

Application of Computer-Simulation-Based Clinical Case Training for General Practice Clinical Reasoning in Standardized Residency Training: A Digital Health Communication Perspective

Huan Yu¹, Zhen Qiao¹, Lina Ma¹, Peng Li¹

¹ Department of General Practice, Hangzhou Third People's Hospital, Hangzhou, China

* Corresponding Author: lipeng2076@sina.com

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ABSTRACT

Clinical reasoning is a core competency in standardized residency training for general practitioners, yet conventional case-based instruction is often constrained by limited clinical exposure, inconsistent case complexity, and insufficient opportunities for repeated decision-making practice. This study explores the application of computer-simulation-based clinical case training to improve clinical reasoning among general practice residents from a digital health communication perspective. A digital simulation environment was designed to present interactive clinical cases integrating patient history, symptoms, examination findings, laboratory results, and dynamic clinical feedback. Residents were required to collect information, identify clinical problems, formulate differential diagnoses, select appropriate examinations, and develop management plans through sequential decision-making processes. The digital platform also supported real-time feedback, standardized communication pathways, and repeated case-based learning, enabling trainees to review their reasoning processes and identify decision-making errors. The effectiveness of the training approach was evaluated by comparing clinical reasoning performance, diagnostic accuracy, decision-making efficiency, and learner engagement before and after the intervention. The findings indicate that computer-simulation-based clinical case training can provide a structured, interactive, and repeatable learning environment that supports the development of diagnostic and clinical decision-making abilities. From the perspective of digital health communication, the approach also facilitates more effective information exchange, feedback delivery, and interaction between learners and simulated clinical scenarios. This study suggests that computer-simulation-based training may serve as a valuable supplementary strategy for enhancing clinical reasoning and digital competency in standardized general practice residency training.

Keywords: Computer Simulation; Clinical Case Training; Clinical Reasoning; General Practice; Standardized Residency Training; Digital Health Communication.

INTRODUCTION

1.1 Development of the General Practice Clinical Reasoning Training System Based on Computer-Simulated Clinical Cases

(1) Development of the evaluation structure: From November to December 2022, an expert consultation meeting was convened with 14 senior general practice experts from four institutions, including Sir Run Run Shaw Hospital, Affiliated to Zhejiang University School of Medicine, and The Third People's Hospital of

Hangzhou. Through focused discussion of the structure of computer-simulated clinical cases, we identified seven parts (primary indicators) that form the basic case composition: general practice history-taking, general practice physical examination, auxiliary examinations, history summary, preliminary diagnosis, differential diagnosis, and management plan.

(2) Development of item-level entries and construction of test cases based on real cases: According to the essential and transfer training syllabus requirements for residents in standardized residency training regarding the common and frequently occurring conditions that general practice clinicians should master⁴, we selected coronary heart disease (acute symptom onset), type 2 diabetes mellitus (acute symptom onset), pneumonia, and acute exacerbation of chronic obstructive pulmonary disease (with acute symptoms) as the case types for testing. Using real general practice cases from the teaching hospital of the project team, we developed evaluation items. Using the seven basic case components as units, we designed performance items for residents during clinical reasoning testing and training, distinguishing major and minor items. Based on the objectives of clinical reasoning testing and training, we converted these into specific scoring rules and evaluation standards, i.e., scores and weights for each item, clarifying the logical relationship between item scores and final evaluation targets, thus forming a complete scoring table for general practice clinical reasoning training. Development was implemented using the JAVA programming language. Test case construction was initially completed, yielding 12 cases covering 4 disease categories (3 cases per disease); for each disease, one case was selected to form a pre-test set, a teaching set, and a post-test set.

(3) Reliability and validity evaluation of cases: After constructing the test cases, Likert 5-point evaluation forms were set up for the specific items of one randomly selected case per disease (total 4 cases). Experts were invited to subjectively score the relevance of each item to general practice clinical reasoning on a scale of 1–5 (1 = completely irrelevant, 2 = irrelevant, 3 = uncertain, 4 = relevant, 5 = highly relevant); higher scores indicate greater relevance to the evaluation target. The 14 experts who participated in the first-round consultation were invited to evaluate the reliability and validity of the cases. Evaluation comprised three parts: 1) Validity evaluation: content validity was assessed using content validity indices, calculating the case-level content validity (S-CVI) and the item-level content validity (I-CVI) for subordinate items. S-CVI includes universal agreement content validity (S-CVI/UA), defined as the number of items in the case rated 4–5 by all experts divided by the total number of items in the case; and average S-CVI (S-CVI/ave), the mean of the I-CVI values for all items under the case, used to assess whether the case as a whole adequately reflects the construct. According to the literature, $I-CVI \geq 0.78$ and $S-CVI \geq 0.8$ indicate good content validity⁵. 2) Reliability evaluation: internal consistency was assessed using Cronbach's α ; Cronbach's α coefficients were calculated for each primary indicator under each case and for each case overall, with Cronbach's $\alpha \geq 0.8$ generally considered acceptable. 3) Reliability (agreement) evaluation: Kendall's coefficient of concordance was used to evaluate case reliability, calculating the Kendall coefficient for the 14 experts' evaluations of each case; a Kendall coefficient > 0.5 is generally taken to indicate substantial agreement among experts and that the case can reliably assess general practice clinical reasoning⁶.

