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Application Research of Virtual Cases Based on Generative AI (such as Large Language Models) in Clinical Reasoning Teaching for General Practitioner Training Programs

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Abstract: This article elucidates that generative AI virtual cases offer advantages such as abundant resources, strong interactivity, and timely feedback. By implementing application approaches—including establishing virtual case repositories, conducting scenario simulations, developing evaluation systems, and training instructors—it can effectively enhance the clinical reasoning abilities of general practice residency trainees, thereby providing a novel model and methodology for general practice education.

Keywords: Generative AI; Virtual case; General practice residency program; Clinical reasoning instruction

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1. Introduction

By the end of 2022, OpenAI's release of the ChatGPT-3.5 model marked a breakthrough in generative AI technologies, particularly those powered by large language models, sparking an innovation wave in the education sector and unlocking new opportunities and limitless possibilities. General practice residency training is pivotal for cultivating qualified general practitioners, with clinical reasoning skills constituting their core competency. The quality of this training directly impacts the standard of medical services provided. However, traditional clinical reasoning instruction in general practice residency training suffers from limitations such as insufficient real-world case resources and monotonous teaching scenarios. In this context, generative artificial intelligence leverages its inherent advantages to provide innovative approaches and effective tools for clinical reasoning education in general practice residency training, facilitating the advancement of medical education toward greater intelligence and efficiency.

2. Advantages of virtual cases in clinical reasoning teaching during general practice residency training

2.1. The case resources are abundant and diverse, covering a wide range of diseases and clinical scenarios.

General practice encompasses a broad spectrum of diseases, yet practical teaching often lacks sufficient resources for typical, rare, or specialized cases, making it difficult for resident trainees to gain comprehensive exposure to various diseases. The virtual case resources are exceptionally rich and diverse. The constructed case repository encompasses not only common and frequently encountered diseases such as community-acquired pneumonia and acute appendicitis, but also rare conditions, multisystem complications, and critical emergencies—including tetralogy of Fallot, diabetes mellitus complicated by ketoacidosis with pulmonary infection [1]. It can simulate real-world clinical scenarios, comprehensively depicting the entire process from basic medical history collection to laboratory examinations, while also detailing disease progression and simulating dynamic changes such as the advancement of chronic conditions and the exacerbation of acute illnesses. Furthermore, the virtual case library supports personalized learning by enabling the customization of cases according to students' needs, thereby catering to diverse learning requirements, broadening their diagnostic and therapeutic perspectives, and enhancing their clinical decision-making and treatment plan implementation capabilities.

2.2. Achieve highly interactive learning by simulating real-world physician-patient communication workflows

In the clinical reasoning instruction during general practice residency training, virtual cases provide a highly interactive learning experience by accurately replicating real-world physician-patient communication workflows. By employing technologies such as speech recognition and affective computing, it is possible to capture in real-time students' questioning patterns, speech rate, pitch, as well as non-verbal behaviors like eye contact and gestures. Additionally, the system can simulate patients exhibiting various emotions, including anxiety, anger, and sadness, to provide dynamic feedback [2]. For instance, when students lack empathy, the virtual patient may provide vague responses or demonstrate distrust, prompting students to refine their communication techniques; if students successfully establish trust, the patient will gradually disclose critical information, facilitating deeper diagnostic and therapeutic progress. The multimodal interaction design encompasses core processes such as information collection, condition notification, and treatment decision-making. It also employs branched narrative algorithms to simulate disease progression, enabling students to experience the complexity and risks of clinical decision-making through dynamic adjustments to communication strategies. Through repeated training, students' diagnostic skills, empathy abilities, and communication efficiency have significantly improved, laying a solid foundation for real-world clinical practice.

2.3. Provide real-time intelligent feedback to accurately assist clinical reasoning training

Virtual cases offer the significant advantage of providing instant intelligent feedback, enabling precise support for clinical reasoning training. After students complete the stages of history-taking, physical examination, diagnosis, and treatment decision-making during virtual case simulations, the system promptly conducts intelligent analysis of each step based on the predefined medical knowledge base and clinical guidelines. If critical information is omitted during consultation, the system will immediately provide prompts and guidance for supplementation; if the diagnostic approach is deviated, the system will offer comparative cases and valid diagnostic criteria to assist students in understanding the error; if the treatment plan is inappropriate, the system will identify issues according to the latest guidelines and provide optimization recommendations [3–4]. This real-time feedback allows students to correct errors promptly during operations, preventing erroneous thinking patterns from becoming entrenched. Additionally, the system generates detailed evaluation reports based on students' performance, identifying their strengths and weaknesses in clinical reasoning. These reports serve as a basis for developing personalized learning improvement plans, effectively enhancing the clinical reasoning and diagnostic-therapeutic competencies of general practice residency trainees.

