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Simulation To Reduce Medical Errors And Improve Patient Safety In Anesthesia

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Abstract

Over the past two decades, simulation in medical education has been adopted by health education programs and established as a proven method of education for health care students and providers. Despite the addition of simulation to healthcare education, medical errors are ranked as the third leading cause of death in the United States. The purpose of this literature review is to investigate the translation of simulation education into increased patient safety and reduction of medical errors in anesthesia. Overall, the literature reviewed confirms that simulation can be used to reduce medical errors and improve patient safety. Additional correlational research between simulation reduction in medical errors and increases in patient safety research is needed.

Simulation to Reduce Medical Errors and Improve Patient Safety in Anesthesia

It is estimated that over four-hundred-thousand mortalities occur each year as a result of medical errors (Burden & Pukenas, 2018). Although multifactorial, these errors commonly occur as a result of poor communication and inadequate situation management (Burden & Pukenas, 2018). In recent decades, simulation training in the medical field has become increasingly accepted as an effective training method to address these issues (Baker et al., 2017). Simulation offers the advantage of exposing medical providers of any level of experience to a standardized simulated experience that can be carried out with compelling realism. Simulation has been shown to not only improve but, sustain individual and team performances (Burden & Pukenas, 2018). A given skill set can be focused on and improved with an individual practitioner or an entirely new skill can be taught to a department using simulation. As many procedures in the field of anesthesia carry potentially lethal complications, simulation offers participants the opportunity to gain experience without the risk of patient interaction and thus, harm. The articles reviewed in this manuscript conclude that various methods of simulation can directly reduce medical errors and increases patient safety.

Methods

A systematic review of keywords was conducted to gather information regarding the topic. Keywords include Simulation, Anesthesia, High-Fidelity Simulation, Student Registered Nurse Anesthetists (SRNAs), Anesthesia Residency, Medical Errors, Virtual Simulation. Platforms used to collect data include EBSCO Host CINAHL Complete, Access Anesthesiology, Pubmed.gov via National Center for Biotechnical Information (NCBI) and UpToDate. Articles were chosen based on their relevance to the topic of simulation in anesthesia and simulation being used to address medical errors or quality improvement. Overall, articles were limited to ten years for currency and relevancy. Only one was included that was greater than ten years (twelve years) as it was of significant importance. The following chart breaks down the results of the systematic review conducted. Note that some of the articles applied to more than one column.

Topics of the 37 Articles Included	Anesthesia	Simulation	Medical Errors & Patient Safety	Included All Topics
Number of Articles	24	33	24	16

Literature Review

Simulation has been recognized as both an improved knowledge consolidation method and an excellent adjunct to fill experience gaps left by classroom teaching (Okuda et al. 2009). Simulation has been endorsed by the Institute of Medicine's (IOM) initiative *The Future of Nursing* as a novel and creative educational tool to assess education, promote dynamic team efficiency and expand the workforce (Cannon-Diehl, Rugari & Jones, 2009). Additionally, the recertification process for anesthesiologists in the United States has adopted a simulation requirement (Okuda, 2009). Many simulation centers currently offer the participant to be recorded, allowing for a play-by-play breakdown of events as they unfold. This allows for an unprecedented level of feedback from clinical educators that opens the experience up for deeper levels of reflection and increased practice improvement. These scenarios can then be repeated as many times as needed for the learner to solidify however many desired skills are being tested (Burden & Punkenas, 2018). Varying degrees of difficulty can be offered to practitioners of any amount of experience. The clinical scenario can be tailored to a multitude of events in the anesthesia field specifically, which can be of high educational value. For example, statistically, most anesthesia providers will never encounter a patient that develops a case of Malignant Hyperthermia. With periodic exposure to simulation, however, anesthesia providers with access to simulation centers are given the opportunity to master this scenario and appropriately perform in the unlikely event of its occurrence (Henrichs et al., 2009).

History of Simulation

Over the past fifty years, the field of anesthesia has been able to reduce the mortality rate from one per ten thousand to one per one hundred thousand anesthetics. Part of this improvement in anesthesia safety is attributed to the exponential development and implementation of simulation as an educational delivery method (Higham & Baxendale, 2017). These developments have allowed the field of anesthesia to become the leader of the development of the level of standardization of simulation that exists today (Burden & Pukenas, 2018).

