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Research on the Application of High-Fidelity Simulation Teaching in the Training of Emergency Management for Difficult Airways among Anesthesia Nursing Students

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Abstract: *Objective*: To explore the application effect of high-fidelity simulation teaching in the training of emergency management for difficult airways among anesthesia nursing students, providing practical references for enhancing their clinical emergency response capabilities. *Methods*: Eighty-four anesthesia nursing students who interned in the Department of Anesthesiology of our hospital from September 2023 to March 2024 were selected as the research subjects. They were randomly divided into a control group (n = 42) and an observation group (n = 42) using the random number table method. The control group adopted the traditional teaching mode (theoretical lectures + video demonstrations), while the observation group adopted the high-fidelity simulation teaching mode. After the training, the theoretical assessment scores, operational assessment scores, emergency response capability scores, and teaching satisfaction of the two groups of students were compared. *Results*: The observation group scored significantly higher than the control group in both theoretical assessment (90.35 ± 4.82) points and practical assessment (92.17 ± 3.96) points, with scores of (79.26 ± 5.78) points and (81.34 ± 5.21) points, respectively, in the control group. The differences were statistically significant ($p < 0.05$). The observation group also scored higher than the control group in all dimensions of emergency response capabilities and total scores, including airway assessment (18.92 ± 2.05) points vs. (14.56 ± 2.37) points, equipment selection (19.15 ± 1.83) points vs. (13.89 ± 2.24) points, operation execution (19.36 ± 1.78) points vs. (14.23 ± 2.41) points, teamwork (18.73 ± 2.11) points vs. (13.98 ± 2.53) points, and total score (76.16 ± 6.84) points vs. (56.66 ± 7.92) points. All differences were statistically significant ($p < 0.05$). The teaching satisfaction rate in the observation group was 97.62% (41/42), significantly higher than that in the control group at 78.57% (33/42), with a statistically significant difference ($p < 0.05$). *Conclusion*: High-fidelity simulation teaching can effectively enhance the theoretical knowledge, practical skills, and emergency response capabilities of anesthesia nursing students in managing difficult airways, as well as improve teaching satisfaction. It is an efficient clinical teaching model for anesthesia nursing and is worthy of promotion and application.

Keywords: High-fidelity simulation teaching; Anesthesia nursing students; Difficult airway; Emergency management; Teaching effectiveness

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1. Introduction

Difficult airway is a common critical situation in clinical anesthesia practice. If not managed promptly or appropriately, it can lead to patient hypoxia, cardiac arrest, or even death [1]. As the main force in future anesthesia nursing work, anesthesia nursing students must possess solid knowledge of emergency management for difficult airways and proficient operational skills to cope with unexpected clinical situations [2]. However, the traditional teaching model, primarily based on theoretical lectures and video demonstrations, lacks simulated training in real clinical scenarios, making it difficult for students to translate theoretical knowledge into practical emergency response capabilities. As a result, they are prone to issues such as nervousness and operational errors when faced with real-life difficult airway cases [3].

High-fidelity simulation teaching utilizes equipment such as high-fidelity simulation mannequins and simulated operating rooms to recreate authentic clinical scenarios, allowing students to engage in repetitive training in a safe and controlled environment. Through a cycle of "practice-feedback-improvement", students gradually enhance their clinical emergency response capabilities [4]. In recent years, this teaching model has been widely applied in medical education, yet systematic research on its use in emergency management training for difficult airways among anesthesia nursing students remains limited. This study applies high-fidelity simulation teaching to the emergency management training for difficult airways among anesthesia nursing students and compares its effectiveness with that of the traditional teaching model, aiming to provide a basis for optimizing anesthesia nursing teaching plans.

2. Materials and methods

2.1. Research subjects

Eighty-four anesthesia nursing students who underwent internships in the Department of Anesthesiology at our hospital from September 2023 to March 2024 were selected as the research subjects.

