Elgheit & Nashat, 2025). For instance, after completing a CBL session on stroke, students should be able to accurately classify different types of stroke, identify key risk factors such as hypertension or atrial fibrillation, interpret imaging findings (such as CT or MRI scans), and propose an evidence-based acute management plan, including thrombolysis for eligible patients. These outcomes provide a concrete basis for assessing student competence, ensuring that the learning experience is both meaningful and goal-oriented. Instructors can use formative assessments, such as quizzes, reflective questions, or case presentations, to monitor student understanding and provide immediate feedback. Summative assessments, such as case reports or objective structured clinical examinations (OSCEs), can be used to evaluate overall performance. By setting clear objectives and aligning them with measurable outcomes, CBL ensures that students not only acquire theoretical knowledge but also develop practical clinical skills essential for neurology practice.

3.3 Student Engagement and Group Dynamics

Student engagement is a fundamental aspect of successful CBL, best achieved through structured small group discussions (Major et al., 2021). These groups create an environment where students actively participate, share perspectives, and collaborate to solve complex clinical problems. In neurology education, where accurate diagnosis and critical thinking are essential, group discussions allow students to explore different viewpoints, debate differential diagnoses, and develop problem-solving strategies. For instance, in a case of sudden-onset weakness, students may discuss whether the cause is a stroke, a seizure, or a transient ischemic attack, each providing their reasoning. This interactive approach transforms passive learners into active problem-solvers, encouraging them to think critically and apply their theoretical knowledge to real-world scenarios. Group discussions also help students gain confidence in expressing their thoughts, listening to others, and defending their clinical reasoning. Such active participation not only enhances understanding but also improves retention of knowledge, making learning more meaningful and enjoyable.

To optimize group dynamics, instructors should ensure that each group is diverse, including students with varying levels of knowledge, skills, and experiences (Mowchun & Davila, 2022). This diversity promotes peer learning, as students can learn from each other's strengths and perspectives. Assigning specific roles within each group, such as a case presenter, discussion leader, and recorder, ensures balanced participation and accountability. The case presenter introduces the case and summarizes patient information, the discussion leader guides the conversation, and the recorder takes notes on key points and conclusions. These roles can be rotated in subsequent sessions, allowing each student to develop a range of skills, from leadership and communication to analytical thinking. Establishing clear guidelines for respectful communication and active listening is crucial to prevent dominance by any single student, ensuring that all voices are heard. Encouraging open dialogue and mutual respect helps create a supportive learning environment, where students feel comfortable expressing their ideas, questioning assumptions, and learning from their mistakes.

3.4 Instructor Facilitation and Guidance

Instructors play a pivotal role in the success of CBL, acting as facilitators rather than traditional lecturers (Hammond et al., 2023). Their primary responsibility is to guide discussions, stimulate critical thinking, and ensure that students remain focused on the learning objectives. In neurology CBL sessions, instructors can enhance learning by asking probing questions, such as "What other conditions could explain this patient's symptoms?" or "What additional tests would you order, and why?" These questions encourage students to think beyond surface-level information and explore differential diagnoses. Instructors can also challenge students to justify their clinical reasoning, prompting them to articulate why they believe one diagnosis is more likely than another. Such guided inquiry helps students develop a systematic approach to clinical reasoning, which is essential in neurology, where accurate diagnosis depends on recognizing subtle differences in symptoms. By maintaining a balance between guiding the discussion and allowing students to explore ideas, instructors can help students become more confident and independent thinkers.

