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Effectiveness of In Situ Simulation-Based Teaching in General Surgery Residency Training: A Randomized Controlled Study

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Abstract

This randomized controlled educational study evaluated the effectiveness of a single-session in situ simulation-based teaching intervention conducted in the actual general surgery ward for residents undergoing standardized general surgery training. Sixty residents at Liuzhou People's Hospital from July 2024 to October 2025 were allocated to an in situ simulation group (n = 30) or a traditional teaching group (n = 30). The intervention group received a 30-minute in situ simulation session based on a real case of severe postoperative hemorrhage following mixed hemorrhoid surgery, whereas the traditional group received conventional instruction. Compared with the traditional teaching group, the in situ simulation group achieved higher theoretical examination scores (86.02 ± 3.97 vs 80.53 ± 5.50; P < 0.001), practical skills examination scores (92.28 ± 2.67 vs 86.56 ± 3.61; P < 0.001), and total examination scores (89.15 ± 2.50 vs 83.55 ± 3.08; P < 0.001), while training satisfaction did not differ significantly between groups (40.07 ± 2.27 vs 39.10 ± 2.26; P = 0.104). These findings suggest that a single-session in situ simulation intervention may improve end-of-rotation theoretical and practical examination performance and may serve as a useful complement to conventional general surgery residency training.

INTRODUCTION

General surgery residency training requires trainees to develop not only theoretical knowledge and procedural skills, but also clinical reasoning, perioperative decision-making, teamwork, and the ability to respond effectively to acute clinical deterioration. Traditional teaching methods, including ward rounds, case discussions, short lectures, and bedside instruction, remain important components of surgical education; however, they may provide limited opportunities for residents to independently manage uncommon, high-risk, or rapidly evolving clinical events. Simulation-based education has therefore been increasingly used to supplement conventional surgical training by providing a controlled environment in which residents can practice clinical decision-making and technical skills without compromising patient safety[1, 2].

Among different simulation approaches, in situ simulation is particularly relevant to postgraduate clinical training because it reproduces, or closely approximates, the actual clinical environment in which patient care occurs. By incorporating realistic workflows, clinical equipment, multidisciplinary team roles, and dynamic changes in a simulated patient's condition, in situ simulation may enhance both technical and nontechnical performance[3]. A recent systematic review showed that in situ simulation was associated with improvements across several educational outcomes, although the magnitude of benefit varied among outcome domains[3].

In general surgery, the management of postoperative complications and acute surgical emergencies requires residents to integrate knowledge, clinical judgment, procedural skills, communication, and teamwork within a time-sensitive setting. Simulation may be particularly useful for training these competencies because it allows residents to repeatedly practice complex scenarios and receive

structured feedback[4]. Recent studies have also shown that simulation-based training can improve surgical skills and may facilitate transfer of training to real operating-room performance[2, 5]. Debriefing further strengthens this learning process by enabling residents to review their decisions, identify deficiencies, and reflect on alternative management strategies[6].

Despite the increasing use of simulation in surgical education, evidence regarding in situ simulation in standardized general surgery residency training remains limited, particularly in randomized studies evaluating both theoretical and practical outcomes. The present study therefore compared in situ simulation-based teaching with traditional teaching among general surgery residents at Liuzhou People's Hospital. We evaluated end-of-rotation theoretical examination scores, practical skills examination scores, total examination scores, and training satisfaction. We hypothesized that in situ simulation-based teaching would improve residents' educational outcomes compared with conventional teaching.

MATERIALS AND METHODS

General Information

This randomized controlled educational study was conducted at Liuzhou People's Hospital from July 2024 to October 2025. A total of 60 participants were allocated to either the in situ simulation group or the traditional teaching group using an envelope-based random allocation method, with 30 participants in each group.

Residents were eligible if they were undergoing standardized general surgery residency training at Liuzhou People's Hospital, had received systematic medical education, and voluntarily participated in the study.There were no statistically significant differences between the two groups in sex or trainee category ($P > 0.05$), indicating baseline comparability.

