

Simulation in Critical Care Medicine: A Meta-analysis

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Abstract

Simulation is a recognized method of teaching in academic medicine. Despite its long availability, only a paucity of information exists regarding its efficacy and utility on patient care and subsequently on patient outcomes. In this meta-analysis, we attempt to systematically study the effect of simulation-based clinical teaching in critical care medicine. A review of literature was conducted, looking across several databases, for any available studies that compare simulation to standard methods of teaching in the setting of critical care medicine on three surrogate outcomes: enhancement of knowledge, improvement in skills, and patient outcomes. In this study, 508 articles were found at the initial screening, however only 14 articles were eligible after applying our inclusion and exclusion criteria. Of these 14 articles only 5 were found to be randomized control trials and their outcomes were either knowledge or skill enhancement, no study on patient outcome was identified. Despite the significant heterogeneity between studies ($\chi^2 (4) = 120.73$) $p < 0.001$), the random effect was significant on both surrogate markers ($p < 0.001$). as a conclusion, albeit only a few randomized trials, simulation has a positive impact on knowledge and skill acquisition in the field of critical care medicine.

Keywords

Simulation; Critical care medicine; Randomized control study; Meta-analysis

Introduction

Simulation is a recognized method of teaching in the medical field and has been used over the last 15 years^[1]. The proliferation of simulation-based literature and research has gained significant momentum due to the fact that simulation plays a keystone role in health profession education and patient safety^[2-4]. It is commonly asserted, albeit with limited substantive data, that every hospital and other health professional training institution has either a simulation center, simulation equipment, or a simulation-based

educational program. Since the Institute of Medicine released "To Err Is Human: Building a Safer Health System in 2000"^[5] patient safety and medical errors has been the focus of many national initiatives. In Saudi Arabia many simulation-based workshops are held in hospitals and academic centers, including the very popular Advanced Cardiac Life Support (ACLS) and Advanced Trauma Life Support (ATLS). Like other centers across the globe, these courses are considered essential requirements for any practicing physician with direct contact to patients. Simulation has the

potential to revolutionize health care and address patient safety issues if appropriately utilized and integrated into the educational and organizational improvement process^[6-10].

Methods

We conducted a research looking at any available data on any existing recourses that discuss that issue. This involved screening articles published between 1966 and 2015 on Medline and PubMed, between 1980 and 2014 on Excerpta Medica dataBASE (EMBASE), between 1982 and 2014 on Cumulative Index to Nursing and Allied Health Literature (CINAHL), between 1967 and 2014 on PsycINFO and available studies listed on Educational Resources Information Center (ERIC). The following strings were each used independently and in combination with each other as queries for Medical Subject Headings (MeSH): simulations; education; medical teaching methods; curriculum; Critical care medicine; patient outcome; physicians, and other health care providers (nurses, paramedics). A hand-search of the bibliographies of relevant articles was also undertaken to identify further articles.

Inclusion Criteria

Article was identified to be eligible if:

- Has simulation in critical care settings; this includes medical and surgical Intensive Care Unit (ICU), Coronary Care Unit (CCU), Emergency room, Anesthesia, and in any setting where life support interventions are required.
- Simulation is compared to other teaching methods i.e. didactic teachings, standard patients, etc.
- The study's primary outcomes are efficacy in enhancing clinical knowledge, skills and competence on any health care providers (physicians, nurses, medical students, etc.) and/or patients' outcomes.
- Types of studies that are eligible are quantitative only.

Exclusion Criteria

- Poorly designed studies: a small number of students (< 5); lack of follow up.

