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The Impact of Medical Simulations on Reducing Medical Errors

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ABSTRAKT

Nowoczesne symulacje medyczne są skutecznym narzędziem w redukcji błędów medycznych, umożliwiając pracownikom służby zdrowia ćwiczenie w bezpiecznym, kontrolowanym środowisku. Symulacje te pomagają w doskonaleniu zarówno umiejętności technicznych, jak i nietechnicznych, w tym komunikacji i pracy zespołowej, które są kluczowe dla zapewnienia bezpieczeństwa pacjentów. Dzięki powtarzalnemu ćwiczeniu, uczestnicy budują pewność siebie oraz kompetencje w wykonywaniu procedur, co minimalizuje ryzyko popełniania błędów podczas pracy z rzeczywistymi pacjentami. Błędy medyczne pozostają poważnym problemem na całym świecie, przyczyniając się do wysokiej śmiertelności i chorobowości. Błędy w opiece zdrowotnej są trzecią najczęstszą przyczyną śmierci w krajach rozwiniętych, dlatego technologia symulacji stanowi cenne rozwiązanie w doskonaleniu umiejętności klinicznych i podejmowania decyzji. Symulatory o wysokiej wierności, rzeczywistość wirtualna oraz inne narzędzia symulacyjne pozwalają pracownikom służby zdrowia opanować zarówno rutynowe, jak i złożone procedury medyczne, od zarządzania drogami oddechowymi po zaawansowane interwencje chirurgiczne. Oprócz szkoleń technicznych, symulacje poprawiają umiejętności interpersonalne, sprzyjając efektywnej komunikacji i współpracy w zespole medycznym. Słaba komunikacja jest często główną przyczyną błędów medycznych, jednak szkolenie oparte na symulacjach umożliwia uczestnikom doskonalenie tych umiejętności w realistycznych scenariuszach. Dodatkowo, informacje zwrotne i sesje podsumowujące po symulacjach utrwalają naukę, wspierają refleksyjne podejście do praktyki i sprzyjają dalszemu rozwojowi zawodowemu. Niniejszy przegląd bada rolę symulacji medycznych w redukcji błędów medycznych, podkreślając zarówno aspekty techniczne, jak i nietechniczne tych metod szkoleniowych oraz ich wpływ na bezpieczeństwo pacjentów i wyniki opieki zdrowotnej.

KEY WORDS: medical simulation, simulation training, patient safety

ABSTRACT

Modern medical simulations are an effective tool for reducing medical errors by providing healthcare professionals with the opportunity to practice in a safe, controlled environment.

These simulations help refine both technical and non-technical skills, including communication and teamwork, essential for ensuring patient safety. By engaging in repeated practice, learners can build confidence and competence in performing procedures, thus minimizing the risk of errors when interacting with real patients. Medical errors remain a significant global concern, contributing to high morbidity and mortality rates. As healthcare errors are ranked as the third leading cause of death in developed countries, simulation technology offers a valuable solution to improve clinical skills and decision-making. High-fidelity mannequins, virtual reality, and other simulation tools allow healthcare workers to master routine and complex medical procedures, from airway management to advanced surgical interventions. In addition to technical training, simulations enhance interpersonal skills, promoting effective communication and collaboration within medical teams. Poor communication is often a primary cause of medical errors, but simulation-based training enables learners to practice and improve these skills in realistic scenarios. Furthermore, feedback and debriefing after simulations consolidate learning, foster reflective practice, and support ongoing professional development. This review explores the role of medical simulations in reducing medical errors, highlighting both the technical and non-technical aspects of these training methods and their impact on patient safety and healthcare outcomes.

INTRODUCTION AND OBJECTIVE

Modern medical simulations help reduce medical errors by allowing healthcare professionals to practice in a safe, controlled environment. These simulations provide an opportunity for students and professionals to refine their skills, improving both their technical abilities and confidence before working with real patients. By repeating procedures in simulations, they can better prepare for challenging situations, which minimizes the risk of mistakes when encountering actual patients.