Teaching Methods

Residents in the in situ simulation group received a single scenario-based teaching session derived from a real clinical case. The teaching was jointly conducted by qualified general surgery instructors and specialized surgical nurses in the actual general surgery ward, using the clinical environment, workflow, and equipment routinely available in patient care. Standardized patients were used to portray the patient, while teaching assistants acted as simulated family members to reproduce patient-family communication and team interaction during acute clinical events.

The simulation focused on the recognition and management of an acute postoperative complication. Before the simulation, relevant theoretical knowledge was reviewed during a morning teaching session. The single simulation-based teaching session lasted approximately 30 minutes and consisted of scenario introduction, scenario execution, and on-site debriefing. Monitoring equipment, clinical instruments, and medications required for the scenario were prepared in advance. Instructors recorded

problems identified during training and provided targeted feedback and recommendations for improvement.

Residents in the traditional teaching group received conventional instruction through teaching ward rounds, clinical case discussions, short lectures, and clinical skills teaching. The instructional content focused on core theoretical knowledge and practical skills required in general surgery residency training.

Simulation Scenario

A representative in situ simulation scenario was developed based on a real case of severe postoperative hemorrhage following mixed hemorrhoid surgery. The scenario was designed to reproduce an acute postoperative deterioration requiring rapid recognition, clinical assessment, emergency decision-making, and multidisciplinary coordination. Standardized patients portrayed the patient, while teaching assistants acted as simulated family members during the scenario.

During the simulation, residents were required to assess the patient's condition, evaluate the severity of bleeding, initiate appropriate emergency management, communicate with nursing staff and other members of the clinical team, and determine the need for further intervention. The patient's condition evolved dynamically during the scenario according to the residents' responses, requiring repeated reassessment and adjustment of the management strategy.

After completion of the scenario, the teaching team conducted an on-site debriefing. Residents reviewed their clinical reasoning, treatment decisions, practical actions, communication, and teamwork, while instructors highlighted key problems observed during the simulation and provided targeted feedback and recommendations for improvement. The key components of the in situ simulation scenario and their corresponding training objectives are summarized in Table 1.

Table 1
In Situ Simulation Scenario and Training Objectives

Scenario component	Description	Key training objectives
Clinical setting	Postoperative period following mixed hemorrhoid surgery	Recognition of postoperative complications
Trigger event	Sudden severe postoperative hemorrhage	Rapid identification and assessment of bleeding
Initial assessment	Evaluation of the patient's clinical status and severity of hemorrhage	Clinical reasoning and situational assessment
Emergency response	Initiation of immediate management and preparation for further intervention	Decision-making and practical skills
Team coordination	Communication with nursing staff and other members of the team	Communication and teamwork
Reassessment	Adjustment of management according to changes in the simulated patient's condition	Dynamic decision-making
Debriefing	Review of assessment, management decisions, communication, and team performance	Reflection and performance improvement

Teaching Evaluation

Teaching effectiveness was evaluated using the routine end-of-rotation assessments conducted at the end of the monthly general surgery rotation. Residents completed the assessments after the single teaching intervention, as part of the routine end-of-rotation examination schedule.

Both the theoretical and practical examinations were routine end-of-rotation assessments used by Liuzhou People's Hospital. The two groups were assessed by the same teaching team using identical assessment criteria. The theoretical examination assessed residents' understanding of core knowledge relevant to general surgery, while the practical skills examination evaluated routine clinical skills required during general surgery residency training. The total examination score was calculated as the arithmetic mean of the theoretical and practical skills examination scores.Training satisfaction was assessed using a nine-item questionnaire developed by the research team specifically for this study. The questionnaire evaluated participants' understanding of the teaching activity, appropriateness of the teaching objectives, instructor guidance, perceived learning gains, self-assessed preparation before teaching, level of participation, explanation of key and difficult points, instructor feedback, and overall evaluation of the teaching activity. Each item was rated on a five-point scale (1–5), yielding a total possible score ranging from 9 to 45, with higher scores indicating greater satisfaction. The questionnaire had not been previously published or formally validated. An English translation of the questionnaire is provided as Supplementary File 1.