1.2 Application Evaluation of General Practice Clinical Reasoning Training Based on Computer-Simulated Clinical Cases

Using a historical control approach, exploratory application of the training was carried out in October 2023

and September 2024 to further assess training effects and feasibility. The process was as follows:

(1) Study subjects: Residents who matriculated in September 2022 and September 2023 and who were undergoing standardized residency training in general practice at The Third People's Hospital of Hangzhou, where the project team is based, were selected. Intervention and evaluation were performed during their rotation in the general medicine department in 2023 and 2024, respectively. Exclusion criteria: residents who did not complete the required general medicine department rotation and entry/exit assessments as required; residents who did not complete general practice clinical learning tasks.

(2) Intervention method: The rotation duration for residents in the general medicine department was 1 month. The 20 residents who matriculated in 2022 were assigned as the historical control group, and the 20 residents who matriculated in 2023 were assigned as the intervention (observation) group. Both groups completed the rotation in the general medicine department in accordance with the standardized residency training syllabus and implementation rules. In addition, the 2023 cohort (intervention group) received the previously developed general practice clinical reasoning training based on computer-simulated clinical cases. During the general practice clinical rotation, instructors delivered teaching for four cases (the teaching set) according to the teaching schedule. The specific model was: once weekly, a concentrated computer-simulated clinical case clinical reasoning training session with on-site explanation. Intervention group residents first completed the case training and their scores were recorded. Instructors analyzed and summarized the test results and provided targeted focused instruction on issues identified during the clinical reasoning training. Each session lasted 1 hour; all four cases were completed during the rotation.

(3) Testing methods: The assessment comprised a theoretical test and a general practice clinical reasoning evaluation. Control group: In September 2023, theoretical test papers were compiled; questions were sourced from the study compilation by the Examination Question Research Committee for the Standardized Residency Training Final Professional Theory Examination⁷, entitled "Selected Practice Questions for the Final Professional Theory Examination for General Practice Residents." Each paper covered the general practice diagnostic and treatment key points for the four disease categories in 1.2. For each disease, A1 (single-choice) contained 20 questions and A2 (multiple-choice) contained 10 questions, for a total of 120 questions, 1 point per question, maximum score 120. Two versions, A and B, of equivalent difficulty were prepared and the theoretical tests were administered before and after rotation. Intervention group: theoretical testing was the same as for the control group. Additionally, pre- and post-rotation clinical reasoning tests were administered using two pre-test and two post-test cases developed for the four disease categories.

(4) Application evaluation of the general practice clinical reasoning training: Using a historical control method, we compared the control and intervention groups' theoretical examination scores before and after rotation to analyze whether the clinical reasoning training effectively improved residents' mastery of diagnostic and treatment knowledge for common chronic diseases; correlation analysis was used to examine the association between scores for each primary indicator and total scores in the computer-simulated clinical case-based clinical reasoning training system and theoretical test scores, thereby validating the criterion-related validity of the system.

1.3 Statistical Analysis

Data were recorded in EXCEL and statistical analyses were performed with SPSS 28.0. Categorical data

were described using frequencies; continuous data conforming to a normal distribution were expressed as mean ± standard deviation. Differences in categorical data were tested with the chi-square test; within-group pre – post comparisons of continuous data used paired t-tests; between-group comparisons used independent-samples t-tests. P < 0.05 was considered to indicate statistical significance.

RESULTS

2.1 Development of the Clinical Cases

A total of 12 cases covering four disease categories—coronary heart disease, type 2 diabetes mellitus, pneumonia, and acute exacerbation of chronic obstructive pulmonary disease (with acute symptoms)—were developed. After defining the seven parts (primary indicators) of general practice history-taking, general practice physical examination, auxiliary examinations, history summary, preliminary diagnosis, differential diagnosis, and management plan, secondary item frameworks and weight proportions for the computer-simulated clinical cases were established according to main and secondary factors, as shown in Table 1.