The highly advanced anesthesia mannequins used in modern simulation laboratories had humble beginnings. The earliest known simulators were mock obstetric torsos that date back to the seventeenth century (Park, 2011). Centuries later in the 1920s, anesthesiologist Dr. John Lundy created the first anatomy laboratory aiming to improve regional anesthesia delivery (Burden & Pukenas, 2018). Later, in the 1960s, two major historical breakthroughs occurred that shaped simulation as it is recognized today. The first was the advent of the cardio-pulmonary resuscitation mannequin by Dr. Peter Safar and the second was the introduction of the first computer-driven, full-body patient simulator known as SimOne (Park, 2011). Influenced by the developing field of simulation and seeking to research medical errors, Dr. Jeffrey Cooper created the Anesthesia Patient Safety Foundation in the 1970s (Burden & Pukenas, 2018). This led to the first mannequin developed for anesthesia training in Sanford, California in 1987. Using aviation education as a format, the first training course designed for this mannequin was unveiled three years later and integrated crew resource management (CRM). CRM as it became known as, combined didactic with non-technical skills in multidisciplinary teams and has since become the foundation for many simulation laboratories use today (Higham & Baxendale, 2017). Today, anesthesia crisis resource management (ACRM) has replaced ACM and incorporates cognitive aids to help guide practitioners during emergency situations (Park, 2011). Simulation's has exponentially evolved over the past few decades to the technologically advanced science that it is recognized as today.

Simulation Defined in the Literature

Simulation is defined as a method to replace or amplify real-patient experiences with guided experiences artificially concocted to elicit or imitate particular characteristics of reality using a fully interactive process (Burden & Punkenas, 2018). Simulation provides an educational setting that is both immersive and experiential without risking contact and thus, harm to patients. Simulation is an umbrella term that can take numerous forms including computer-simulated, physical mannequin, a combination of physical-computer mannequins, virtual reality, task trainers, screen-based simulations (via computer or tablet) or computer games. These various forms of simulation deal heavily in active learning which contrasts from traditional, classroom methods. Park (2011) described simulation as:

> A simulator is a generic term referring to a physical object, device, situation, or environment by which a task or a series of tasks can be realistically and dynamically represented. Simulation is a process or event; it can be defined as 'a person, device, or set of conditions which attempts to present evaluation problems authentically. (p. 14)

Simulation offers many advantages built into its current design, which makes it such a valuable teaching tool (Park, 2011). Motycka et al. (2018) list simulation-based training as the superior learning method when compared to traditional, problem-based learning in medical education. However, Burden and Pukenas (2018) state that to be effective, simulation must adhere to three key features inorder to promote the most effective use of simulation: encouraging deliberate practice (DP), teaching and assessing non-technical skills and replicating reality.

Deliberate practice has been shown to result in an accurate predictor of professional accomplishment when compared to experience or academic aptitude and is especially beneficial for the education of technical skills. DP is effective because it allows learners to reflect on and improve the performance of aspects of nontechnical skills such as decision making, teamwork, and communication. When combined, simulation and DP are an effective strategy at improving skills and procedures such as intubations, provider-to-provider handoff, central line placement and lumbar punctures (Burden & Pukenas, 2018).

DP is not the only factor that contributes to simulation's success. Teamwork also improves as a result of simulation. Burden and Pukenas (2018) describe communication as a major element of teamwork and its failure is often found to be the common denominator for medical errors. As healthcare acknowledges the increasing need for collaborative approaches to solving this problem, an interdisciplinary approach has had positive outcomes when performed in the simulation laboratory. The researchers report that interdisciplinary simulation enables participants to develop judgment, leadership, communication and decision-making skills and is a practical method for operating room (OR), labor and delivery (LD) and intensive care unit (ICU) teams in both the simulation laboratory and in the clinical workplace itself. As medical errors are prevalent across all of medicine, this is one example of simulation's benefit for medical fields outside of the anesthesia community that can profit from its implementation.

The replication of reality is the third key to simulation having a lasting and positive impact on the participant. For example, internal medicine residents who underwent Advanced Cardiac Life Support (ACLS) training in the simulation laboratory demonstrated retained skills at both six and fourteen-month intervals post-intervention (Burden & Pukenas, 2018). Bruppacher (et al. 2010) conducted a Level II, single-blinded, prospective study to determine if simulation was able to improve anesthesia resident's ability to effectively learn and treat cardiopulmonary bypass (CPB) weaning, a particularly challenging anesthesia concept. Twenty anesthesiology residents, postgrad year of four or higher, all inexperienced in CPB weaning were randomly divided into two educational groups to assess the effectiveness of high-fidelity simulation (HFS) versus interactive seminar training and found that the simulation group scored higher than the interactive-seminar group through both the two-week and five-week posttest. Additionally, the transfer of both technical skills and non-technical skills was noted to be higher in the simulation group. Here, the study's creators credit the realism of the HFS as a major factor in an attempt to explain why the HFS yielded such a higher and consistent posttest (Bruppacher et al., 2010). Burden and Pukenas (2018) also report that residents' advanced cardiac life support (ACLS) skills at six- and fourteen-month intervals do not decay when taught using simulation. The replication of reality is a major foundational factor for educational simulation.