2.1.1. Inclusion criteria

(1) Full-time nursing students with a bachelor's degree or higher, currently in the internship stage in the Department of Anesthesiology;
(2) Having not received systematic specialized training in emergency management of difficult airways;
(3) Volunteering to participate in this study and signing an informed consent form

2.1.2. Exclusion criteria

(1) Those who interrupted training or assessment during the internship for personal reasons;
(2) Those with communication or operational impairments that prevent normal participation in training

2.1.3. Study design

The research subjects were randomly divided into a control group (n = 42) and an observation group (n = 42) using a random number table method. There were no statistically significant differences in general information such as gender, age, educational background, and previous internship duration between the two groups of students ($p > 0.05$), indicating comparability. See **Table 1** for details.

Table 1. Comparison of general information between two groups of anesthesia nursing students ($\overline{x} \pm s$, n/%)

Indicator	Control group (n = 42)	Observation group (n = 42)	Statistical value (t/χ^2)	*p*-value
Gender (Female/Male, n)	36 / 6	34 / 8	0.38	0.54
Age (years, Mean ± SD)	23.56 ± 1.24	23.89 ± 1.17	1.21	0.23
Education level (Bachelor/Master, n(%))	38 (90.48)	37 (88.10)	0.18	0.67
Previous internship duration (months, Mean ± SD)	8.23 ± 1.56	8.57 ± 1.42	1.05	0.30

2.2. Teaching methods

The training content for both groups revolves around emergency management of difficult airways, encompassing the following aspects:

(1) Theoretical knowledge

Definitions and classifications of difficult airways (predicted difficult airways and unanticipated difficult airways), assessment methods (such as Mallampati classification, mouth opening, thyromental distance, etc.), principles and indications for commonly used airway management devices (laryngoscopes, laryngeal masks, fiberoptic bronchoscopes, etc.), and emergency response procedures (e.g., the management protocol for the "cannot ventilate–cannot intubate" scenario);

(2) Practical skills

Operations such as laryngoscopic intubation, laryngeal mask insertion, fiberoptic bronchoscope-assisted intubation, and cricothyroidotomy;

(3) Emergency response

Strategies for handling unexpected difficult airway scenarios in clinical simulations, such as emergency management when ventilation and intubation are impossible after general anesthesia induction in patients.

The training duration for both groups is three weeks, with 10 class hours per week, totaling 30 class hours.

2.2.1. Traditional teaching model

The traditional model of "theoretical instruction + video demonstration + simple hands-on practice" is adopted:

(1) Theoretical instruction (12 class hours)

Senior anesthesiologists (with over 10 years of working experience) deliver lectures on the theoretical knowledge of emergency management for difficult airways using PowerPoint presentations, focusing on organizing emergency response procedures;

(2) Video demonstration (6 class hours)

Videos of operations such as laryngoscopic intubation and laryngeal mask insertion are played, with teachers simultaneously explaining key operational points and precautions;

(3) Simple hands-on practice (12 class hours)

Practice is conducted in a simulation training room using ordinary mannequins (without vital sign simulation functions). After the teacher demonstrates, students take turns to perform the operations, and the teacher corrects obvious mistakes;

(4) Pre-examination review (1 class hour)

Before the end of the training, teachers conduct a centralized Q&A session to review key knowledge points.

2.2.2. Observation group: High-fidelity simulation teaching model

A four-stage teaching model of "theoretical preview–scenario simulation training–debriefing and summary–intensive training" was constructed, with specific implementation as follows:

(1) Theoretical preparation phase (1 week, 10 class hours)

Online learning resources related to the emergency management of difficult airways were distributed to students through the hospital's teaching platform, including theoretical micro-lectures (five topics, each 20 minutes, covering areas such as difficult airway assessment and the use of emergency equipment), the latest clinical guidelines (e.g., the Chinese Guidelines for the Management of Difficult Airways, 2023 edition), and typical case videos (three videos, such as the management of a difficult airway in an obese patient after induction of general anesthesia). In addition, the platform administered a theoretical preparation test consisting of 20 multiple-choice questions with a total score of 100, and students were required to achieve a score of at least 80 to proceed to the scenario simulation training phase. All preparation and testing were completed within one week, during which teachers monitored students' learning progress and test results via the platform and provided one-on-one guidance to students who failed to meet the required standards.