Table 1. Items and Weights of General Practice Clinical Reasoning Cases Based on Computer-Simulated Clinical Cases

Primary Indicator	No. of Secondary Items	Principal Contents	Weight (%)
General practice history-taking	8	chief complaint; history of present illness; past medical history; personal and social history; marital and reproductive history; family history; allergy history; menstrual history (female patients)	20
General practice physical examination	27	general examination and vital signs; inspection, auscultation, and palpation of the head and neck; ear, nose, and throat functional examination; chest inspection; etc.	15
Auxiliary examinations	24	General blood tests (hemoglobin, white blood cells, and red blood cells); leukocyte series; other complete blood count indices; liver function indices; etc.	15
History summary	3	analysis of the chief complaint; analysis of major abnormal indicators; etiological analysis	10
Preliminary diagnosis	2	primary diagnosis; secondary diagnosis	20
Differential	2	differential diagnoses; key differentiating	10

diagnosis		features	
Management plan	5	general treatment; referral plan (shared decision-making with the patient); further testing plan; assessment of disease prognosis; pharmacotherapy and adjustment plan	10

2.2 Reliability and Validity of the Clinical Cases

One case from each of the four disease categories (total 4 cases) was randomly selected and evaluation questionnaires were designed. Fourteen senior general practice experts were invited to perform reliability and validity evaluation. The experts' mean age was 45.65 ± 11.20 years, including 6 males and 8 females, from 5 different institutions, with mean practice years of 22.12 ± 6.51 years; all held titles of associate chief physician/associate professor or above. Questionnaire distribution and recovery rate: 14/14 (100%).

The reliability and validity evaluation of the cases showed that the item-level content validity index (I-CVI) for items under the seven primary indicators (e.g., general practice history-taking, general practice physical examination) ranged from 0.820 to 0.943, S-CVI = 0.864, all greater than 0.80. Cronbach's α coefficients for the primary indicators ranged from 0.822 to 0.976, and the overall Cronbach's α coefficient was 0.899. These results indicate that the computer-simulated general practice clinical reasoning cases have good reliability and validity. The Kendall agreement coefficients for the four cases of coronary heart disease (acute symptom onset), type 2 diabetes mellitus (acute symptom onset), pneumonia, and acute exacerbation of chronic obstructive pulmonary disease (with acute symptoms) were 0.756, 0.691, 0.780, and 0.802, respectively ($P < 0.05$), indicating substantial agreement among experts in evaluating the level of general practice clinical reasoning using the cases.

Table 2. Reliability and Validity of General Practice Clinical Reasoning Cases Based on Computer-Simulated Clinical Cases

Primary indicators	Number of evaluation items (4 cases)	I-CVI	S-CVI	Cronbach's α coefficient
General practice history-taking	32	0.897	/	0.902
General practice physical examination	108	0.873	/	0.822
Auxiliary examinations	96	0.820	/	0.840
History summary	12	0.940	/	0.925
Preliminary diagnosis	8	0.857	/	0.917
Differential diagnosis	8	0.839	/	0.976

Management plan	20	0.943	/	0.901
Overall scale	284	/	0.864	0.899

2.3 Application of General Practice Clinical Reasoning Training Based on Computer-Simulated Clinical Cases

The 20 residents matriculating in 2022 had a mean age of 23.12 ± 1.22 years, including 6 males and 14 females; 17 had a bachelor's degree (proportion 85.%). The 20 residents matriculating in 2023 had a mean age of 22.87 ± 1.48 years, including 5 males and 15 females; 17 had a bachelor's degree (proportion 85.%). There were no statistically significant differences between the two groups with respect to sex, age, and education level (all $P > 0.05$).

First, comparison of the two groups' theoretical assessment scores before and after the general medicine department rotation showed no statistically significant difference in pre-rotation theoretical scores ($P > 0.05$). After rotation, theoretical scores increased in both groups, with pre-post improvements reaching statistical significance ($P < 0.05$); post-rotation theoretical scores in the observation group were higher than those in the control group, and the difference was statistically significant ($P < 0.05$).

Table 3. Comparison of Theoretical Examination Scores before and after Rotation in the General Medicine Department between the Two Groups

Group	Pre-rotation theory score	Post-rotation theory score	T value (within group)	<i>P</i> value
Observation group (N = 20)	73.50 ± 6.05	106.05 ± 5.87	19.554	0.000
Control group (N = 20)	75.05 ± 6.64	101.60 ± 7.38	14.050	0.000
T value (between groups)	-0.771	2.110		
<i>P</i> value	0.445	0.041		

Using coronary heart disease (acute symptom onset) and acute exacerbation of chronic obstructive pulmonary disease (with asthma) as the pre- and post-rotation test cases, and using the mean scores of six primary indicator scores and the total score in these two cases for analysis, we found that in the observation group the seven scoring items, including general practice history-taking and general practice physical examination, and the total score showed statistically significant differences before versus after rotation ($P < 0.05$); see Table 3 for details.

Pre- and post-rotation, the observation group's total clinical reasoning training score was positively correlated with theoretical assessment scores: pre-rotation correlation coefficient $R = 0.427$, $P = 0.024$; post-rotation correlation coefficient $R = 0.0471$, $P = 0.018$.

