Biomedical and Biopharmaceutical Research
Abbreviation: Biomed. Biopharm. Res.
Volume: 22: Issue: 02 |Year: 2025
Page Number: 815-823

Effectiveness of Simulation-Based Training in Improving Endotracheal Intubation Competence Among Undergraduate Medical Students: A Prospective Interventional Study

Dr Monika[1], Dr Priyanka Chourasia[2], Dr Geeta Bhandari[3], Dr Jahanara[2], Dr Rahul Saxena[2]

[1] 3rd year Post graduate resident, Department of Anaesthesiology, Critical Care, Pain & Palliative Medicine, Government Medical College & Dr. Susheela Tiwari Hospital, Haldwani, Nainital, Uttarakhand

[2] Assistant professor, Department of Anaesthesiology, Government Medical College & Dr. Susheela Tiwari Hospital, Haldwani, Nainital, Uttarakhand

[3] Professor and Head, Department of Anaesthesiology, Critical Care, Pain and Palliative Medicine, Government Medical College & Dr. Susheela Tiwari Hospital, Haldwani, Nainital, Uttarakhand

Corresponding Author

Dr Rahul Saxena

Assistant professor, Department of Anaesthesiology, Government Medical College & Dr. Susheela Tiwari Hospital, Haldwani, Nainital, Uttarakhand

Received: 21-06-2025

Accepted: 05-07-2025

Published: 09-08-2025

ABSTRACT

Background: Endotracheal intubation is a critical, life-saving procedure requiring not only theoretical knowledge but also well-developed procedural skills and clinical judgment. Traditional teaching meth-ods for undergraduate medical students are increasingly limited by medico-legal concerns and patient safety priorities. Simulation-based training (SBT) has emerged as a valuable educational tool, offering safe, controlled environments for procedural practice. This study aimed to assess the effectiveness of simulation-based training in improving endotracheal intubation competence among undergraduate med-ical students.

Methods: A prospective interventional study was conducted at the Department of Anaesthesiology, Dr. Sushila Tiwari Memorial Government Hospital, Haldwani, India, over 18 months. A total of 140 medi-cal interns were randomly assigned to either a Simulation group (n=70) or a Non-simulation group (n=70). Both groups received standardized theoretical training, followed by six days of either manne-quin-based simulation practice or hands-on clinical practice. On the seventh day, endotracheal intuba-tion competence was assessed in the operating theatre by a blinded assessor using a validated 6-item scoring system. Secondary outcomes included intubation time, trainee satisfaction, and complication rates.

Results: Both groups were demographically comparable in terms of age (p=0.77) and gender distribu-tion (p=0.61). The Simulation group demonstrated significantly faster mean intubation times (8.27 ± 3.64 seconds vs. 9.79 ± 3.84 seconds; p=0.018), higher equipment handling scores (p=0.001), and bet-ter intubation technique scores (p=0.019) compared to the Non-simulation group. Overall competency scores were also significantly higher in the Simulation group, with 75.7% achieving excellent scores versus 41.4% in the Non-simulation group (p<0.001). Individual satisfaction was markedly higher in the Simulation group (94.3% vs. 61.4%; p<0.001). Although complication rates were lower in the Simu-lation group, the difference was not statistically significant (p=0.30).

Conclusion: Simulation-based training significantly enhances endotracheal intubation competence, pro-cedural efficiency, technical proficiency, and learner satisfaction among undergraduate medical stu-dents. These benefits were independent of demographic factors and support the integration of simula-tion modules into undergraduate medical curricula to improve procedural skills and patient care out-comes.

KEYWORDS: Simulation-based training, Endotracheal intubation, Clinical skills training, Patient safety.

INTRODUCTION

Endotracheal intubation is one of the most critical procedures performed in emergency and perioperative care, playing a decisive role in maintaining airway patency and ensuring patient safety. Its successful execution demands not only theoretical knowledge but also well-developed procedural skills and sound clinical judgment. For undergraduate medical students, acquiring competence in this procedure is essential, as it directly impacts patient outcomes and minimizes the risk of potentially life-threatening complications.