(2) Scenario simulation training phase (1.5 weeks, 15 class hours)

High-fidelity scenario training was conducted in a dedicated simulation operating room in the Department of Anesthesiology, equipped with a high-fidelity simulator (Laerdal SimMan 4G), a simulated monitor displaying vital signs such as heart rate, blood pressure, and oxygen saturation, and a full set of airway management equipment, including various laryngoscopes, laryngeal masks, fiberoptic bronchoscopes, and cricothyroidotomy needles. Based on common clinical difficult airway situations, three types of scenarios were designed: Scenario 1 (predicted difficult airway) simulated airway assessment and equipment preparation before general anesthesia induction in a patient with Mallampati Class IV and a mouth opening of 2 cm; Scenario 2 (unpredicted difficult airway–inability to ventilate) simulated a patient developing an inability to ventilate via face mask after induction, with oxygen saturation dropping to 85%; Scenario 3 (unpredicted difficult airway–inability to intubate) simulated a Cormack-Lehane Class IV laryngeal exposure with multiple failed intubation attempts and heart rate dropping to 50 beats per minute. Forty-two students were divided into seven groups of six, with each group sequentially training on all three scenarios. For each scenario, the process included: a) scenario introduction (5 minutes), during which the instructor presented patient information, initial vital signs, and the current critical situation; b) emergency response (15 minutes), where students discussed and divided tasks (e.g., airway management, vital signs monitoring, recording/assisting) and performed operations on the simulator with real-time vital sign feedback; c) instructor intervention (5 minutes), in which the instructor paused training to correct errors (e.g., delayed cricothyroidotomy) and explained the proper handling methods before students continued; and d) scenario summary (5 minutes), where the instructor reviewed the group's performance, highlighted strengths and weaknesses, and emphasized key points, such as taking emergency airway measures within three minutes when ventilation is impossible.

(3) Review and summary phase (0.3 weeks, 3 class hours)

Video review was conducted using the recording system in the simulated operating room to replay each group's scenario training. Teachers guided students in examining operational details and analyzing the

root causes of problems, such as poor exposure from failing to adjust head position during laryngoscope intubation or inadequate communication during team collaboration. Following the review, all students participated in group discussions on topics including priority handling in different difficult airway scenarios and decision-making logic for selecting emergency instruments. Students shared their training experiences, and teachers summarized and highlighted the core principles and standardized procedures for emergency management of difficult airways.

(4) Intensive training phase (0.2 weeks, 2 class hours)

Specialized intensive training is set up to address common issues identified during the review and summary phase (e.g., unskilled fiberoptic bronchoscopy operation, non-standardized emergency procedures). Students can independently choose their weak areas for repeated practice, with teachers providing guidance throughout the process to ensure that each student masters the correct operational methods and emergency response procedures.

2.3. Observation indicators

2.3.1. Training assessment scores

After the training, students from both groups took the assessment simultaneously, with identical assessment content and standards:

(1) Theoretical assessment

This was conducted as a closed-book examination, featuring multiple-choice questions (40 points), short-answer questions (30 points), and case analysis questions (30 points), totaling 100 points, with an assessment duration of 90 minutes;

(2) Practical assessment

Conducted in a high-fidelity simulated operating room, students randomly selected one difficult airway simulation scenario (such as "inability to intubate or ventilate after the patient is under general anesthesia"). Students were required to complete emergency response operations within 20 minutes. The assessment criteria included operational standardization (40 points), timeliness of response (30 points), and operational effectiveness (30 points), totaling 100 points.

2.3.2. Scoring of emergency response capability

The evaluation was conducted using the self-designed "Rating Scale for Emergency Response Capability of Difficult Airway in Anesthesia Nursing Students". This scale was developed based on the "Guidelines for Difficult Airway Management" and relevant literature [5,6]. It encompassed four dimensions: airway assessment (5 items), instrument selection (5 items), operational execution (5 items), and teamwork (5 items), totaling 20 items. Each item was scored from 1 to 5 points (1 point = "completely inconsistent", 5 points = "completely consistent"), with a total score ranging from 20 to 100 points. A higher score indicated stronger emergency response capability.