Table 4. Comparison of Clinical Reasoning Assessment Scores before and after Rotation in the General Medicine Department in the Observation Group

Item	Post-rotation score (mean $\pm$ SD)	Pre-rotation score (mean $\pm$ SD)	T value	<i>P</i>
General practice history-taking	17.79 ± 1.45	14.08 ± 1.37	7.512	0.000

General practice physical examination	12.05 ± 1.15	8.80 ± 1.00	7.815	0.000
Auxiliary examinations	11.81 ± 1.06	8.85 ± 1.14	7.447	0.000
History summary	8.75 ± 0.57	5.62 ± 0.70	16.169	0.000
Preliminary diagnosis	17.05 ± 1.11	14.12 ± 1.46	8.427	0.000
Differential diagnosis	8.71 ± 0.62	5.62 ± 0.86	11.755	0.000
Management plan	8.87 ± 0.63	5.88 ± 0.82	12.913	0.000
Total score	85.02 ± 2.48	62.96 ± 2.60	26.935	0.000

DISCUSSION

With continued development of the general practice discipline and ongoing implementation of the family doctor contract service system, clinical reasoning has become one of the essential skills for primary care general practitioners and a cornerstone for delivering person-centered, whole-life-cycle care. The use of simulation, internet-based information technology, and virtual methods to conduct general practice clinical teaching and improve clinical reasoning ability has become widely accepted and has been shown to allow effective use of fragmented time for clinical reasoning training and to improve teaching efficiency^{8,9}. Reports on effective practical application of this model in general practice education are still limited; therefore, this study explored use of computer-simulated clinical reasoning training based on real cases within standardized residency training for general practice, to provide reference for further enhancing the quality and effectiveness of general practice standardized residency training.

To ensure the scientificity and reliability of the general practice clinical reasoning training and to fully reflect the characteristics of general practice, we first used authoritative expert consultation to, from the basic definition of clinical reasoning and in light of general practice diagnostic and treatment features, confirm the seven-part basic case structure including general practice history-taking and general practice physical examination. This structure not only conforms to the routine sequence of daily general practice care in China, but also, by including differential diagnosis and management plan sections, further strengthens assessment and training requirements for physicians' critical thinking and medium- to long-term patient care planning. After developing specific assessment items based on real general practice cases, we invited general practice experts to evaluate the cases' reliability and validity. The I-CVI of items under the seven primary indicators ranged from 0.820 to 0.943, and the overall S-CVI was 0.864, indicating expert consensus that the developed case content can effectively measure residents' clinical reasoning in general practice and has high validity. In addition, Cronbach's α for each primary indicator and for the cases overall exceeded 0.8, and the experts' Kendall coefficients exceeded 0.6, indicating that the cases' overall reliability and consistency are well supported¹⁰. Combining the reliability and validity results, the computer-simulated case-based general practice clinical reasoning training developed in this study can be considered an effective tool for measuring and evaluating clinical reasoning ability in general practice.

Building on this, the study used a historical control design to explore the practical value of the

developed clinical reasoning training tool. By comparing pre- and post-rotation assessments of residents who completed rotations in the general medicine department at our site in consecutive years (2022 and 2023), we found that applying general practice clinical reasoning training during the residents' general medicine department rotation effectively improved theoretical assessment scores: the observation group's post-rotation theoretical assessment scores were significantly higher than those of the control group. Furthermore, pre-post clinical reasoning evaluation scores were significantly positively correlated with theoretical assessment scores. Taken together, these results indicate that providing computer-simulated case-based general practice clinical reasoning training during residents' rotations can effectively improve the quality of general practice education during rotation and promote residents' mastery of diagnostic theory and routine management of common and frequently occurring conditions^{11,12}.

In summary, this study first constructed a computer-simulated general practice clinical reasoning training tool with good reliability and validity based on clinical practice and authoritative expert consultation. It can serve both as an effective assessment tool for residents' clinical reasoning ability and as teaching material to improve disease diagnosis and management competence and overall teaching quality and effectiveness during rotations in the general medicine department. The tool facilitates residents' flexible self-practice and assessment and can also be used by general practice instructors as a practical teaching tool, with promising application prospects.

The limitations of this study include constraints of resources and time: the number of disease categories covered by the developed cases remains limited and the empirical evaluation sample size is relatively small. Future work should increase resource investment to further enrich the disease coverage in line with the standardized residency training syllabus requirements so that assessments are more comprehensive. In addition, designing and conducting multicenter, parallel controlled studies with larger and more diverse samples is recommended to further validate the tool's effectiveness and to provide more comprehensive evidence for enriching the teaching content of general practice standardized residency training and improving teaching quality, thereby truly promoting overall improvements in primary care general practice human resource quality.

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