Effective facilitation requires a delicate balance. Instructors must avoid dominating the discussion or providing immediate answers, as this can discourage independent thinking and hinder active learning (Sunde et al., 2018). Instead, they should create an open, supportive environment where students feel comfortable expressing their thoughts, making mistakes, and learning from them. For instance, if students are struggling with a differential diagnosis, rather than providing the correct answer, the instructor might ask, "What symptoms are most concerning here?" or "Could this be explained by another condition?" Such questions guide students toward the correct answer without directly giving it away. When misconceptions arise, instructors should provide clear explanations, linking theoretical knowledge to clinical practice. Regular feedback is also essential, helping students recognize their strengths and identify areas for improvement. Instructors can highlight strong clinical reasoning, correct misunderstandings, and suggest strategies for better problem-solving. Skilled facilitation transforms CBL sessions into dynamic, interactive learning experiences, where students actively build their diagnostic and decision-making skills.

3.5 Assessment and Evaluation

Assessment is an integral part of CBL, providing a means to measure student performance and ensure that learning objectives are achieved (Berkowitz & Chang, 2024). Formative assessments are used during the learning process to monitor student understanding and provide immediate feedback, allowing students to identify their strengths and areas for improvement. These assessments can take various forms, including short quizzes to test basic knowledge, reflective questions that encourage critical thinking, or brief case reports where students summarize their diagnostic reasoning and management plans. For example, in a neurology CBL session on stroke, students may be asked to list key diagnostic criteria for stroke, identify common risk factors such as hypertension or atrial fibrillation, and outline an initial management plan that includes thrombolysis for eligible patients. Formative assessments also allow instructors to gauge

student progress in real-time, identify misconceptions, and provide targeted feedback. This continuous feedback loop helps students build confidence in their diagnostic skills, refine their clinical reasoning, and become more effective problem-solvers.

In addition to formative assessments, summative assessments are used to evaluate students' overall performance and mastery of the material (Tolchin et al., 2015). These assessments provide a comprehensive evaluation of student learning at the end of a CBL module or course. Summative assessments can include comprehensive case reports, where students demonstrate their ability to synthesize patient information, develop differential diagnoses, and propose evidence-based management plans. Group presentations can assess students' teamwork, communication, and critical thinking skills, as they present their analysis of complex neurological cases. Objective Structured Clinical Examinations (OSCEs) are another effective summative assessment tool, allowing students to demonstrate their ability to assess and manage clinical cases in a simulated environment. In neurology, OSCEs may include scenarios such as performing a neurological examination, interpreting CT or MRI results, and making urgent management decisions for conditions like status epilepticus. Combining formative and summative assessments provides a complete view of student learning, ensuring that CBL effectively enhances students' diagnostic, clinical reasoning, and decision-making skills.

4 Reflection

4.1 Teaching Design

The teaching design of CBL was carefully crafted to ensure an engaging and educational experience. Cases were selected to represent a wide range of neurological conditions, including common disorders like stroke and epilepsy, as well as complex conditions such as multiple sclerosis and myasthenia gravis. Each case included a complete patient history, clinical findings, diagnostic test results, and management options, providing a comprehensive view of real-world scenarios. The learning objectives were clearly defined, emphasizing core competencies in neurology, such as diagnostic reasoning, differential diagnosis, and evidence-based management. This structured approach enabled students to develop critical thinking skills, apply theoretical knowledge to practical situations, and practice clinical decision-making. The variety of cases ensured that students were exposed to different aspects of neurology, promoting a deeper understanding of the subject. This well-designed framework allowed students to gradually progress from basic symptom recognition to complex diagnostic analysis, effectively bridging the gap between classroom learning and clinical practice.

Despite careful planning, there were limitations in the teaching design of CBL. Some cases were either too simple or overly complex for the students' level of training, leading to frustration or disengagement. Beginners struggled with advanced cases, while experienced students found some basic cases unchallenging. Additionally, the diversity of cases, though broad, may not have covered rare but clinically significant neurological conditions, limiting students' exposure to less common disorders. Learning objectives, while clear, were sometimes too general, making it difficult to measure student achievement effectively. For instance, objectives like "improving diagnostic skills" were too vague without specifying measurable outcomes. Moreover, the absence of alternative scenarios for each case restricted students ' ability to explore different diagnostic pathways, reducing the opportunity for critical thinking. Finally, the lack of pre-session materials meant that some students were unprepared for case discussions, affecting the depth of analysis.

