

Construction and Implementation of a Competency Based Neurosurgical Case Repository Integrated with the PBL Teaching Model



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Abstract: Medical students in institutional education must undergo clinical practice to develop into physicians with competency-based capabilities. Neurosurgical diseases are characterized by high diagnostic and therapeutic complexity, rapid clinical progression, and substantial procedural risks, thereby requiring strong competencies in clinical decision-making and team collaboration. However, neurosurgery is often not included in undergraduate clinical internship rotations, and the rotation period during standardized residency training is typically short, resulting in limited opportunities for clinical practice. The construction and implementation of a competency-based neurosurgical case repository can effectively compensate for these deficiencies in clinical exposure. When integrated with the PBL teaching model, the case repository enables learners to engage with authentic clinical scenarios, promoting active, problem-driven inquiry and learning. This approach facilitates the systematic acquisition of knowledge related to the diagnosis and management of common and frequently encountered neurosurgical conditions, enhances communication and teamwork skills, and fosters the development of lifelong learning competencies. In addition, it contributes to improving instructors' teaching capabilities and their ability to employ modern educational technologies in instructional practice.

Keywords: competency-based, neurosurgery, case repository, PBL teaching model

1. Introduction

We are currently in an era of competency-based, medicine–education integrated training. Medical students in institutional education must undergo clinical practice in order to develop into physicians with competency-based capabilities. Neurosurgical diseases are characterized by high diagnostic and therapeutic complexity, rapid clinical progression, and substantial procedural risks, thereby requiring strong core competencies in clinical decision-making and team collaboration. However, neurosurgery is typically not included in undergraduate internship rotations, and during standardized surgical residency training, the neurosurgery rotation is limited to approximately two months, resulting in insufficient clinical exposure.

Case-based teaching serves as an essential supplement to rotation-based learning, compensating for the limitations of clinical teaching caused by limited case availability and constraints within the

healthcare environment, and aligning with the requirements of competency-based talent cultivation (Li & Dong, 2024). It also accommodates the relatively compressed training cycle of professional degree postgraduate education in China (Dai et al., 2023). However, the field of neurosurgery currently lacks a well-structured, hierarchically organized, and comprehensive teaching case system (Jiang et al., 2025), particularly in terms of multimodal imaging, complete surgical documentation, and team-based training components.

Since 2023, this institution has progressively developed a multimodal competency-based neurosurgical case repository and implemented teaching through integration with the PBL teaching model. This approach enables the integration of horizontal knowledge and vertical clinical competencies (Zhu et al., 2025), effectively enhancing core competencies such as clinical reasoning, teamwork, and self-directed learning.

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2. Construction of a Multimodal Neurosurgical Case Repository

As an important instructional approach, case-based teaching has been widely applied across various disciplines. Guided by competency-based principles, representative cases of moderate difficulty are selected to cultivate students' comprehensive clinical reasoning and innovative abilities, and to facilitate the transformation of theoretical knowledge into clinical practice (Li et al., 2021). The design of teaching cases should emphasize effective linkage of knowledge points, support the construction of systematic knowledge frameworks, stimulate inquiry-based learning, and enhance students' autonomous learning capabilities (Peng & Xiao, 2023). Educators must thoroughly understand the connotations and requirements of competency-based practice to ensure that selected cases align with competency expectations (Liu & Liu, 2024).

With advancements in information storage technologies and artificial intelligence, the documentation and presentation of medical information should extend beyond traditional text and images to incorporate multimodal data integration, thereby enabling a more comprehensive and authentic reconstruction of clinical cases. In addition to disease-specific information, medical history collection should include patients' psychological and social conditions. Imaging data should be recorded in both DICOM and standard image formats, with DICOM data supporting image reconstruction. Interventional procedures and surgical processes should be documented באמצעות video recordings, while pathological findings should be preserved as images. Through standardized multimodal documentation—including text, images, and audiovisual data—cases can be more faithfully represented, reflecting the holistic bio-psycho-social medical model and providing high-quality clinical data for both teaching and research.

2.1 Selection of case types for inclusion

In accordance with the neurosurgical internship syllabus and the requirements of standardized residency training, common and representative cases should be systematically selected, including: cerebral contusion and laceration, subdural hematoma, epidural hematoma, glioma, meningioma, pituitary adenoma, brain metastases, vestibular schwannoma, trigeminal neuralgia, hemifacial spasm, intracranial aneurysm, cerebral arteriovenous malformation, hypertensive intracerebral hemorrhage, hydrocephalus, and intraspinal tumors.