Historically, the apprenticeship model and opportunistic learning in clinical settings have formed the backbone of procedural training for medical students. In the case of intubation, traditional teaching methods typically involve didactic lectures, demonstrations, and supervised hands-on practice in operation theatres. However, limitations such as reduced patient availability, medico-legal concerns, and the growing emphasis on patient rights have increasingly restricted opportunities for trainees to gain adequate practical exposure [1]. These challenges have driven educators to seek alternative training modalities that prioritize both learner development and patient safety.

Simulation-based training (SBT) has emerged as an effective complement to conventional clinical teaching. By creating realistic, controlled environments using mannequins, part-task trainers, and high-fidelity simulators, simulation allows students to repeatedly practice procedures, refine their skills, and receive immediate feedback without risking patient harm [2–5]. Notably, it also enables the replication of rare but critical airway scenarios, such as unanticipated difficult intubations, thus preparing students for situations they might encounter infrequently in routine practice [6–8].

Over the years, simulation has demonstrated its value across various domains of medical education. Studies have consistently shown improvements in clinical competence, procedural efficiency, teamwork, and decision-making skills among students and healthcare professionals who undergo simulation-based training [9–12]. Recognizing its educational potential, the National Medical Commission (NMC) of India has recently mandated the establishment of skill laboratories within medical institutions, providing students with structured access to simulation-based learning opportunities for procedures including endotracheal intubation, cardiopulmonary resuscitation, and intravenous access [13].

Despite accumulating evidence favoring simulation in clinical skills education, comparative studies evaluating its effectiveness specifically for endotracheal intubation training among Indian medical undergraduates remain scarce. This prospective interventional study aims to address this gap by comparing simulation-based and non-simulation-based training methods in terms of intubation competence, intubation time, trainee satisfaction, and procedural complications. The insights gained from this research could help refine undergraduate medical education strategies, ensuring future healthcare professionals are better equipped to deliver safe and effective patient care.

METHODOLOGY

Study Design and Setting

This prospective interventional study was conducted at the Department of Anaesthesiology, Dr. Sushila Tiwari Memorial Government Hospital, Haldwani, India, over 18 months following institutional ethics approval. The study compared simulation-based training (Group A) versus direct hands-on clinical training (Group B) for endotracheal intubation (ETI) competence among medical interns.

Study Population and Eligibility criteria:

- **Sample Size and Sampling**: A total of 140 interns were enrolled, with each batch of 6 interns rotated through the department every 14 days. Purposive sampling (complete enumeration) was used.
- **Inclusion Criteria**: Medical undergraduate interns completing a compulsory 14-day rotatory internship in anaesthesiology during the study period.
- **Exclusion Criteria**: Interns declining informed consent.

Ethical Approval
The study protocol was approved by the Institutional Ethics Committee. Written informed consent was obtained from all participants prior to enrolment.
Intervention Protocol
1. **Theoretical Training**:
All interns received standardized theoretical education on endotracheal intubation(ETI) via: Blackboard tutorials, Video lectures, Live demonstrations of ETI techniques.
2. **Randomization**:
   Participants were randomly allocated to Group A or B using a computer-based random number generator (www.randomization.com).
3. **Group-Specific Training**:
- **Group A (Simulation-Based Training; *n* = 70)**:
Under supervision of a trained anaesthetist (X), participants practiced ETI on an airway management mannequin for 6 days (6 attempts total).
- **Group B (Clinical Training; *n* = 70)**:
Under supervision of a trained anaesthetist (Y), participants performed ETI directly on patients in the operating theatre (OT) for 6 days (6 attempts total).
Patients were 18–60 years, ASA I/II or MPS I/II, with no anticipated difficult airway, and consent was obtained per institutional policy.
Competency Assessment
On day 7, a blinded anaesthetist (Z) assessed ETI competence in the OT using a validated 6-item scoring system.
1. **Equipment check**
2. **Patient positioning**
3. **Pre-intubation airway management**
4. **Laryngoscopy technique**
5. **Endotracheal tube insertion**
6. **Confirmation of tube placement**

Scoring:
Each item was rated 0–3 (0: unsatisfactory; 3: excellent). Cumulative scores categorized competence as:
- 0–4: Unsatisfactory
- 5–9: Marginal
- 10–14: Acceptable
- 15–18: Excellent.