4.2 Teaching Implementation

The implementation of CBL was successful in promoting active learning and student engagement. Students were organized into small groups, where they actively discussed cases, shared perspectives, and collaboratively solved clinical problems. In neurology, where diagnostic reasoning is crucial, this interactive approach allowed students to explore different viewpoints, debate differential diagnoses, and develop problem-solving skills. The instructor effectively facilitated these discussions, using probing questions to guide students without providing direct answers. For instance, when students struggled with a case, the instructor would ask, "What other conditions could explain these symptoms?" or "What tests would you prioritize?" Such questions encouraged students to think critically. Roles were assigned within each group, such as case presenter, discussion leader, and recorder, ensuring balanced participation. Regular feedback was provided, allowing students to reflect on their performance and improve.

However, several challenges were encountered during implementation. Group dynamics were not always balanced; some students dominated discussions, while others remained passive, missing out on learning opportunities. In some groups, discussions occasionally went off-topic, making it difficult to maintain focus on case objectives. Although the instructor generally facilitated well, there were instances where guidance became too directive, limiting students' ability to explore their ideas independently. Time management was another issue, as some groups required more time to complete discussions, leading to rushed conclusions. Technical issues with accessing online case materials also disrupted learning in a few sessions, highlighting the need for a more reliable digital platform. Finally, not all students were

comfortable with the group format, with some preferring individual case analysis, suggesting that a mix of group and individual activities may be more effective.

4.3 Teaching Effectiveness

The effectiveness of CBL was reflected in the noticeable improvement in students' diagnostic reasoning, clinical problem-solving, and teamwork skills. Formative assessments, such as quizzes, reflective questions, and brief case reports, demonstrated that most students developed a strong understanding of neurological conditions. Summative assessments, including comprehensive case reports and group presentations, showed that students were able to accurately analyze patient cases, develop differential diagnoses, and propose evidence-based management plans. Students also reported high levels of satisfaction with the CBL approach, appreciating the opportunity to apply theoretical knowledge in a practical, interactive setting. Many students expressed that the group discussions enhanced their confidence in clinical decision-making, and the immediate feedback from instructors helped them recognize and correct errors in their reasoning.

Despite these successes, there were also areas for improvement in teaching effectiveness. Some students struggled with clinical reasoning, especially when faced with complex or ambiguous cases, indicating a need for more structured guidance. The assessment methods, while effective in measuring knowledge, may not have fully captured students' communication and teamwork skills, which are critical in clinical practice. For instance, students who were less confident in expressing their opinions tended to participate less actively in group discussions, missing out on valuable learning experiences. Although feedback was provided, it was not always specific enough to help students understand their mistakes or how to improve. Additionally, the rapid pace of some CBL sessions left little time for in-depth analysis, and students who required more time to process information felt overwhelmed. Finally, while most students found CBL engaging, a few struggled to adapt to the active learning format, preferring traditional lectures.

5 Conclusion

This study explored the application of CBL in neurology education, focusing on five key dimensions: case design and selection, learning objectives and outcomes, student engagement and group dynamics, instructor facilitation and guidance, and assessment and evaluation. These dimensions provided a comprehensive framework for implementing CBL effectively, ensuring that students develop critical thinking, diagnostic reasoning, and problem-solving skills essential for clinical practice. However, the reflection revealed three main areas for improvement. First, the complexity of cases was not always appropriately matched to students' levels, resulting in frustration for some and lack of challenge for others. Second, group dynamics were inconsistent, with some students dominating discussions while others remained passive. Finally, the assessment methods, though generally effective, did not always capture communication and teamwork skills, which are crucial in clinical practice. Addressing these issues can further enhance the effectiveness of CBL, ensuring that it remains an engaging, student-centered approach that effectively bridges the gap between theoretical knowledge and practical skills in neurology.

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