Selected cases should be authentic and representative, with a clear instructional focus, complete diagnostic and therapeutic processes, and key surgical video documentation. The content should avoid academic controversies and adhere strictly to ethical standards.

2.2 Standardized data entry format

The standardized structure should include: basic information, medical history, physical examination, auxiliary examinations, diagnosis, differential diagnosis, surgical and other treatments. Medical history should be recorded in document format, and physical examination findings should be entered systematically. Auxiliary examinations should include laboratory tests, microbiological analyses, imaging studies, neurophysiological examinations, pathology, and digital subtraction angiography (DSA). Imaging data must include images, videos, and DICOM files.

Diagnosis should include both primary and secondary diagnoses, while differential diagnosis should include at least two alternatives. Surgical treatment should encompass perioperative management, as well as microscopic and endoscopic surgical videos, and endovascular intervention recordings. Other treatments should include chemotherapy and radiotherapy regimens, along with their therapeutic outcomes and adverse effects.

2.3 Role allocation and regular review

The responsible resident physicians should undertake case collection, while senior experts provide guidance and review both the format and content of cases. Regular meetings should be convened to evaluate newly collected cases. Guided by competency-based principles, particular attention should be paid to the alignment of cases with the development of clinical reasoning, decision-making, teamwork, and innovation capabilities.

2.4 Periodic evaluation, maintenance, and updating

A combined approach of formative and summative evaluation should be adopted. During teaching sessions, case-based teaching evaluation forms should be completed, while post-session feedback and suggestions should be collected to identify strengths and weaknesses and continuously improve the competency-based neurosurgical case repository (Guo et al., 2025). After each teaching cycle, cases should be revised through evaluation and group discussion. Furthermore, with the release of updated neurosurgical guidelines, relevant cases should be promptly updated and supplemented to

ensure sustained teaching effectiveness.

3. Integration of the Neurosurgical Case Repository with the PBL Teaching Model

In neurosurgical clinical teaching, conventional approaches primarily include teaching ward rounds, case discussions, mini-lectures, and skills training. Although these methods meet basic instructional requirements, they are relatively rigid in format and often fail to sufficiently engage learners, thereby limiting the development of competency-based capabilities. Since 2023, the competency-based neurosurgical case repository integrated with the PBL teaching model has been implemented among undergraduate students at the First Clinical Medical College of Guangdong Pharmaceutical University and surgical residents undergoing standardized training at the First Affiliated Hospital, yielding favorable outcomes. The implementation process is as follows:

3.1 Pre-class preparation

Three days prior to case-based sessions, medical history and physical examination data are distributed, along with preliminary imaging findings. Students are required to familiarize themselves with the case, summarize key clinical features, review relevant theoretical knowledge, consult the literature, and formulate major clinical questions.

3.2 Class organization

Students work in groups to summarize case characteristics, establish preliminary diagnoses and differential diagnoses, and propose further diagnostic investigations. Subsequently, additional examination results are provided by the instructor, and through guided discussion, a definitive diagnosis and treatment plan are established.

Role-playing and scenario-based simulations are subsequently conducted, including simulated physician-patient communication and shared decision-making. For surgical residents undergoing standardized training, operative videos are additionally presented to facilitate critical appraisal of key technical aspects. Pathological findings are then introduced to establish a definitive pathological diagnosis and to formulate individualized, comprehensive treatment strategies. Finally, the instructor synthesizes students' classroom performance and concept maps, and outlines subsequent learning objectives.

3.3 Post-class Self-directed learning (SDL)

Based on the key clinical questions generated during class discussions, students engage in literature

review and collaborative group work to produce PBL outcomes, which are presented and evaluated in subsequent PBL sessions. Post-class assignments also adopt a staged case-release format to simulate the clinical diagnostic and therapeutic process, thereby reinforcing clinical reasoning through iterative practice.

3.4 Evaluation

Following case-based teaching sessions, instructors evaluate both classroom performance and PBL outcomes. Questionnaire-based surveys are conducted for reflection and feedback, enabling analysis of strengths and limitations, and assessment of competencies such as clinical reasoning, teamwork, and learning ability. This process helps to define future learning directions and improvement strategies (Li, 2025). Student feedback is further utilized to optimize the competency-based neurosurgical case repository and refine teaching approaches.