Secondary Outcomes
1. **Intubation Time**: Duration from laryngoscope blade advancement to 4 consistent et CO_2 wave forms[14].
2. **Individual Satisfaction**: Assessed via post-procedure questionnaire
3. **Complications**: Mucosal injury, dental malocclusion, lip cuts, uvular/tonsillar bleeding, or vocal cord damage.
- Safety Protocol: Failed intubation (≥2 attempts) or complications prompted intervention by anaesthetist Z.

Statistical Analysis
Data were analyzed using SPSS version 20.0. Continuous variables, such as intubation time and competence scores, were presented as mean ± standard deviation (SD), while categorical variables were expressed as percentages. Paired *t*-tests were used to compare intubation times, chi-square tests were applied to assess differences in success rates, and one-way ANOVA was performed to evaluate the relationship between competence scores and training duration. A *p*-value of less than 0.05 was considered statistically significant.

RESULT

A total of 140 undergraduate medical students were included in this study, divided equally into Simulation and Non-simulation groups (70 in each). The following tables and figure summarize the outcomes observed across various parameters assessing the competence of endotracheal intubation.

In this study the mean age of participants in the SIMULATION group was 24.30 years (SD = 1.788), while the NS group had a mean age of 24.39 years (SD = 1.671). The standard error of the mean was 0.214 for the SIMULATION group and 0.200 for the NS group. Statistical analysis revealed no significant difference in age between the two groups ($p = 0.77$), indicating that the groups were comparable in terms of age distribution.

Regarding gender distribution, the NS group consisted of 40 females and 30 males, while the SIMULATION group included 37 females and 33 males. Across both groups, there were a total of 77 females and 63 males. A chi-square test showed no significant difference in gender distribution between the groups ($\chi^2 = 0.26$, $p = 0.61$), confirming a balanced gender representation.

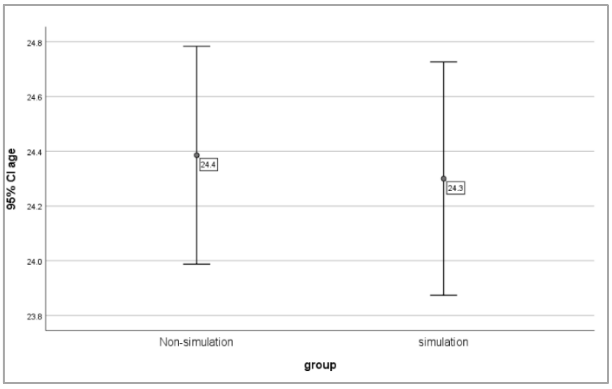

Fig 1. Distribution of study subjects as per age

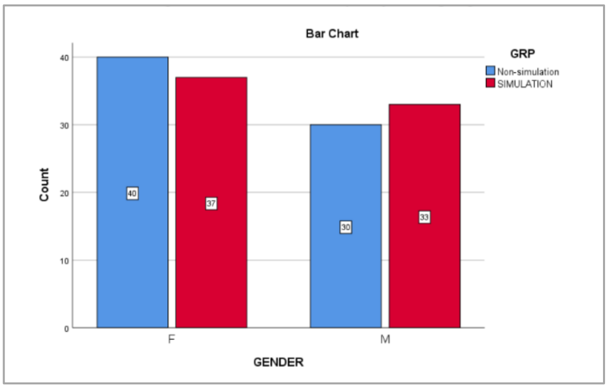

Fig 2. Distribution of study as per gender

The presents study showed that the mean intubation times for study subjects in two groups: Simulation and Non-simulation. The Simulation group, consisting of 70 participants, had a mean intubation time of 8.27 seconds with a standard deviation of 3.64, while the Non-simulation group had a mean of 9.79 seconds with a standard deviation of 3.84. The p-value of 0.018 indicates a statistically significant difference in intubation times between the two groups, with the Simulation group performing the task more quickly on average. (table 1)