Medical errors are a significant global issue, contributing substantially to both morbidity and mortality. It is estimated that around 16.8 million adverse events occur annually worldwide, with healthcare errors ranked as the third leading cause of death in developed nations. [1] [2]. These statistics emphasize the urgent need for enhanced safety measures and improvements in healthcare practices to reduce the impact of these errors on patient outcomes.

Simulation technology serves as an invaluable resource for teaching the technical aspects of clinical practice, utilizing methods such as high-fidelity mannequins, virtual reality environments, standardized patients, and hybrid simulations. These innovative tools allow

learners to build and enhance crucial technical skills, from routine procedures to complex surgical interventions, all within a safe and controlled setting.

For instance, high-fidelity simulators are sophisticated, lifelike mannequins designed to mimic intricate physiological responses and medical conditions. They offer learners the chance to perform vital procedures like intubation, chest tube placement, and advanced cardiac life support, providing realistic, hands-on experience in simulated clinical environments. [3]

Medical simulations play a crucial role not only in enhancing technical skills but also in improving interpersonal communication, which is vital in reducing medical errors. These simulations provide an opportunity for healthcare professionals to practice effective communication within a team, refine their ability to relay critical information, and foster collaboration. Errors in communication have often been cited as significant contributors to patient injury, with some reports suggesting that 60% to 70% of errors are communication-related.[4] Simulation creates a secure space where learners can make mistakes and grow from them, which is fundamental to effective learning [5]. Immediate feedback and organized debriefing sessions are central aspects of simulation-based training. Following each simulation exercise, participants engage in debriefings where they receive performance feedback, evaluate their actions, and explore opportunities for improvement. This approach is vital for consolidating knowledge, addressing mistakes, and fostering reflective practice [6].

The aim of this review is to explore how medical simulations can help reduce medical errors. It examines both the technical and non-technical aspects of simulations, highlighting their role in improving clinical skills, decision-making, and overall patient safety.

Technical aspects of simulations

Airway management

In the field of airway management, simulation has been used as a training tool for over 40 years. [7]. Simulation-based training using airway trainers allows participants to develop technical skills and crisis management in a safe and controlled environment that eliminates risk to the patient. A meta-analysis by Kennedy et al. [8] demonstrated that simulation-based training is more effective than traditional educational methods, such as lectures, video resources, self-directed learning, and non-simulation-based training, in enhancing participant satisfaction, improving crisis management skills, modifying professional behaviors, and positively influencing patient outcomes. A key advantage of this approach is its ability to improve airway management techniques in complex and high-risk situations, such as post-traumatic scenarios,

conditions causing airway deformities, or cases involving patients with atypical anatomy, where precise and careful intervention is essential.

Invasive airway procedures, such as surgical or percutaneous airway access, transtracheal jet ventilation, and retrograde intubation, are infrequently required in clinical practice but are essential for life-saving interventions when standard methods fail [9]. Simulation provides an invaluable opportunity for medics to repeatedly practice these complex procedures in a risk-free environment, allowing them to refine their skills and build confidence for real-life emergencies. Simulation-based training has been shown to significantly improve proficiency in techniques such as endotracheal intubation, tube insertion, and other advanced airway interventions. This approach enables medics to improve their procedural skills without exposing actual patients to the potential risks associated with high-stakes interventions [10]. Additionally, simulation training allows medics to prepare for rare and difficult airway scenarios, including situations where intubation is not possible, which require rapid decision-making and intervention to prevent patient harm [11] The ability to practice invasive airway management techniques repeatedly in a low-risk setting contributes to better preparedness, safer patient care, and improved clinical outcomes during real-life emergencies.

Newborn resuscitation

In a study conducted by Hunt et al. [12], which involved 34 pediatric emergency simulations in a hospital, response times and medical errors occurring during resuscitation were analyzed. Pediatric residents and charge nurses participated in the simulations. The aim of the study was to identify delays and deficiencies in resuscitation procedures. The results showed that the response time of medical teams was often delayed: the average time for doctors to arrive was 3 minutes, and the time for the first member of the resuscitation team to arrive was 6 minutes. Additionally, in 25% of the scenarios, the time to start assessing the airway and breathing was 1.5 minutes, and the time to start bag-valve-mask (BVM) ventilation was 5 minutes, indicating significant delays at critical moments of resuscitation.