3. Application pathways of generative AI-based virtual cases in clinical reasoning teaching for general practice residency training

3.1. Establish a virtual case library for general practice medicine and integrate multimodal teaching resources

The establishment of a virtual case database for general practice medicine must be grounded in authentic clinical data, with patient privacy safeguarded through anonymization processing. Utilizing natural language processing technology, unstructured electronic medical records are transformed into structured data, from which key information is extracted to generate case metadata (**Figure 1**). Furthermore, multimodal teaching resources should be integrated. Static resources include high-definition medical images (e.g., X-rays, CT, MRI), pathological images, and anatomical atlases, all supporting zooming and annotation. Dynamic resources encompass surgical videos, operational animations, and virtual patient voice responses to enhance teaching interactivity. Utilizing 3D modeling technology, interactive models can be created; for instance, a virtual liver model demonstrates anatomical structures and supports "virtual sectioning" to observe internal blood vessels. Simultaneously, by integrating authoritative medical literature databases and real-time case data, a dynamic updating mechanism is established to regularly incorporate cases of new diseases and novel therapies, ensuring the case database remains aligned with clinical practice [5]. Taking the case of "acute heart failure complicating pregnancy" as an example, the database first presents symptom descriptions and auxiliary examination results, thereby constructing a comprehensive clinical information chain. Through the virtual consultation module, students interact with "patients", and the system generates real-time responses tailored to the clinical condition while displaying changes in physical signs. During the virtual physical examination session, students operate a virtual stethoscope, with the system providing real-time feedback on abnormal signs. Upon entering the MDT consultation module, students select a treatment plan. The system simulates patient outcomes and provides multidisciplinary expert decision-making rationale. Upon completion of treatment, the system generates a multidimensional evaluation report and delivers targeted learning resources, establishing a closed-loop teaching system encompassing "case study-decision-making training-feedback-driven improvement."

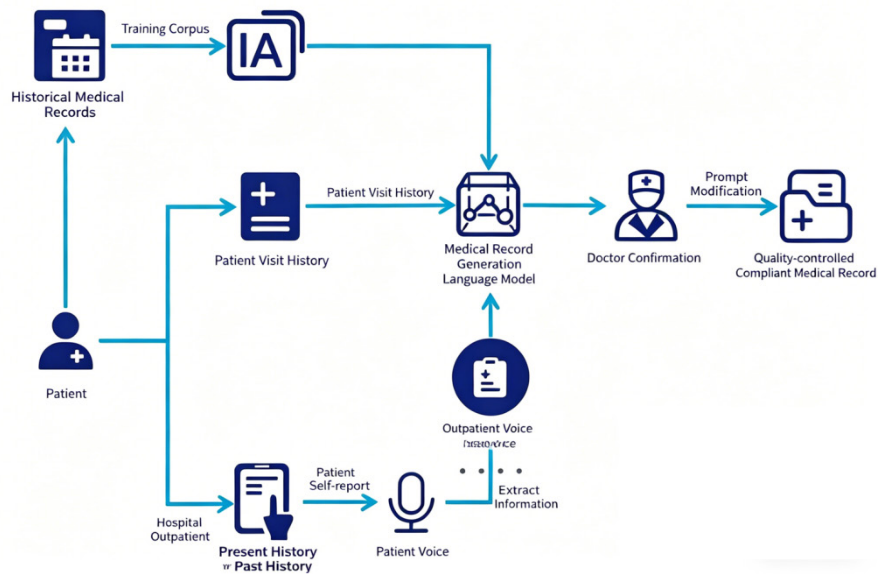

Figure 1. Digitalized medical diagnostic process based on an AI corpus

3.2. Conduct interactive case scenario simulations and implement tiered reasoning ability training

To conduct interactive case scenario simulations, it is essential to fully leverage the powerful advantages of generative AI in natural language processing and scenario generation, meticulously creating highly realistic and dynamically evolving virtual clinical scenarios. During the simulation process, the system strictly adheres to the general practice knowledge framework and clinical workflows to establish case scenarios with varying levels of difficulty and complexity. The simulation should commence with simple cases of common and frequently encountered diseases, such as community-acquired pneumonia, before progressively transitioning to complex cases involving multi-system involvement and more insidious clinical presentations, such as diabetes mellitus complicated by multiple chronic comorbidities accompanied by acute infection [6]. In the virtual environment, students assume the role of general practitioners and engage in real-time dialogue with virtual patients. By collecting information such as medical history, symptom characteristics, and lifestyle habits, the system utilizes generative AI to generate logical responses tailored to the patient's identity in real time. It simultaneously simulates non-verbal cues like facial expressions and tone of voice, significantly enhancing the authenticity of the interaction. Additionally, students must perform virtual physical examinations, during which the system provides corresponding clinical findings, such as pulmonary rales or heart murmurs, based on their actions, thereby assisting them in comprehensively gathering clinical data.