Table 1: Mean Intubation time:

Group	**N**	**Mean (sec)**	**SD**	**Std. Error Mean**	**P Value**
Simulation	70	8.27	3.64	0.44	**0.018**
Non-Simulation	70	9.79	3.84	0.46	

In our study the Non-simulation group, 47.1% of participants had an excellent score, 15.7% had an acceptable score, 30.0% had a marginal score, and 7.1% had an unsatisfactory score. In the Simulation group, 75.7% had an excellent score, 12.9% had an acceptable score, 5.7% had a marginal score, and 5.7% had an unsatisfactory score. The chi-square value of 16.52 and p-value of 0.001 indicate a statistically significant difference in equipment scores between the two groups. (Table 2)

Table 2: Distribution as per Equipment Score

Equipment Score	**Non-Simulation (N=70)**	**Simulation (N=70)**	**P Value**
Excellent	33 (47.1%)	53 (75.7%)	**0.001**

Equipment Score	Non-Simulation (N=70)	Simulation (N=70)	P Value
Acceptable	11 (15.7%)	9 (12.9%)	
Marginal	21 (30.0%)	4 (5.7%)	
Unsatisfactory	5 (7.1%)	4 (5.7%)	

In the present study it showed that the Non-simulation group, 65.7% of participants had an excellent score, 11.4% had an acceptable score, 11.4% had a marginal score, and 11.4% had an unsatisfactory score on their intubation technique. In the Simulation group, 87.1% achieved an excellent score, 7.1% had an acceptable score, 2.9% had a marginal score, and 2.9% had an unsatisfactory score. The chi-square value of 9.99 and p-value of 0.019 indicate a statistically significant difference in intubation technique scores between the two groups.(Table 3)

Table 3: Intubation Technique Score

Intubation Score	Non-Simulation (N=70)	Simulation (N=70)	P Value
Excellent	46 (65.7%)	61 (87.1%)	**0.019**
Acceptable	8 (11.4%)	5 (7.1%)	
Marginal	8 (11.4%)	2 (2.9%)	
Unsatisfactory	8 (11.4%)	2 (2.9%)	

In present assessment of study subjects based on their total competency scores in two groups: Non-simulation and Simulation. Among the Non-simulation group, 41.4% had excellent scores, 50.0% had acceptable scores, and 8.6% had marginal scores. In the Simulation group, 75.7% had excellent scores, 22.9% had acceptable scores, and 1.4% had marginal scores. The chi-square test yielded a value of 17.67 with a p-value of less than 0.001, indicating a statistically significant difference in total competency scores between the two groups.(Table 4)

Table 4: Total Competency Score

Competency Score	Non-Simulation (N=70)	Simulation (N=70)	P Value
Excellent	29 (41.4%)	53 (75.7%)	**<0.001**
Acceptable	35 (50.0%)	16 (22.9%)	
Marginal	6 (8.6%)	1 (1.4%)	
Unsatisfactory	0 (0%)	0 (0%)	

In this study showed that the Non-simulation group, 61.4% of participants were satisfied and 38.6% were unsatisfied. In the Simulation group, 94.3% were satisfied and 5.7% were unsatisfied. The Chi-square test produced a value of 21.92 with a p-value of less than 0.001, indicating a statistically significant difference in individual satisfaction between the two groups.(Table 5)

Table 5: Individual Satisfaction

Satisfaction Level	Non-Simulation (N=70)	Simulation (N=70)	P Value
Satisfied	43 (61.4%)	66 (94.3%)	**<0.001**

Satisfaction Level	Non-Simulation (N=70)	Simulation (N=70)	P Value
Unsatisfied	27 (38.6%)	4 (5.7%)	