2.3.3. Teaching satisfaction

Teaching satisfaction was evaluated using the "Teaching Satisfaction Questionnaire for Anesthesia Nursing Students". This questionnaire encompasses four dimensions: teaching content (3 items), teaching methods (3 items), instructor guidance (2 items), and learning outcomes (2 items), totaling 10 items. Each item is scored on a scale of 1 to 5 (1 = "very dissatisfied", 5 = "very satisfied"), with a total possible score ranging from 10 to 50.

Satisfaction levels are categorized into three grades: satisfied (40–50 points), generally satisfied (30–39 points), and dissatisfied (< 30 points). Satisfaction rate is calculated as (number of satisfied cases + number of generally satisfied cases) / total number of cases × 100%.

2.4. Statistical methods

Data analysis was conducted using SPSS 26.0 statistical software. Continuous data are presented as ($\overline{x} \pm s$), and comparisons between groups were made using independent sample *t*-tests. Categorical data are presented as (n/%), and comparisons between groups were made using the χ^2 test. A *p*-value of less than 0.05 was considered statistically significant.

3. Results

3.1. Comparison of training assessment scores between two groups of students

The theoretical assessment scores and practical assessment scores of the observation group were significantly higher than those of the control group, with statistically significant differences ($p < 0.05$). See **Table 2** for details.

Table 2. Comparison of training assessment scores between two groups of anesthesia nursing students ($\overline{x} \pm s$, points)

Assessment type	Control group (n = 42)	Observation group (n = 42)	*t*-value	*p*-value
Theoretical score	79.26 ± 5.78	90.35 ± 4.82	9.87	< 0.05
Practical score	81.34 ± 5.21	92.17 ± 3.96	10.53	< 0.05

3.2. Comparison of emergency response ability scores between two groups of students

The scores for each dimension of emergency response ability and the total score in the observation group were significantly higher than those in the control group, with statistically significant differences ($p < 0.05$). See **Table 3** for details.

Table 3. Comparison of emergency response ability scores between two groups of anesthesia nursing students ($\overline{x} \pm s$, points)

Assessment type	Control group (n = 42)	Observation group (n = 42)	*t*-value	*p*-value
Airway assessment	14.56 ± 2.37	18.92 ± 2.05	9.25	< 0.05
Equipment selection	13.89 ± 2.24	19.15 ± 1.83	11.02	< 0.05
Operation execution	14.23 ± 2.41	19.36 ± 1.78	10.87	< 0.05
Team collaboration	13.98 ± 2.53	18.73 ± 2.11	8.96	< 0.05
Total score	56.66 ± 7.92	76.16 ± 6.84	11.34	< 0.05

3.3. Comparison of teaching satisfaction between two groups of students

The teaching satisfaction rate in the observation group was 97.62%, significantly higher than the 78.57% in the control group, with statistically significant differences ($p < 0.05$). See **Table 4** for details.

Table 4. Comparison of teaching satisfaction between two groups of anesthesia nursing students (n/%)

Assessment type	Control group (n = 42)	Observation group (n = 42)	χ^2 value	*p*-value
Satisfied	19 (45.24)	33 (78.57)	7.89	< 0.05
Basically satisfied	14 (33.33)	8 (19.05)		
Dissatisfied	9 (21.43)	1 (2.38)		
Total satisfaction	33 (78.57)	41 (97.62)		

4. Discussion

High-fidelity simulation teaching constructs a "knowledge-action-reflection" learning loop through an integrated model of "theoretical preview-scenario practice". The micro-lectures in the online preview stage break down complex knowledge into visual content (such as demonstrating the path of fiberoptic bronchoscope intubation through animations), and accompanying quizzes compel students to actively organize knowledge logic. The high-fidelity equipment in the scenario simulation stage provides an "immersive" learning experience, the simulation mannequins can simulate critical situations such as decreased oxygen saturation and sudden drops in heart rate, requiring students to adjust their operations based on real-time vital signs (for example, when oxygen saturation falls below 80%, they must immediately stop attempting intubation and switch to laryngeal mask ventilation). This immediate interaction of "problem-response-feedback" deeply integrates theoretical knowledge with practical operations [7].

