ORIGINAL ARTICLE

# Simulation Training in Hemodynamic Monitoring and Mechanical Ventilation: An Assessment of Physician's Performance

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## Abstract

**Background:** Simulation is to imitate or replicate real-life scenarios in order to improve cognitive, diagnostic and therapeutic skills. An ideal model should be good enough to output realistic clinical scenarios and respond to interventions done by trainees in real time. Use of simulation-based training has been tried in various fields of medicine. The aim of our study was to prospectively evaluate the effectiveness of simulation model "CRITICA"™ (MEDUPLAY systems) in training critical care physicians.

**Materials and methods:** The advanced intensive care unit (ICU) simulator "CRITICA"™ (MEDUPLAY systems) was developed as a joint collaboration between the Indian Institute of Science, Bengaluru and St John's Medical College, Bengaluru. Two-day workshop was conducted. Intensive didactic and case-based scenarios were simulated to formally teach principles of advanced ICU scenarios. The physicians were tested on clinical scenarios in hemodynamic monitoring and mechanical ventilation displayed on the simulator. Assessment of the analytical thinking and pattern recognition ability was carried out before and after the display of the scenarios. Pre- and posttest scores were collected.

**Results:** The postsimulation test scores were higher than pretest scores and were statistically significant in hemodynamic monitoring and mechanical ventilation module. [Hemodynamic monitoring pre- and posttest scores 4.41 (2.06) vs 5.23 (2.22) $p < 0.001$] [Mechanical ventilation pre- and posttest scores 4 (2–5.5) vs 7.5 (6.5–8.5) $p < 0.001$]. A greater increase in posttest scores was seen in the mechanical ventilation module as compared to hemodynamic module. There was no effect of specialty or designation of a trainee on difference in pre- and posttest scores.

**Conclusion:** Simulator-based training in hemodynamic monitoring and mechanical ventilation was effective. Comparison of routine classroom teaching and simulator-based training needs to be evaluated prospectively.


**Keywords:** Hemodynamic monitoring, Mechanical ventilation, Simulation, Training.

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## Background

Simulation is to imitate or replicate real-life scenarios. It has been widely used in various fields, including healthcare, where it has helped in training, understanding, and implementing skillsets in order to improve patient care and outcome.[1–4] An ideal simulation model should be good enough to demonstrate realistic clinical scenarios and respond to interventions done by trainees in real time.

In intensive care units (ICU), effective management of the critically ill is a difficult task and involves assimilation and integration of large volumes of information, critical thinking and correct decision-making.[2,4] In ICU, simulators are used in teaching cardiopulmonary resuscitation, difficult airway management and teaching skills like intravascular access.[5–7] The use of simulation in teaching advanced ventilatory and hemodynamic scenarios has not been well described.

The aim of our study was to prospectively evaluate the effectiveness of simulation model "CRITICA"™ (MEDUPLAY systems) in training critical care physicians. Primary objective was to evaluate clinician's performance as assessed by pre- and posttest scores. Secondary objective was to evaluate usefulness of the workshop as assessed by "Likert scale".

## Materials and Methods

The advanced ICU simulator "CRITICA"™ (MEDUPLAY systems) was developed as a joint collaboration with the Indian Institute of Science and St. John's Medical College in the year 2015. It is a complex macrosimulator. While designing the simulator, each feature of the simulator was tested among ICU trainees, and based on the feedback given, necessary modifications were done.

The simulator used in this study consists of a mannequin which is intubatable and simulates clinically examinable respiratory and cardiac functionality. In addition, there are two screens (Figs 1 and 2). One screen displays electrocardiogram (ECG), pulse oximetry, end tidal $CO_2$ ($EtCO_2$), noninvasive blood pressure (NIBP), arterial blood pressure, and cardiac output (Fig. 1). Additional functionalities like assessment of fluid responsiveness by systolic pressure variation, pulse pressure variation and demonstration of passive leg raising are also possible. The effect of drugs and pathological conditions on arterial wave morphology can be easily simulated.