In present study it showed that 18.6% of students in the Non-simulation group experienced oesophageal intubation, compared to 11.4% in the Simulation group. Lip trauma occurred in 2.9% of the Non-simulation group and none in the Simulation group, while mucosal ulceration was equally distributed at 2.9% in both groups. The majority of students in both groups had no complications (75.7% in Non-simulation vs. 85.7% in Simulation). The chi-square test yielded a value of 3.62 with a p-value of 0.30, indicating no statistically significant difference between the two groups in terms of complication rates.(Table. 6)

Table 6: Complication Rates

Complication	Non-Simulation (N=70)	Simulation (N=70)	P Value
Oesophageal Intubation	13 (18.6%)	8 (11.4%)	0.30
Lip Trauma	2 (2.9%)	0 (0%)	
Mucosal Ulceration	2 (2.9%)	2 (2.9%)	
No Complication	53 (75.7%)	60 (85.7%)	

DISCUSSION

This prospective interventional study assessed the effectiveness of simulation-based training in improving endotracheal intubation competence among undergraduate medical students. The study included 140 participants equally divided into Simulation and Non-simulation groups, ensuring well-matched demographic variables to minimize potential confounding factors.

The age distribution between the Simulation and Non-simulation groups was comparable, with mean ages of 24.30 ± 1.79 years and 24.39 ± 1.67 years, respectively. A p-value of 0.77 confirmed no statistically significant difference between the groups, ensuring that age was unlikely to influence the study outcomes. These findings are consistent with those reported by Marc Lilot et al. [15], where no significant age differences were observed between groups in a similar simulation-based training study. This demographic balance reinforces the validity of attributing performance differences to the training methodology itself.

Similarly, the gender distribution was balanced, with 77 females and 63 males across both groups, and no statistically significant difference (p = 0.61) between them. These results mirror the observations of Cook et al. [16] and Zendejas et al. [17], who established that gender does not significantly affect the outcomes of simulation-based training, supporting its applicability across diverse learner groups. The demographic uniformity in this study enhances the reliability of attributing observed differences in intubation competence to the intervention itself rather than to inherent group differences.

In evaluating procedural efficiency, a statistically significant difference was observed in mean intubation times between the two groups. The Simulation group achieved faster intubation times (8.27 ± 3.64 seconds) compared to the Non-simulation group (9.79 ± 3.84 seconds; p = 0.018). This finding aligns with the results of Cook et al. [16] and Wang et al. [18], who reported that simulation-based training enhances both procedural speed and accuracy. The improved efficiency seen here is particularly relevant in emergency care settings where rapid, accurate intubation is crucial.

Equipment handling proficiency also showed significant improvement in the Simulation group, with 75.7% of participants achieving excellent scores compared to 47.1% in the Non-simulation group (p = 0.001). This outcome corroborates the work of Heinz R. Bruppacher et al. [19] and Chandra et al. [20], who demonstrated that simulation-based training significantly enhances technical skills, with simulation-trained participants showing superior equipment management skills that effectively translate to clinical practice.

A marked difference was observed in intubation technique scores, with the Simulation group achieving a significantly higher percentage of excellent scores (87.1%) compared to the Non-simulation group (65.7%; p = 0.019). This result is in agreement with Fauzia Minai's findings [21], which showed that simulation-trained groups performed significantly better in critical procedural tasks such as laryngoscope handling and intubation. The current study's results further substantiate the role of simulation in refining procedural techniques.
The total competency score also revealed a statistically significant difference favoring the Simulation group. Specifically, 75.7% of Simulation-trained students achieved excellent overall competency scores versus 41.4% in the Non-simulation group ($p < 0.001$). These findings resonate with those of Minai et al. [21], who observed significant disparities in overall competence favoring simulation-trained cohorts. The ability of simulation to provide a controlled, risk-free, and repetitive practice environment likely contributes to the superior competency outcomes observed in this study.
Participants' satisfaction levels were significantly higher in the Simulation group (94.3%) compared to the Non-simulation group (61.4%; $p < 0.001$). These results echo the findings of Boet et al. [22], who reported greater satisfaction among learners undergoing simulation-based training. Simulation's capacity for immersive, hands-on learning experiences and immediate feedback is believed to enhance learner confidence, engagement, and overall educational satisfaction.
While complication rates did not differ significantly between the two groups (p = 0.30), the Simulation group consistently exhibited lower complication rates across specific events such as oesophageal intubation (11.4% vs. 18.6%). Although not statistically significant, this trend aligns with studies by Sahu et al. [23] and Barsuk et al. [24], which reported reduced procedural complications following simulation training. The opportunity for repeated practice and error correction in a safe environment likely contributes to this reduction, reinforcing simulation's value in clinical education.
In summary, this study demonstrates that simulation-based training significantly improves endotracheal intubation competence among undergraduate medical students, as reflected in faster intubation times, superior equipment handling, better intubation technique, higher total competency scores, and greater learner satisfaction. These benefits were observed independent of demographic factors such as age and gender, reinforcing the effectiveness and broad applicability of simulation-based education. The findings support integrating simulation into undergraduate medical curricula to enhance procedural proficiency and improve patient care outcomes.