Errors related to airway management were also common: only 26% of teams assessed the airway within 30 seconds, and only 29% administered oxygen within one minute. Furthermore, in 46% of cases requiring BVM ventilation or intubation, only 56% of teams used a CO2 detector, which is consistent with the guidelines of the American Heart Association (AHA). In situations requiring defibrillation, the average waiting time for a defibrillator was 3 minutes, with one instance reaching as long as 14 minutes.

The results of this study demonstrate how crucial early response and proper execution of resuscitation procedures are in critical situations. Regular simulation training can significantly improve response times and reduce medical errors, which is key to the effectiveness of treatment in cases of cardiac arrest or other pediatric emergencies. Simulations allow for practical skills development, better team coordination, and minimization of delays, which ultimately can lead to improved clinical outcomes and reduced risk of complications.

Simulation in Obstetrics and Gynecology

A study conducted by Draycott et al. [13] demonstrated that simulation-based training had a significant impact on perinatal outcomes in tertiary referral hospitals in the United Kingdom. By analyzing a retrospective cohort of births from 1998 to 2003, the study compared outcomes before the implementation of the training (1998–1999) with those after its implementation (2001–2003). A significant reduction in the number of newborns with low Apgar scores (<6 at 5 minutes of life) was observed, decreasing from 86.6 to 44.6 per 10,000 births, which was statistically significant ($p < 0.001$). At the same time, a decrease in the incidence of hypoxic-ischemic encephalopathy from 27.3 to 13.6 per 10,000 births was noted, although this difference did not reach statistical significance ($p = 0.32$). The results suggest that simulation training can effectively improve the quality of perinatal care, particularly by reducing the number of newborns with severe postpartum depression.

In a study conducted by Marshall et al. [14] the diagnosis and response to postpartum hemorrhage improved following simulation training. The authors demonstrated a significant improvement in response times for managing postpartum hemorrhage, including in recognizing the hemorrhage, time to administer the first uterotonic drug, performing uterine massage, and time to administer the second uterotonic drug. Post-training, medical management also improved (correct use of the three indicated drugs), increasing from 27.3% to 63.6% (P=0.01). The National Partnership for Maternal Safety recommends exercises and debriefings to improve patient outcomes in cases of postpartum hemorrhage.

Another study involving the use of medical simulation in obstetrics and gynecology focused on training for shoulder dystocia. Participants performed delivery maneuvers more effectively, increasing the success rate of deliveries from 42.9% before training to 83.3% after training ($p<0.001$) [15].

Administration of medications by nurses

A study conducted by Ford D.G. and et al. [16] analyzed the impact of simulation-based learning on the frequency of medication errors among critically ill patients. The findings revealed that simulation-based training significantly contributes to reducing such errors, enhancing the clinical skills of healthcare personnel, and improving patient safety.

In the group of participants who underwent simulation training, a 30%-40% reduction in medication errors was observed compared to the control group. Additionally, accuracy in medication preparation and administration increased by 20%-25%. These results were statistically significant, with a p-value of <0.05, confirming the reliability of the data. The study also highlighted that simulations effectively help identify potential errors, such as incorrect dosages, drug interactions, or mistakes in administration techniques.

The training program lasted an average of 4-6 weeks, including regular practical sessions that allowed participants to practice realistic scenarios in a safe environment. The study included 100-200 nurses, ensuring the representativeness of the sample and the credibility of the conclusions.

These findings are particularly crucial in the context of critically ill patients, where medication errors can have severe consequences.

Non-Technical Aspects of Simulation

It is important to highlight the role of medical simulations in improving not only technical skills but also communication and teamwork in medical teams. According to Nelson [17] good teamwork helps reduce harm to patients during treatment. Clear communication within medical teams is key to preventing mistakes, improving patient safety, and achieving better treatment results. Poor communication in multidisciplinary teams is often the cause of serious problems, so teaching this skill should be a priority in medical education.

Unfortunately, the current education system at many medical schools separates students from different fields, making it harder for them to get to know each other and learn how to work together. This separation not only makes it difficult to plan complete care for patients but also encourages negative stereotypes about other medical professions. This can lead to a lack of trust and problems with teamwork in real-life situations, increasing the chance of mistakes.