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**Conflict of interest:** None

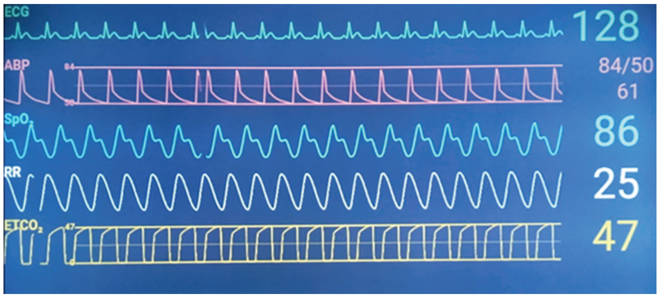


**Fig. 1:** Vital signs on simulator

The second screen replicates and simulates the outputs of a modern ICU ventilator and displays ventilator scalars, loops, different ventilator parameters and alarms settings (Fig. 2). Different modes like pressure control, volume control, pressure-regulated volume control, and pressure support can be simulated. The resistance and compliance of the simulated respiratory system are fully controllable by the trainer and changes made in these parameters are reflected in the loops and the scalars with high fidelity.

This simulator has been extensively and exclusively used in our institutional workshops for critical care trainees from 2015 to 2018. Total six workshops were conducted during this period. Pre- and posttest scores were available for five workshops. Before the workshop, teaching material was emailed to the registered participants. On day 1, mechanical ventilation was taught, and on day 2, hemodynamic monitoring was taught. Intensive didactic and case-based scenarios were simulated to formally teach principles of advanced ICU scenarios. Trainee's performance was tested by pretest and posttest scores. Pretest followed by posttest was conducted on day 1 and day 2 for the respective modules.

The questionnaire in mechanical ventilation included pattern recognition and clinical reasoning (Appendix: Supplementary material, Fig. A1). The scenarios in mechanical ventilation included identification of mode of ventilation, clinical reasoning for the same, phase variables, identifying compliance or resistance issues as in acute respiratory distress syndrome (ARDS) and chronic obstructive pulmonary disease (COPD) respectively, and it also included aspects of changing mode from volume to pressure control. For hemodynamic monitoring, the questionnaire comprised of complex integration of the available information and testing the skills on critical thinking and decision-making (Appendix: Supplementary material, Fig. A2). It included fluid assessment, arterial blood gas (ABG) analysis, ultrasonography (USG), echocardiographic evaluation and designing the management plan. Pretest included 10 questions each and for posttest, same questionnaire was given. Total score out of 10 was calculated.

Statistical analysis was done using Stata v14™ (College station, TX). Continuous variables were represented as mean (SD) or median (interquartile range) as appropriate. Paired "*t*" test was used for parametric data and "Wilcoxon signed rank" test was used for nonparametric data. Effect of specialty and designation on change in scores was evaluated by ANOVA (analysis of variance). At the end of workshop, feedback form consisting of five questionnaire was given and response was evaluated based on "Likert scale" (Appendix: Supplementary digital content, Table A1).

## Results

A total of 143 participants were evaluated. The presimulation test scores and postsimulation test scores were calculated.