CONCLUSION

This prospective interventional study highlights the effectiveness of simulation-based training in enhancing endotracheal intubation competence among undergraduate medical students. The findings demonstrated that students who underwent simulation-based training achieved significantly faster intubation times, superior equipment handling, higher intubation technique scores, and greater overall competency compared to those trained through conventional methods. Furthermore, individual satisfaction levels were notably higher in the simulation group, reflecting improved learner engagement and confidence.
While no statistically significant differences were observed in complication rates between the two groups, the trend toward fewer complications in the simulation group reinforces the safety benefits associated with simulation-based education. Importantly, demographic factors such as age and gender were comparable between groups, affirming that the differences in clinical competence were attributable to the training methodology rather than participant characteristics.
In conclusion, simulation-based training represents a valuable adjunct to traditional clinical education, offering a safe, structured, and effective platform for students to acquire and refine essential procedural skills. The results of this study support the integration of simulation-based modules into undergraduate medical curricula to improve procedural proficiency, enhance learner satisfaction, and ultimately promote better patient care outcomes.

REFERENCES

1. V. Mejia, C. Gonzalez, A.E. Delfino, F.R. Altermatt, M.A. Corvetto, Acquiring skills in malignant hyperthermia crisis management: comparison of high-fidelity simulation versus computer-based case study, Rev. Bras. Anestesiol. 68 (3) (2018) 292–298
2. Cooper JB, Taqueti VR. A brief history of the development of mannequin simulators for clinical education and training. Qual Saf Health Care 2004; 13: 111–8
3. Abrahamson S, Denson JS, Wolf RM. Effectiveness of a simulator in training anesthesiology residents. J Med Educ 1969; 44: 515 –9
4. Denson JS, Abrahams S. A computer-controlled patient simulator. J Am Med Assoc 1969; 208: 504–8
5. Howard SK, Gaba DM, Fish KJ, Yang G, Sarnquist FH. Anaesthesia crisis resource management training: teaching anesthesiologists to handle critical incidents. Aviat Space Environ Med 1992; 63: 763 –70
6. Fletcher G, Flin R, McGeorge P, Glavin R, Maran N, Patey R. Anaesthetists' non-technical skills (ANTS): evaluation of a behavioural marker system. Br J Anaesth 2003; 90: 580–8
7. Flin R, Patey R, Glavin R, Maran N. Anaesthetists' non-technical skills. Br J Anaesth 2010; 105: 38 –44
8. Flin R, Maran N. Identifying and training non-technical skills for teams in acute medicine. Qual Saf Health Care 2004; 13: 180–4
9. J.S. Denson, S. Abrahamson, A computer-controlled patient simulator, JAMA 208 (3) (1969) 504–508.
10. F. Minai, F. Shafiq, M.I. Ul Haq, Value of real life (in situ) simulation training for tracheal intubation skills in medical undergraduates during short duration anaesthesia rotation, J. Anaesthesiol. Clin. Pharmacol. 30 (4) (2014) 484–487,
11. W.X. Sheng, F. Feng, B.J. Zhao, The application of medical simulation teaching methods in nerve block teaching, Cont. Med. Educ. 30 (10) (2016) 12–13