Theoretical and practical examination scores were collected after completion of the end-of-rotation assessments, and the satisfaction questionnaire was completed on the final day of the rotation.

Statistical Analysis

Statistical analyses were performed using SPSS version 26.0. Normally distributed continuous variables were expressed as mean ± standard deviation and compared between groups using independent-samples t tests. Categorical variables were expressed as *n* (%) and compared using the chi-square test, with continuity correction applied for 2 × 2 contingency tables when appropriate. A two-sided *P* value < 0.05 was considered statistically significant. For the main continuous outcomes, mean differences with 95% confidence intervals (CIs) and Cohen's d effect sizes were additionally calculated to quantify the magnitude of between-group differences. This study was reported with reference to the Consolidated Standards of Reporting Trials (CONSORT) guidelines. The completed CONSORT checklist is provided as Supplementary File 2.

RESULTS

Participant Characteristics

A total of 60 residents were included in the study, with 30 participants in the in situ simulation group and 30 in the traditional teaching group. All 60 randomized residents completed the study without withdrawal. Thirty residents were allocated to the in situ simulation group, and 30 were allocated to the traditional teaching group. In the in situ simulation group, 26 residents (86.67%) were men and 4 (13.33%) were women; 15 residents (50.00%) were undergraduate-entry residents and 15 (50.00%) were professional master's students undergoing integrated residency training. In the traditional teaching group, 25 residents (83.33%) were men and 5 (16.67%) were women; 13 residents (43.33%) were undergraduate-entry residents and 17 (56.67%) were professional master's students undergoing integrated residency training. There were no statistically significant differences between the two groups in sex or trainee category (*P* > 0.05), indicating baseline comparability (Table 2).

End-of-Rotation Examination Scores

Residents in the in situ simulation group achieved significantly higher theoretical examination scores, practical skills examination scores, and total examination scores than those in the traditional teaching group. The mean theoretical examination score was 86.02 ± 3.97 in the in situ simulation group and 80.53 ± 5.50 in the traditional teaching group, corresponding to a mean difference of 5.49 points (95% CI, 3.01–7.97; Cohen's d = 1.14; *P* < 0.001). The mean practical skills examination score was 92.28 ± 2.67 and 86.56 ± 3.61, respectively, with a mean difference of 5.72 points (95% CI, 4.08–7.36; Cohen's d = 1.80; *P* < 0.001). The mean total examination score was 89.15 ± 2.50 and 83.55 ± 3.08, respectively, corresponding to a mean difference of 5.60 points (95% CI, 4.15–7.05; Cohen's d = 2.00; *P* < 0.001; Table 3).

Training Satisfaction

The mean training satisfaction score was 40.07 ± 2.27 in the in situ simulation group and 39.10 ± 2.26 in the traditional teaching group. The mean difference was 0.97 points (95% CI, − 0.20 to 2.14; Cohen's d = 0.43; *P* = 0.104), indicating no statistically significant between-group difference (Table 4).

Table 2
Baseline Characteristics of Participants

Characteristic	**In Situ Simulation Group (*n* = 30)**	**Traditional Teaching Group (*n* = 30)**	***χ²***	***P***
Male, *n* (%)	26 (86.67)	25 (83.33)	0.144	0.704
Female, *n* (%)	4 (13.33)	5 (16.67)		
Undergraduate-entry residents, *n* (%)	15 (50.00)	13 (43.33)	0.067	0.796
Professional master's students undergoing integrated residency training, *n* (%)	15 (50.00)	17 (56.67)		

Sex: χ^2 = 0.144, *P* = 0.704. Trainee category: χ^2 = 0.067, *P* = 0.796.