4. Educational Value of the Integrated Case Repository and PBL Teaching Model in Clinical Education

4.1 Accelerating the development of clinical reasoning

The application of theoretical knowledge to clinical practice typically requires prolonged experiential accumulation. Case-based teaching, grounded in authentic clinical cases, guides students through case summarization, diagnostic reasoning, and cognitive rehearsal, effectively simulating clinical practice. It supplements cases not encountered during internships and rotations, promotes integration of theory and practice, accelerates the development of clinical reasoning, and facilitates systematic mastery of common and frequently encountered neurosurgical conditions (Li, 2025).

4.2 Fostering active learning and critical thinking

The integration of the competency-based neurosurgical case repository with the PBL teaching model emphasizes learning attitudes, processes, and outcomes. By simulating real clinical scenarios, students are encouraged to engage in active thinking and decision-making within specific contexts. Through staged case presentation, the clinical workflow is replicated, enabling students to identify clinical problems, formulate hypotheses, conduct diagnostic reasoning, consult evidence-based literature, and independently explore solutions. Differential diagnoses are proposed and subsequently

validated through case progression, deepening understanding of diagnostic processes. Treatment plans are developed based on evidence-based medicine and critically evaluated against actual case outcomes, thereby enhancing analytical and reflective capabilities. This problem-oriented approach significantly strengthens learner autonomy and motivation.

4.3 Enhancing communication, collaboration, and innovation

Unlike traditional one-way knowledge transmission, this approach emphasizes group discussion and collaborative problem-solving. Students progressively develop teamwork skills essential for real-world clinical environments, including multidisciplinary collaboration. Case-based learning encourages flexible and diverse problem-solving strategies, fostering exploration of more efficient clinical solutions and validation of their effectiveness. It also helps students recognize the inherent risks of innovation and develop resilience by learning from failure, thereby strengthening their overall innovative competence (Wang, Zhao, et al., 2025).

4.4 Improving teaching competencies of instructors

The implementation of this integrated teaching model requires instructors to update educational philosophies and transform teaching methods. Teaching activities extend beyond the classroom, and instructional approaches are no longer limited to didactic lectures. Instead, instructors facilitate pre-class preparation, guide in-class discussions, and adjust teaching strategies based on post-class feedback, with the goal of enhancing students' competency-based capabilities, including clinical reasoning, self-directed learning, and communication.

Moreover, the construction of the competency-based neurosurgical case repository compels instructors to continuously update their professional knowledge, deepen their understanding of teaching content, and compensate for limitations in clinical experience, thereby significantly improving teaching effectiveness (Li & Dong, 2024).

4.5 Promoting the application of modern educational technologies

Case repository-based teaching fully leverages modern educational technologies, including platforms such as Rain Classroom, Zhihuishu, and Chaoxing, to support smart classroom reforms and enable precision teaching. This facilitates the

adoption of contemporary educational design principles, teaching techniques, and best practices, while allowing instructors to experience high-quality case-based teaching environments and workflows (Xia et al., 2025). Training and application of digital and intelligent teaching methods contribute to continuous improvement in teaching quality and promote instructors' professional development.

Despite these advantages, the integration of the competency-based neurosurgical case repository with the PBL teaching model requires substantial teaching resources, including personnel and physical space, and necessitates continuous updating of teaching concepts and ongoing faculty training. Challenges remain, including unclear learning objectives, variability in student acceptance, and limitations in addressing individualized learning needs (Wang, Jiang, et al., 2025).

Furthermore, the development of medical teaching case repositories is still in a relatively early stage, with slow updating processes and insufficient funding and personnel dedicated to construction and maintenance, which significantly constrain the broader implementation of this approach. The development of a competency-based neurosurgical case repository is inherently a continuous and dynamic process, requiring sustained collaboration among instructors and expert teams for ongoing maintenance, updating, and refinement.

With the rapid advancement and increasing adoption of technologies represented by artificial intelligence in medical education, the construction of comprehensive and scientifically robust case repositories is expected to accelerate. This will improve efficiency, reduce costs, and enable intelligent updating mechanisms to meet evolving educational demands, ultimately providing students with more systematic and realistic clinical training and facilitating their transition into physicians with competency-based capabilities.

Conflict of Interest

The authors declare that they have no conflicts of interest in this work.

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