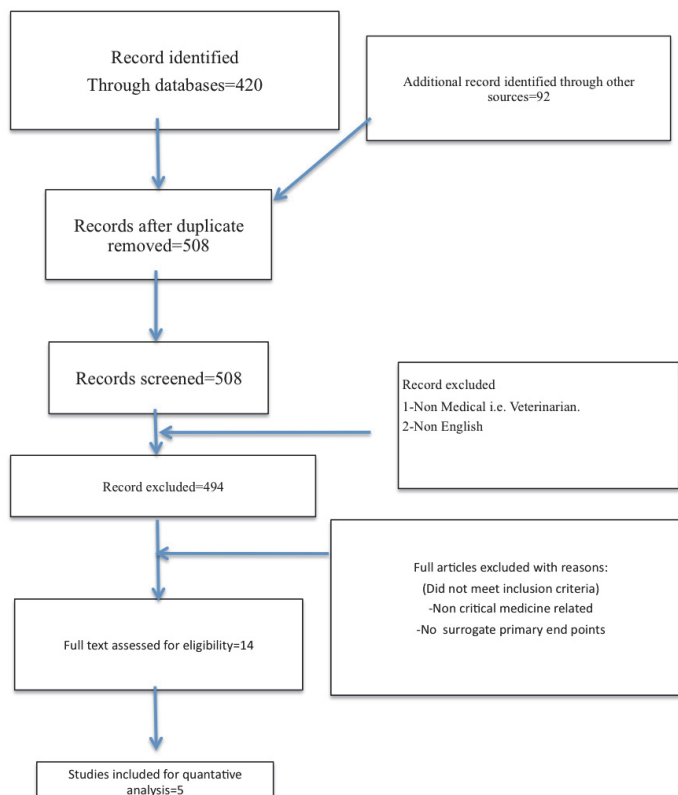


Figure 1. Summary of meta-analysis flow chart.

- Violation of any of the above inclusion criteria.
- Inability to discriminate the effect of simulation from another method of teaching.
- Non-English publication.
- Non-medical related simulation.

Figure 1 summarizes the systemic review flow diagram.

Three independent raters coded each study independently, then the cumulative data were summarized in a single coding sheet that provided the location of the study, the design, the sample size, the modality of simulation used and the effect on either knowledge or skills. Mean \pm standard deviation (SD) of each group was determined, then the data were entered into Stata12 program for calculating the effect size and generating the Forest plot.

Results

Out of the 14 articles we identified 5 randomized control trials^[11-15] that compared simulation in critical care sitting to the standard method of teaching. All of these trials were conducted in a single US center with the exception of one of which was a multinational multicenter trial. The first trial^[11] was conducted on internal medicine (IM) resident PGY3, the second^[12] was on IM residents from four different hospitals and 4 different PGY levels of training. The third and fourth^[13,14] were on nursing students, and the last^[15] was on trauma team members (including ER physicians, nurses and residents). These trials are summarized respectively in Table 1. The areas of testing for studies 1 and 2, and 5^[11,12,15] were airway management, Sepsis skill enhancement and mean t-notches score on resuscitation time, length of stay in hospital. Studies 3 and 4 were mainly knowledge enhancement in the subject of advanced problem solving in critical care medicine: cardiology, pulmonary, monitoring, neurology, endocrine, renal and other

domains like proper sterilization for study number 3; confidence and competence in dealing with different critical scenarios for study number 4. None of the trials reported the effect on patient outcomes. High Fidelity simulators were used in all studies and in all studies the standardized teaching method was lecture-based teaching.

Regarding sample size, a total of 426 participants were involved in the simulation arm vs. 466 in the standard teaching arm, with one study contributing 219 participants of the total. After the independent coding was done using three different raters, a summary table of the Mean and SD was developed (Table 1) and data entered to "Stata" Program. A Forest plot was generated by "Stata" and depicted in Figure 2. Both random effect and fixed effect were calculated around the line of unity and the cumulative results were depicted as a line with a small and a large diamond for fixed and random effect, respectively. Heterogeneity was also reported using chi square (χ^2) and I square. Four out of the five studies showed a positive impact on knowledge and skills. However, the second trial showed a negative impact of simulation on sepsis management compared to standard lecture.

Table 2 summarizes the effect size of each study, its correspondent confidence intervals and the magnitude with which each study contributes to the analysis.

Finally, the Forest plot (Fig. 2) shows the five studies' random and fixed effect size with a positive impact of simulation on both surrogate markers of knowledge and skills.

Despite the significant heterogeneity between studies (χ^2 (4) = 120.73) $p < 0.001$, the random and fixed effect was statistically significant ($p < 0.001$), the funnel plot (Fig. 2) also supports the same finding with a very wide range of standard error of effect sizes due to heterogeneity.