Table 3
Comparison of End-of-Rotation Examination Scores

Outcome	**In Situ Simulation Group (*n* = 30)**	**Traditional Teaching Group (*n* = 30)**	**Mean Difference (95% CI)**	**Cohen's d**	***t***	***P***
Theoretical examination score	86.02 ± 3.97	80.53 ± 5.50	5.49 (3.01–7.97)	1.14	4.425	< 0.001
Practical skills examination score	92.28 ± 2.67	86.56 ± 3.61	5.72 (4.08–7.36)	1.80	6.981	< 0.001
Total score	89.15 ± 2.50	83.55 ± 3.08	5.60 (4.15–7.05)	2.00	7.735	< 0.001

Values are presented as mean ± standard deviation. Mean differences are reported with 95% confidence intervals (CIs). Cohen's d represents the standardized between-group effect size. The total examination score was calculated as the arithmetic mean of the theoretical and practical skills examination scores.

Table 4
Comparison of Training Satisfaction Scores

Outcome	In Situ Simulation Group (*n* = 30)	Traditional Teaching Group (*n* = 30)	Mean Difference (95% CI)	Cohen's d	*t*	*P*
Training satisfaction score	40.07 ± 2.27	39.10 ± 2.26	0.97 (− 0.20 to 2.14)	0.43	1.650	0.104

Values are presented as mean ± standard deviation. Mean differences are reported with 95% confidence intervals (CIs). Cohen's d represents the standardized between-group effect size.

DISCUSSION

This randomized controlled study showed that residents receiving in situ simulation-based teaching achieved significantly higher theoretical examination, practical skills, and total examination scores than those receiving traditional teaching. In contrast, training satisfaction was numerically higher in the simulation group but did not differ significantly between groups. These findings indicate that the principal benefit of the intervention was reflected in objective educational performance rather than in subjective satisfaction.

The improvement in theoretical performance may be related to the integration of preparatory knowledge review with active application during realistic clinical scenarios. Residents were required to use previously learned knowledge to recognize and manage postoperative complications and acute surgical conditions, rather than simply recalling information in a classroom setting. Recent surgical education research has increasingly incorporated simulation into competency-based assessment, emphasizing its value for evaluating integrated clinical tasks and decision-making rather than isolated knowledge alone[7].

The difference in practical skills scores was more pronounced and is consistent with recent surgical simulation research[8]. Grossi et al. reported that simulator-based training improved technical performance among thoracic and general surgery residents[2]. More recently, high-fidelity simulation has been used to address limited resident exposure to vascular trauma, a relatively infrequent but clinically important situation in which opportunities for hands-on training may otherwise be restricted[9]. These findings are relevant to the present study because postoperative critical complications and acute surgical conditions are similarly difficult to reproduce consistently during routine residency rotations. In particular, the representative scenario of severe postoperative hemorrhage following mixed hemorrhoid surgery required residents to rapidly integrate patient assessment, recognition of hemorrhagic deterioration, emergency decision-making, and coordination. Such scenarios may be difficult to encounter predictably during routine rotations, making simulation particularly suitable for deliberate practice of low-frequency but potentially high-risk postoperative events. In situ simulation allows these

events to be deliberately incorporated into training and repeated without placing patients at additional risk.

Another potentially important feature of our intervention was its multi-role simulation design. The simulation involved general surgery instructors, specialized surgical nurses, standardized patients, and teaching assistants acting as simulated family members, followed by structured debriefing[10]. A randomized study similarly used interdisciplinary simulation to train residents in communication surrounding unexpected perioperative complications and demonstrated the feasibility of integrating multidisciplinary interaction and structured debriefing into resident education[11]. The educational effect observed in our study may therefore reflect not only simulation itself but also the combination of realistic scenarios, active participation, team interaction, and immediate feedback.