When implementing tiered reasoning skill training, it is essential to develop customized training programs tailored to students at different learning stages and with varying abilities. For undergraduate students, the focus is on training fundamental clinical reasoning skills. Through simple case simulations, they are guided to make preliminary diagnoses promptly based on typical symptoms and signs, integrating their acquired knowledge, and to propose basic treatment plans. The system provides timely prompts and guidance during student practice to assist them in organizing their diagnostic reasoning, such as suggesting, "The patient presents with fever and cough; which respiratory diseases should be considered?" [7]. As students' competencies progressively improve and they enter the intermediate training phase, the complexity and uncertainty of case scenarios are increased, with the inclusion of misleading information and atypical symptoms. This requires students to make differential diagnoses among numerous possibilities, thereby cultivating their critical thinking and comprehensive analytical skills. For example, when simulating cases involving abdominal pain, in addition to common gastrointestinal disorders, clues related to gynecological or urinary system diseases are incorporated, enabling students to comprehensively evaluate various etiologies. During the advanced training phase, high-difficulty and complex case simulations are conducted, simulating scenarios involving multiple coexisting diseases, critical conditions, and rapid disease progression. Students are required to make accurate judgments and decisions within a short timeframe, coordinate multidisciplinary resources for comprehensive treatment, and thereby enhance their clinical adaptability and teamwork skills.

3.3. Establish an intelligent feedback and evaluation system to generate personalized learning diagnostics

Establishing an intelligent feedback and evaluation system is crucial for enabling generative AI to fully leverage its potential in clinical reasoning instruction during general practice residency training. Leveraging the deep learning and data analysis capabilities of generative AI, the system can track each operational step of students in interactive case scenario simulations in real time, assessing aspects such as the comprehensiveness of the consultation, the accuracy of physical examinations, the rationality of diagnostic reasoning, and the appropriateness of treatment plans [8–9]. Upon completing case management, students receive immediate intelligent feedback from the system, which clearly identifies their strengths and areas for improvement. If critical information was omitted during the consultation process, the system specifies the missing details and their significance. For diagnostic errors, the system provides a detailed explanation of the error causes based on medical databases and relevant clinical guidelines, along with the correct diagnostic methods and key differentiation criteria. Furthermore, leveraging students' comprehensive behavioral data, including case handling accuracy, decision-making speed, and proficiency in applying knowledge points, the intelligent assessment system employs scientific algorithm models to generate comprehensive, objective, and personalized learning diagnostic reports. The report not only provides feedback on students' current clinical thinking abilities and proficiency levels, but also identifies their competency gaps, such as limited understanding of rare diseases and insufficient integrative thinking skills in complex scenarios. Based on these learning diagnostic findings, the report offers personalized learning improvement recommendations and provides targeted links to learning resources. It specifically recommends relevant literature and case studies to help students address knowledge gaps and enhance their clinical thinking capabilities.

3.4. Enhance teachers' AI teaching competency training to promote the integration of virtual and real-world teaching methods

The school should establish a tiered training system, designing specialized courses tailored to different teaching stages for teachers. For novice teachers, the training focuses on fundamental operations of AI tools. Through case-based workshops, participants learn how to utilize large language models to generate typical medical cases and simulate consultation scenarios, enabling them to master key skills such as using virtual case repositories and engaging in natural language interaction. For core faculty members, advanced training is provided on integrating generative AI with clinical reasoning instruction. Through thematic seminars and project-based practices, they are guided to design blended teaching frameworks incorporating virtual cases—such as combining real patient data with AI-generated cases to create comparative teaching scenarios, thereby fostering students' critical thinking skills [10]. Meanwhile, a closed-loop training mechanism integrating "theory + practice + feedback" has been established. In terms of theoretical instruction, medical education experts and AI technology engineers are jointly invited to deliver lectures, elucidating the technical principles of generative AI in case generation and disease simulation, thereby helping educators clarify the boundaries and advantages of AI-assisted teaching. During the practical training phase, instructors were organized to participate in a comprehensive simulation of the entire virtual case teaching process, covering case design, student operational guidance, and outcome evaluation, thereby accumulating hands-on experience. During the feedback phase, the effectiveness of the training is regularly assessed using multidimensional data such as teaching observations, student evaluations, and teacher self-assessments, allowing for adjustments to the training content based on identified weaknesses. If deficiencies are identified in teachers' review of the medical logic in AI-generated cases, an additional course on medical knowledge graph applications will be introduced to enhance their ability to ensure the scientific rigor of these cases.

4. Conclusions

Generative artificial intelligence has brought transformative changes to clinical reasoning instruction in general practice residency training. Leveraging its robust content generation and interaction capabilities, it addresses the limitations of traditional teaching methods, enabling students to gain a richer, more authentic, and personalized learning experience. With continuous technological advancements, the application prospects of AI in medical education have become even more promising. In the future, it is essential to conduct in-depth research on how to achieve deep integration between generative artificial intelligence and general practice residency training programs, leveraging its advantages to enhance teaching quality and elevate general medical education to new heights.

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Disclosure statement

The authors declare no conflict of interest.

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