Table 1. Summary of the five studies, with each one reporting N1= number of participants in the simulation arm; N2 = number of participants in the control arm; Mean1= mean of results related to simulation; Mean2 = mean results related to standard method of teaching; SD1 = Standard deviation related to results of simulation; SD2 = Standard deviation related to results of standard method of teaching.

	Name of the Study	N1	MEAN 1	SD1	N2	MEAN 2	SD2
1	Kory <i>et al.</i> , Chest 2007 ^[11]	32	25	5.3	30	9.9	8.8
2	Li <i>et al.</i> , Emerg Med 2011 ^[12]	47	85.6	15.8	51	91.1	6.27
3	Hoffman <i>et al.</i> , Simul Healthc 2007 ^[13]	29	62.76	7.18	29	52.52	8.4
4	Mould <i>et al.</i> , Contemp Nurse 2011 ^[14]	219	3.7	0.69	219	2.5	0.88
5	Steineman <i>et al.</i> , J Surg Educ 2011 ^[15]	99	17.7	5.0	136	16.7	5.0

Table 2. Summary of the standard mean difference (SMD) and effect size between the two arms of each of the studies; the confidence interval of each effect size; the weight given to each study; and the heterogeneity between studies using X and I squared methods. I-V Fixed effect and the D+L= Random effect.

Study	SMD	95% Conf. Interval	% Weight
1. Kory <i>et al.</i> , Chest 2007 ^[11]	2.095	(1.472 - 2.719)	5.27%
2. Li <i>et al.</i> , Emerg Med 2011 ^[12]	-0.465	(-0.866 - -0.063)	12.70%
3. Hoffman <i>et al.</i> , Simul Healthc 2007 ^[13]	1.310	(0.741 - 1.880)	6.33%
4. Mould <i>et al.</i> , Contemp Nurse 2011 ^[14]	1.518	(1.365 - 1.730)	45.30%
5. Steineman <i>et al.</i> , J Surg Educ 2011 ^[15]	0.200	(-0.060 - 0.460)	30.41%
I-V pooled SMD	0.883	(0.740 - 1.026)	100%
D+L pooled SMD	0.915	(0.053 - 1.776)	100%

Heterogeneity Chi-squared = 120.73 (d.f. = 4) $p = 0.000$
I-squared (Variation in SMD attributable to heterogeneity) = 96.7%
Test of SMD = 0: $z = 12.09, p = 0.000$.

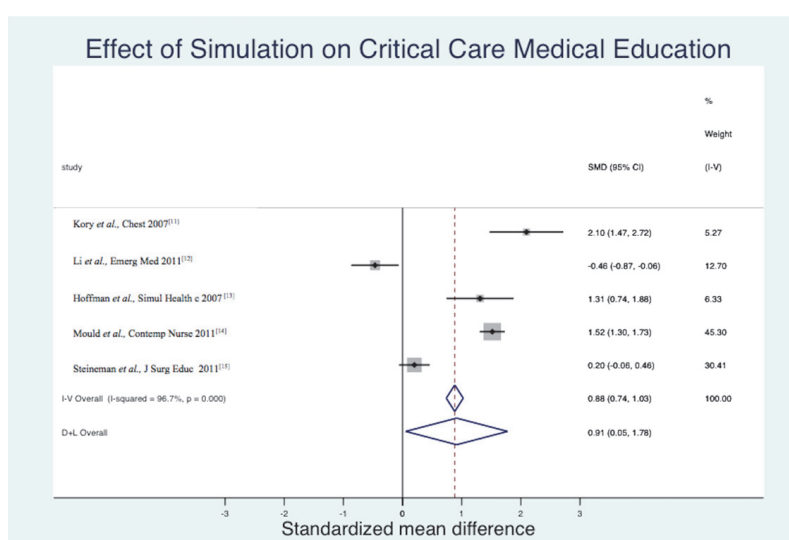


Figure 2. Forest plot of the meta-analysis. Small diamond is the fixed effect and the large diamond is the random effect.