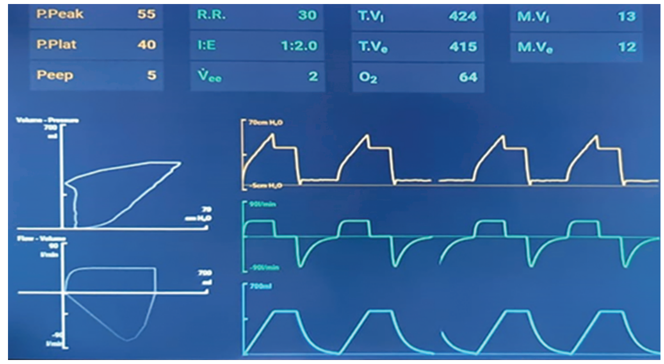


**Fig. 2:** Ventilator graphics on simulator

**Table 1:** Pre- and posttest evaluation of trainees

| *Variables* | *Hemody-namic (n = 75), mean (SD)* | *Mechanical ventilation (n = 71), median (IQR)* | *Pattern recognition question-naire (n = 143), me-dian (IQR)* | *Analytical thinking question-naire (n = 143), me-dian (IQR)* |
|---|---|---|---|---|
| Pretest | 4.41 (2.06) | 4 (2–5.5) | 1 (0–3) | 2 (0–3.5) |
| Posttest | 5.23 (2.22) | 7.5 (6.5–8.5) | 3 (0–5) | 4 (2–5.5) |
| Paired *t* test/ Wilcoxon signed rank test | $p < 0.001$ | $z = 7.281$, $p < 0.001$ | $z = 6.100$, $p < 0.001$ | $z = 6.591$, $p < 0.001$ |

Participants underwent 2 days workshop for hemodynamic monitoring and mechanical ventilation. Only participants who had both pre- and posttest results were included in analysis. Paired data were available for 75 participants for hemodynamic monitoring and 71 for mechanical ventilation. Pre- and posttest scores for both the modules were calculated. Posttest scores were higher for both the modules and were statistically significant (Table 1). Mechanical ventilation module posttest score was higher than the hemodynamic monitoring module. The analysis based on types of questionnaire, such as, pattern recognition or analytical thinking, posttest scores were higher and statistically significant as shown in Table 1. The feedback by trainees has been displayed using a Likert scale (Fig. 3). Trainees in different specialties were divided into two groups, such as, intensivist and nonintensivists. Similarly, designation of trainees was grouped into consultants and students. There was no effect of specialty and designation on difference between pre- and posttest scores in mechanical ventilation module, [$F(2,1)$ 0.67, $p = 0.51$] and in hemodynamic monitoring module [$F(2,1)$ 1.45, $p = 0.24$] (Appendix: Supplementary digital content, Tables A2 and A3). There was no effect of specialty on difference between pre- and posttest scores in pattern recognition questionnaire [$F(2,1)$ 0.37, $p = 0.69$] and in analytical thinking questionnaire [$F(2,1)$ 0.72, $p = 0.48$] (Appendix: Supplementary digital content, Tables A4 and A5).

## Discussion

The present ICU simulator has shown that teaching of advanced ventilator and hemodynamic monitoring is possible. It has helped the trainees in understanding the principles of mechanical ventilation and hemodynamic monitoring as shown by posttest scores. Trainees found this workshop as relevant and helpful and

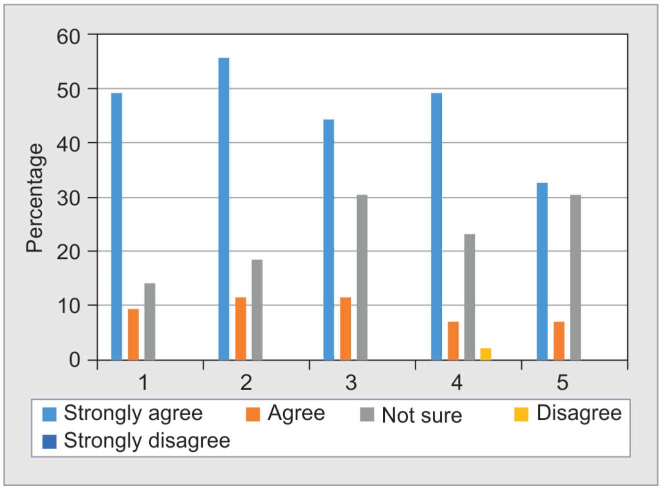


**Fig. 3:** Likert scale questionnaire assessment

were satisfied with the topics taught as suggested by feedback score analyzed by "Likert scale". There was no effect of specialty and designation on scores of trainees, possible reason being, this method of teaching was new and there was no prior experience of simulator-based training in the cohort evaluated in this study.

