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 (2.5) 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 monitoring. 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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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 participated in future workshops. The present study has shown that the present ICU simulator can be used for teaching advanced critical care trainees in critical care specialties.

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

| Variables                                      | Hemodynamic module | Mechanical ventilation module | Pattern recognition questionnaire | Analytical thinking questionnaire |
|------------------------------------------------|--------------------|-------------------------------|----------------------------------|---------------------------------|
| Pretest                                        | 4.41 (2.06)        | 5.23 (2.22)                   | 1 (0–3)                          | 2 (0–3.5)                      |
| Posttest                                       | 4.23 (2.62)        | 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           |

**Results**

A total of 143 participants were evaluated. The presimulation test scores and postsimulation test scores were calculated.
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. These studies found that simulation-based learning was effective. It was also found to be useful in identification of medication-related errors.

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. In pediatric population, simulation of ARDS ventilation was found to be useful in improving time to effective interventions and behavioral skills. 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.

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.

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. 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. 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, Sriman Sampath helped in statistical analysis and drafting the manuscript, and Sarvana Kumar Paramasivam helped in designing questionnaire.

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

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

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
Simulation Training in Critical Care

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 / HCO₃ - 18 / PCO₂ - 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 / HCO₃ - 15 / PCO₂ - 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*

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

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