Discussion

A significant amount of research evidence supports the benefits of simulation. Simulation is a well-established tool for training personnel in aviation, the military, and industry and is rapidly being transferred to the medical field. However, the extent to which simulation technology is available and used in academic medicine has not been systematically reviewed.

Within the field of critical medical education, simulation has been used as early as the late 1940s in anesthesia. However, mainly due to its cost, it did not grow rapidly until the late 1980s with the help of mannequins, when it became the standard of teaching in courses like ACLS and ATLS. Procedures like intubation and central line insertion are taught universally using simulators. However, despite the

rapid acquisition of such approaches in teaching, the evidence to support these trends remains unclear. Through a systematic review of the available literature, we tried to identify the most robust evidence available that supports the use of simulators and its utility in critical care medicine.

Despite the significant contribution of simulation in medical education, there is still a paucity of robust data to assess the impact on clinical knowledge and skill acquisitions and even less on the effect on patients' outcome. The quality of the studies selected for this paper was the best to be found, yet their inclusion remained quite challenging. The design of each study included is not standardized hence a significant heterogeneity was noted. The lack of reporting certain factors such as age, gender, duration

of intervention, and level of raters made it difficult to undertake further analysis such as subgroup analysis or meta-regression analysis to correct for confounders and more importantly to reveal determinants of latent factors or successful settings where simulation works best. Most of the studies also had a small sample size and therefore were underpowered to a degree that could skew the data results.

Nevertheless, understanding how labor-intensive it is to conduct a simulation-based study make these data very valuable and as they stand, they provide an overview that simulation works nicely in enhancing knowledge and skills in the right setting if conducted properly.

The limitations of this meta-analysis are as follows: few studies were identified to be eligible; each with the exception of one were relatively small size studies; heterogeneity between the studies; and the inability to identify a specific moderator for such heterogeneity.

Conclusion

Despite the limited number of randomized control studies, simulation based medical education has a positive impact on knowledge and skill acquisition in the field of critical medical education. Further follow-up with more recent publications would help this seminal work to more capably achieve its primary objectives.

Conflict of Interest

The author has no conflict of interest.

Disclosure

The author did not receive any type of commercial support either in forms of compensation or financial for this study. The author has no financial interest in any of the products or devices, or drugs mentioned in this article.

Ethical Approval

Obtained.

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التعليم بالمحاكاة وتأثيره على طب العناية الحرجة: تحليل مقارن

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المستخلص. المحاكاة وسيلة معترف بها في مجال التدريس الأكاديمي الطبي، وبالرغم من أن هذه الوسيلة كانت ولا تزال متاحة لفترة طويلة، هناك قلة في المعلومات المتعلقة بفاعليتها كوسيلة تعليمية تؤثر على منسوب المهارات والمعرفة ثم على رعاية المرضى، ولذلك اخترنا دراسة بحثية متكاملة لدراسة تأثير التعليم بالمحاكاة على طب العناية الحرجة. قمنا بمراجعة شاملة للأبحاث في العديد من قواعد البيانات لأي دراسات متاحة ومقارنة المحاكاة بأي أسلوب قياسي آخر على ثلاث نتائج مهمة وهي: تعزيز المعرفة وتحسين المهارات وتحسين نتائج المرضى. تم العثور على ٥٠٨ مقالة علمية تناقش هذا الموضوع في الفحص الأولي، ١٤ منها كان مؤهلاً لتطبيق المعايير والشروط. من هذه المواد البحثية تم العثور على خمس بحوث أصيلة (دراسات سيطرة العشوائيات) وكانت نتائجها متعلقة بالمعرفة أو تعزيز المهارات الاكلينيكية، ولم يتعرف على أي مقالة تدرس التأثير على نتائج المرضى. على الرغم من عدم التجانس بين الدراسات إلا ان التأثير الاحصائي كان ايجابيا على تعزيز المعرفة والمهارات لدى الممارسين الصحيين. على الرغم من محدودية الدراسات العلمية إلا ان التعليم الطبي في طب العناية الحرجة بالمحاكاة له تأثير ايجابي مثبتاً علمياً وإحصائياً على اكتساب المعرفة وتحسين المهارات.