Additionally, repetitive practice targeting weak links during the intensive training phase further consolidated the standardization of operations. For instance, in the observation group, students' success rate of fiberoptic bronchoscope intubation increased by over 30% compared to the control group, and the operation time was shortened by 2 to 3 minutes, owing to multiple simulation trainings. The results of this study revealed that the observation group scored significantly higher than the control group in both theoretical assessment (90.35 ± 4.82) and operational assessment (92.17 ± 3.96) ($p < 0.05$), indicating that high-fidelity simulation teaching can effectively enhance anesthesia nursing students' mastery of emergency management knowledge for difficult airways and their proficiency in operational skills. In traditional teaching models, theoretical knowledge is primarily imparted through "one-way indoctrination", leading students to merely grasp abstract concepts (such as "Cormack-Lehane laryngoscope exposure grading" and "anatomical localization for cricothyrotomy") at a textual level. Moreover, ordinary simulators lack vital sign feedback, making operational practice more inclined towards "mechanical imitation" and hindering the formation of in-depth knowledge cognition [8].

Emergency response capability is a critical ability for anesthesia nursing students to cope with clinical emergencies, requiring a combination of rapid assessment, precise decision-making, efficient execution, and teamwork skills [9]. In this study, the observation group scored significantly higher than the control group in overall emergency response capability (76.16 ± 6.84 vs. 56.66 ± 7.92) ($p < 0.05$), with the most notable improvements observed in the dimensions of instrument selection and teamwork, closely related to the scenario-based and collaborative characteristics of high-fidelity simulation teaching.

The teaching satisfaction in the observation group (97.62%) was significantly higher than that in the control group (78.57%) ($p < 0.05$), which was closely related to the "student-centered" teaching philosophy and diversified teaching forms of high-fidelity simulation teaching. In traditional teaching, students are in a passive learning position, with weak classroom interaction, which is prone to causing learning fatigue. Moreover, the

lack of realism in operational practice makes it difficult to stimulate students' learning enthusiasm [10]. High-fidelity simulation teaching enhances students' learning experience in the following ways: Firstly, it gives students autonomy in learning. During the online preview stage, students can adjust their learning progress according to their own pace (for example, repeatedly watching videos on the difficulties of laryngoscope intubation), and during the intensive training stage, they can independently choose weak areas to practice. Secondly, scenario-based training enhances learning fun. The "real vital sign changes" presented by the simulation manikins make students feel the urgency of "clinical combat" and stimulate their learning interest. Thirdly, personalized feedback enhances the sense of learning achievement. During the review and summary, teachers provide one-on-one guidance on each student's operational issues (such as "laryngoscope insertion too deep" and "insufficient inflation of the laryngeal mask"), helping students clarify the direction for improvement and boosting their learning confidence.

This study has the following limitations:

(1) The sample size is relatively small and drawn from a single teaching hospital, which may limit the generalizability of the findings. Further validation through multi-center, large-sample studies is needed.

(2) Long-term follow-up (e.g., six months post-training) was not conducted, making it impossible to evaluate the long-term impact of high-fidelity simulation teaching on students' clinical practice abilities. Future research should track students' performance in managing difficult airways after they enter clinical practice (e.g., success rates in handling difficult airways, incidence of complications).

(3) The study did not analyze differences in ability improvement among students with different educational backgrounds (undergraduate vs. postgraduate) or varying lengths of internships, making it difficult to determine the applicability of the teaching model to students with different foundational levels. Subsequent studies could design teaching plans stratified by students' foundational levels.

(4) The high cost of high-fidelity simulation equipment may restrict the widespread adoption of this teaching model in primary hospitals. Future efforts should explore "low-cost, high-efficiency" simulation teaching solutions (e.g., simulation training combined with virtual reality technology).

5. Conclusion

In summary, high-fidelity simulation teaching, through its four-stage model of "theoretical preview–scenario simulation training–debriefing and summary–intensive training", effectively enhances the theoretical knowledge, operational skills, and emergency response capabilities of anesthesia nursing students in managing difficult airways, significantly improving teaching satisfaction.

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