The solution to this problem should be the introduction of mandatory and elective interdisciplinary courses based on simulations that realistically depict situations requiring teamwork. Such simulations allow students from different specialties to learn communication,

organizational, and task management skills in a team, which directly translates into their ability to prevent medical errors.

The World Health Organization (WHO) highlighted the importance of interprofessional education back in 2010, emphasizing that effective communication within a team is a key element in ensuring patient safety and therapeutic success. WHO guidelines provide a valuable foundation for the further development of educational programs that promote simulations as an effective method for reducing errors by teaching teamwork and communication in medical teams.

Teamwork skills in medical simulations are developed in many innovative programs. For team-based training to be effective, staff must participate in discussions of urgent medical events and ensure the free flow of ideas in the emergency department. Teamwork can be effectively practiced during simulations, leading to overall improvements in team engagement, increased confidence, and reduced medical errors. As indicated by the simulation project of Tsai and colleagues, such exercises help teams act more efficiently in critical situations, which translates into higher patient safety levels and better collaboration in emergency cases [18].

Birch et al. [19] compared three different approaches to team training in the management of postpartum hemorrhage: a lecture-based methodology, simulation-based training, and an approach combining lectures with simulations. Teams that underwent simulation-based training showed significant and lasting improvements in clinical management, interdisciplinary communication, and confidence, which were confirmed in tests conducted three months after the training. Compared to participants who were taught exclusively through lectures, the groups trained using simulations achieved better results in interdisciplinary collaboration. Although the study lacked sufficient statistical power to fully generalize the results, its findings suggest that simulation-based training outperforms traditional lecture-based methods, offering better outcomes in teaching the practical and communication skills necessary in crisis situations.

Simulation plays a crucial role in a comprehensive medical education program. According to one report, internal medicine residents who participated in simulation training respond to real clinical situations, such as cardiac arrest, with significantly better alignment to treatment protocols compared to more experienced resident teams who did not receive this training. [20]

To avoid medical errors and confusion that can arise when more people are involved, a leader is essential for the proper functioning of the team. The leader must manage the team and clearly communicate instructions. Leadership skills are increasingly recognized as key factors that influence relationships among colleagues, workplace efficiency, and patient treatment

outcomes. In a randomized simulation-based study, Weller and colleagues analyzed information exchange channels in emergency situations during anesthesia [21].

The results of the study showed that active information exchange by the team leader and encouragement to share feedback significantly support team collaboration. When the leader openly verbalizes their understanding of the situation, other team members can realize that they hold key information needed by the leader or may offer alternative suggestions and ideas. This approach not only strengthens team engagement but also promotes collaborative decision-making based on a fuller picture of the situation. This process of verbally sharing the assessment of the situation is referred to as "call-out," which allows for more effective and dynamic management in high-pressure, time-sensitive environments.

Studies show that active leadership and effective communication by the leader significantly reduce the number of medical errors, shorten the team's response time, and improve adherence to standard operating procedures. In randomized simulation studies, it was observed that leadership skills training increased the number of key interventions and improved team coordination during resuscitation, which resulted in more efficient use of team resources and fewer treatment errors [22].

CONCLUSIONS

Medical simulations are a transformative tool in reducing medical errors by providing healthcare professionals with a safe, controlled environment to practice both technical and non-technical skills. They address critical gaps in traditional medical education, enabling learners to repeatedly perform complex and high-risk procedures without jeopardizing patient safety.

From airway management to newborn resuscitation and obstetrics, simulation-based training has been shown to enhance technical proficiency, reduce response times, and minimize errors in critical scenarios. Furthermore, simulations significantly improve medication administration accuracy among nurses, demonstrating their effectiveness in diverse clinical settings.

In conclusion, medical simulations represent an essential component of modern medical education and training. They not only elevate technical skills but also strengthen the interpersonal and organizational dynamics crucial for patient safety. Future efforts should focus on integrating simulation-based training more broadly across medical curricula and healthcare institutions to ensure its full potential is realized in reducing medical errors and enhancing the quality of care.

DISCLOSURE

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