12. J.Y. Wu, T. Wang, Z. Wang, X.M. Qin, W.H. Lu, X.J. Jin, The value of simulation based medical education in central venous catheterization multimedia teaching, Chin. J. Clin. 10 (2)(2016) 303–306
13. J.H. Campos, E.A. Hallam, K. Ueda, Training in placement of the left-sided double-lumen tube among non-thoracic anaesthesiologists: intubation model simulator versus computer-based digital video disc, a randomised controlled trial, Eur. J. Anaesthesiol. 28 (3) (2011) 169–174
14. Ahmed, Syed Moied; Doley, Kashmiri; Athar, Manazir; Raza, Nadeem; Siddiqi, Obaid Ahmad; Ali, Shahna, 60-Comparison of endotracheal intubation time in neutral position between C-Mac® and Airtraq® laryngoscopes: A prospective randomised study, Indian Journal of Anaesthesia, 2017;61(4):p 338-343,
15. Lilot, Marc & Ehrenfeld, Jesse & Lee, C & Harrington, B & Cannesson, M & Rinehart, J. (2015). Variability in practice and factors predictive of total crystalloid administration during abdominal surgery: Retrospective two-centre analysis. British journal of anaesthesia. 114. 10.1093/bja/aeu452.
16. Cook TM, Woodall N, Harper J, Benger J; Fourth National Audit Project Major complications of airway management in the UK: Results of the Fourth National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society. Part 2: intensive care and emergency departments. Br J Anaesth. 2011;106:632–42.
17. Zendejas B, Brydges R, Wang AT, Cook DA. Patient outcomes in simulation-based medical education: a systematic review. J Gen Intern Med. 2013 Aug;28(8):1078-89. doi: 10.1007/s11606-012-2264-5. PMID: 23595919; PMCID: PMC3710391.
18. Wang HE, Seitz SR, Hostler D, Yealy DM Defining the learning curve for paramedic student endotracheal intubation. Prehosp Emerg Care. 2005; 9:(2)156-62
19. Bruppacher HR, Alam SK, LeBlanc VR, Latter D, Naik VN, Savoldelli GL, Mazer CD, Kurrek MM, Joo HS. Simulation-based training improves physicians' performance in patient care in high-stakes clinical setting of cardiac surgery. Anesthesiology. 2010 Apr;112(4):985-92. doi: 10.1097/ALN.0b013e3181d3e31c. PMID: 20234305.

20. Chandra DB, Savoldelli GL, Joo HS, Weiss ID, Naik VN. Fiberoptic oral intubation: the effect of model fidelity on training for transfer to patient care, Anesthesiology, 2008, vol. 109 (pg. 1007-13)
21. Urner M, De Lama G, Mema B. Mental Practice as an Additional Step Before Simulation Practice Facilitates Training in Bronchoscopic Intubation. Respir Care. 2021;66(8):1299-1305
22. Boet S, Bould MD, Fung L, Qosa H, Perrier L, Tavares W, Reeves S, Tricco AC. Transfer of learning and patient outcome in simulated crisis resource management: a systematic review. Can J Anaesth. 2014 June;61(6):571-82. doi: 10.1007/s12630-014-0143-8. Epub 2014 Mar 25. PMID: 24664414; PMCID: PMC4028539.
23. Jubaraj Sahu, Joseph L. Steger, Numerical simulation of three-dimensional transonic flows, Volume10, Issue8, Special Issue:Use of Supercomputers in the Solution of Complex Flow Problems, June 1990, Pages 855-873
24. Barsuk JH, McGaghie WC, Cohen ER, O'Leary KJ, Wayne DB. Simulation-based mastery learning reduces complications during central venous catheter insertion in a medical intensive care unit. Crit Care Med. 2009 Oct;37(10):2697-701. PMID: 19885989.