Various studies have used static simulation for teaching cardiopulmonary resuscitation, difficult airway management, ECG, and echocardiography.[5,6,8] These studies found that simulation-based learning was effective. It was also found to be useful in identification of medication-related errors.[9]

Simulation of mechanical ventilation was used in one study. This was a comparison between computer-based and mannequin-based learning and it showed that mannequin-based learning has the advantage of improving skills in managing mechanical ventilation.[10] In pediatric population, simulation of ARDS ventilation was found to be useful in improving time to effective interventions and behavioral skills.[11] Similar study was done in pediatric population using the embedded simulation training program, which involved three phases of training and study was done over a period of 2 years. This study showed 6–12 months of learning curve in implementation of training program. Repeated exposure to simulation is more beneficial than single exposure. This is in contrary to our study in which only a single assessment was done and our study did not look at long-term impact of simulator-based training.[12]

A meta-analysis comprising of 17 studies testing the use of simulator in various acute care settings, such as, emergency, trauma, operation room and ICU showed feasibility of simulation-based training in acute care settings, but there is lack of evidence on its effect on patient outcome.[13]

As compared to previous studies, this simulator is a high fidelity model and one can simulate any scenario by altering resistance and compliance of the respiratory system. In the hemodynamic monitoring module, various types of shocks can be simulated. Previous studies have shown that teaching a particular task, such as, echocardiography, extracorporeal membrane oxygenation (ECMO), pneumonia, palliative care, ARDS and cardiac surgery by using simulator is possible.[14–19] The advantage of the current simulation model is a single simulation model, which can help to understand cardiorespiratory pathophysiology and any cardiorespiratory derangement can be simulated but present simulator does not have difficult airway management module.

Our study has certain limitations. It was a single-center study. The trainee's performance was tested after 2 days of training and it showed improvement in the performance. In practice, based on one clinical assessment, it is difficult to find out if trainee has achieved adequate level of competence in dealing with the complex real-life critical care scenarios. It was a 2-day workshop training and the majority of participants who attended were not from same institute; hence, repeat assessment of the trainee's performance was not possible. As compared to previous studies, effect of stress and anxiety level was not tested and behavioral skills were not evaluated.[12,20] We could not compare simulator-based training with classical method of training.

## Conclusion

Present simulation model has shown to be beneficial in teaching advanced mechanical ventilation and hemodynamic monitoring to critical care physicians. Considering the complexity in managing critically ill patients as compared to other routine modalities of training, advantage of simulation-based training is that there is no harm to patients during training. Comparison of routine classroom teaching and simulator-based training needs to be evaluated prospectively.

## Take Home Message

Simulator-based training in hemodynamic monitoring and mechanical ventilation is effective and it may help the trainees to learn different aspects of hemodynamic monitoring and mechanical ventilation without causing any harm to the patient

## Availability of Data and Materials

The datasets used and analyzed in the present study are available from the corresponding author upon request.

## Author's Contribution

Amarja Ashok Havaldar helped in designing the study, designing questionnaire data collection, analysis, and drafted the manuscript. Bhuvana Krishna helped in drafting the manuscript, Sriram Sampath helped in statistical analysis and drafting the manuscript, and Sarvana Kumar Paramasivam helped in designing questionnaire

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# Appendix: Supplementary Materials

**Advanced Simulation Training in Critical Care (ASTriCC)**
**PRETEST MECHANICAL VENTILATION- DAY - 1**

1. Can you identify the mode of ventilator? P

2. Can you give the reason for same. A

3. Identify variables P

   a. Trigger :

   b. Limit :

   c. Cycle :

   d. Baseline :

4. In which of the following next two scenario the raised peak airway pressure will be harmful to lungs ? A

   a.

   b.