The lack of a statistically significant difference in training satisfaction deserves separate consideration. Objective performance and subjective learner perceptions do not necessarily change in parallel[12]. Simulation can be cognitively demanding and requires residents to participate actively, respond under time pressure, and expose gaps in their own performance. Recent research in general surgery residents has specifically examined motivation and engagement in simulation curricula, suggesting that learner experience is influenced by factors beyond technical effectiveness alone[13]. In our study, the small absolute difference in satisfaction scores may also have been difficult to detect with 30 participants per group. Therefore, the absence of a significant satisfaction difference should not be interpreted as evidence that the intervention lacked educational value.

From a competency-based education perspective, the present findings support the use of simulation as a complement to conventional clinical teaching rather than as a replacement for it. Recent surgical education literature has increasingly linked simulation with competency frameworks such as entrustable professional activities, emphasizing the value of observing residents perform integrated clinical tasks rather than assessing isolated knowledge alone[7]. In situ simulation may be particularly suited to this approach because it permits deliberate practice of clinical situations that combine assessment, decision-making, procedural action, communication, and teamwork.

Limitations

First, this was a single-center study with a relatively small sample size, which may limit the generalizability of the findings. Second, baseline theoretical knowledge and practical performance were not assessed before the intervention. Although participants were randomly allocated and the groups were comparable with respect to the recorded baseline characteristics, pre-existing differences in academic or clinical performance cannot be completely excluded. Third, the study primarily assessed short-term educational outcomes and did not evaluate long-term knowledge retention, subsequent clinical performance, or transfer of learning to real patient care[14]. Fourth, training satisfaction was assessed using a locally developed questionnaire that had not undergone formal psychometric validation. Finally, baseline comparisons were limited to sex and trainee category. Future multicenter

studies with larger samples, baseline performance assessments, validated competency-based outcome measures, and longer follow-up are needed to confirm these findings and determine whether the observed educational benefits translate into sustained improvements in clinical performance.

CONCLUSIONS

A single-session in situ simulation-based teaching intervention conducted in the actual general surgery ward was associated with significantly higher theoretical, practical skills, and overall examination scores among residents undergoing standardized general surgery training compared with traditional teaching. Training satisfaction did not differ significantly between groups. By allowing residents to practice the recognition and management of acute postoperative complications in the real clinical environment, in situ simulation may provide a useful complement to conventional residency training. Further multicenter studies with baseline performance assessment and longer follow-up are needed to determine whether these educational benefits are sustained and translate into improved clinical performance.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of Liuzhou People's Hospital (Approval No. KY-2024-075; February 28, 2024). The study was conducted in accordance with the ethical requirements approved by the committee, and informed consent procedures were implemented in accordance with the approved study protocol.

Competing interests

The authors declare that they have no competing interests.

CRediT authorship contribution statement

Liuwen Wang: Conceptualization, Investigation, Writing – original draft.

Donghao Tang: Methodology, Writing – review & editing.

Li Wang: Investigation, Teaching intervention, Data collection, Writing – review & editing.

Minmin Zhang: Investigation, Teaching intervention, Supervision.

Hongyan Li: Formal analysis, Data collection.

Yan Zhang: Teaching intervention, Investigation, Teaching intervention, Data collection.

Jinxiu Huang: Data curation, Project administration.

Qijie Li: Conceptualization, Methodology, Supervision, Project administration, Writing – review & editing.

All authors have read and approved the final version of the manuscript.

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Author Contribution

Liuwen Wang: Conceptualization, Investigation, Writing – original draft.Donghao Tang: Methodology, Writing – review & editing.Li Wang: Investigation, Teaching intervention, Data collection, Writing – review & editing.Minmin Zhang: Investigation, Teaching intervention, Supervision.Hongyan Li: Formal analysis, Data collection.Yan Zhang: Teaching intervention, Investigation, Teaching intervention, Data collection.Jinxiu Huang: Data curation, Project administration.Qijie Li: Conceptualization, Methodology, Supervision, Project administration, Writing – review & editing.All authors have read and approved the final version of the manuscript.

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The authors have no acknowledgements to declare.

Data Availability

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementaryFile1TrainingSatisfactionQuestionnaire.docx