5. What maneuver need to be done to identify the same ? (cont of Q 4) A

6. What's the reason for the ventilator not to deliver the set TV P

7. The patient has developed ARDS now, what is the abnormality in the scalar & cause for the same. A

8. Now due to refractory hypoxemia patient has been proned, what's the abnormality? & reason for same. P

9. How to set up a ventilator when you change from VC to PC mode.

A

Question no. 1, 3,6,8 are pattern recognition

Question no 2,4, 5,7,9 are analytical questions

**Fig. A1:** Questionnaire for mechanical ventilation

**Table A1:** Questionnaire for evaluating feedback from the physicians

| | | | | | |
|---|---|---|---|---|---|
| 1. How satisfied were you with the workshop? | 1 | 2 | 3 | 4 | 5 |
| 2. How relevant and helpful do you think it was for your daily practice? | 1 | 2 | 3 | 4 | 5 |
| 3. How satisfied were you with the logistics? [Time given for each station] | 1 | 2 | 3 | 4 | 5 |
| 4. How satisfied were you with lectures and workstations? | | | | | |
| Day 1 (fundamentals of mechanical ventilator) | 1 | 2 | 3 | 4 | 5 |
| 5. How satisfied were you with lectures and workstations? | | | | | |
| Day 2 [hemodynamic monitoring] | 1 | 2 | 3 | 4 | 5 |

**Advanced Simulation Training in Critical Care (ASTriCC)**
**PRE-TEST HEMODYNAMIC MONITORING - DAY –2 –**

1. Interpretation of fluid status P
2. How you are going to resuscitate the patient A
   ABG: PH- 7.25 / $HCO_3$ – 18 / $PCO_2$ – 35 / Lactate – 3.6
3. a. Interpretation of Echo A
   b. What additional test you would like to do
4. Interpretation of arterial line P
5. Patient's ABG repeated, what is your next plan of action?
   ABG: PH- 7.2 / $HCO_3$ – 15 / $PCO_2$ – 38 / Lactate – 4 A
6. Which strategy you will use to improve patient's condition? A
7. Day 4 on ventilator support, Patient planned for extubation, repeat ECHO, USG was done, what is your plan? A

Question no. 2, 3,5,6,7 are analytical thinking type

Question no. 1, 4 are pattern recognition type

**Fig. A2:** Questionnaire for hemodynamic monitoring

**Table A2:** Change in mechanical ventilation module scores in specialty and designation

| *Specialty* | *Designation consultants* | *Students* | *Total* |
|---|---|---|---|
| Intensivist | 3.5 | 3.42 | 3.47 |
| Nonintensivist | 4.42 | 3.75 | 4.28 |
| Total | 3.69 | 3.46 | 3.62 |

**Table A3:** Change in hemodynamic monitoring module scores in specialty and designation

| *Specialty* | *Designation consultants* | *Students* | *Total* |
|---|---|---|---|
| Intensivist | 0.026 | 0.91 | 0.46 |
| Nonintensivist | 0.42 | –1.87 | 0.089 |
| Total | 0.104 | 0.8 | 0.42 |

**Table A4:** Change in pattern recognition scores in specialty and designation

| *Specialty* | *Designation consultants* | *Students* | *Total* |
|---|---|---|---|
| Intensivist | 0.84 | 0.77 | 0.81 |
| Nonintensivist | 1.38 | 0.75 | 1.19 |
| Total | 0.91 | 0.76 | 0.86 |

**Table A5:** Change in analytical thinking scores in specialty and designation

| *Specialty* | *Designation consultants* | *Students* | *Total* |
|---|---|---|---|
| Intensivist | 0.98 | 1.18 | 1.05 |
| Nonintensivist | 2.22 | 0.75 | 1.76 |
| Total | 1.13 | 1.14 | 1.13 |