High Fidelity Simulation

Of all the forms simulation has evolved to, HFS offers the most convincing realism. HFS has gained significant popularity with medical schools and nursing schools alike. HFS offers many advantages to its use that have been built into its current design which affirms it as a valuable teaching tool. Further validation for HFS comes from Shin, Park & Kim (2014) when they reconfirmed previous meta-analysis findings that HFS in medical education has more benefits than low-fidelity simulation (LFS). Across simulation literature, verisimilitude reappears as a highly valued factor in simulation education.

The SimMan 3G© is the epitome of HFS. The SimMan 3G© is an electric, wireless, full-body mannequin that can operate both preprogrammed and customized simulations. It features a separate but synched electrocardiogram display, pulse oximetry, carbon dioxide, arterial and non-invasive blood pressures, central venous pressures, pulmonary capillary wedge pressures, cardiac outputs, temperature, anesthetic agents, x-rays display and train of four monitoring. The simulation controls on this model offer rewind, pause, fast-forward and ability to store information. This mannequin has eyes that can blink at differing rates of speed, adjust pupillary diameters and even speed of response to trainee intervention. The SimMan 3G© mannequin can simulate seizures and fasciculations, bleeding from multiple sites and reflect vital signs expected to accompany degrees of blood loss. Bowel, heart, and lung sounds can all be mimicked while programmed or custom voice responses can be displayed from any distant site wirelessly. Foley catheterization, intubation, intravenous access, intraosseous access, and synchronized pulse palpation from multiple areas are all possible (Laerdal Medical, 2019).

The SimMan 3G© also has a host of respiratory features that cater to the anesthesia providers simulation education. Some of the breathing features include the ability for unilateral or bilateral chest rise, CO2 exhalation, normal and abnormal breath sounds to be auscultated. This model also boasts the ability to allow for bag-mask ventilation complete with controllable airway patency, head and chin tilts, jaw-thrust ability, mock cricothyrotomy, transtracheal ventilation, endotracheal, retrograde, nasotracheal and fiberoptic intubation, and supraglottic airway placement. The lungs can also simulate multiple settings of different airway resistances and compliances during ventilation and can simulate esophageal and right main intubation. These features allow anesthesia providers to simulate multiple scenarios, for example, cannot intubate/cannot ventilate, laryngospasm, manipulation of head position to secure airway and decreased cervical range of motion to name a few (Laerdal Medical, 2019). These features culminate to provide the highest degree of realism for the student in the simulation to enhance the translation of skills from the laboratory to the clinical setting (Park, 2011). The SimMan 3G© is an all-encompassing, fully automated model that demonstrates the height of simulation's technological abilities and advancement.

Offering dynamic options for scenarios, the SimMan 3G© is not only useful for training students but also can be incorporated in simulation studies as well. In the prospective study conducted by Rábago et al. (2017), twelve anesthesiology residents were evaluated to investigate if endotracheal intubation skills learned on a SimMan 3G© transferred to clinical practice. A checklist of twenty-eight behaviors was created to evaluate the anesthesiology resident's first clinical intubation. The result of the study found that 75% of the participants were able to complete more than twenty-one out of the twenty-eight skills established in simulation during their first clinical intubation. A secondary outcome was evaluated as well. Participants in this study were also evaluated on their first intubation in the clinical workplace using a customized checklist and found that more than 83% of the participants demonstrated a high level of self-efficacy in performing the technique for the four professional attitudes chosen for this parameter (Rábago et al., 2017). Additionally, the authors do note the absence of post-dural puncture headaches during this study. Although this study did underpin successful translation of skills from simulation into clinical practice, one limitation that resulted was its underpowered sample size of only twelve participants. Still, airway management skills were translated successfully into clinical practice using HFS.

Airway management is a frequently examined topic in anesthesia simulation. Sun et al. (2017) examined the effectiveness of airway simulations using a meta-analysis. Whether the simulation was HFS, computer-based, video-based or discussion-based, simulation training was found to offer a lasting effect on learners. Specifically, SBT was found to have improved behavior performances when repeated. This meta-analysis of 17 eligible studies conversely found that the success rate of procedure completion on live patients was not improved. This questions whether the translation of skills learned in simulation laboratory are always translated over into the clinical practice. This systematic review also determined that many of the studies that comprised the final sum often had small population sizes weakening the overall strength of the analysis. As seen with Rábago et al. (2017), small sample sizes are a common theme in simulation literature. Additionally, lasting effects of learning outcomes were confirmed with simulation education.

Blaine, Gorse, Rolleau, Figueiredo, and Benhamou (2018) conducted a prospective randomized study to assess learning outcomes from HFS. In four designed simulations, three anesthesia residents assumed the role of active participants while other anesthesia residents observed in a separate room. The participants were randomly divided into either the active-participant/observer group (AP-O group) or the observer only group (O group) and were issued questionnaires before, immediately after and three months after the event and included self-reported assessment of satisfaction, medical knowledge, and nontechnical skills. One hundred-four questionnaires were returned completed and after analysis revealed that the AP-O group demonstrated a significantly higher increase in medical knowledge than the O-group.

Nontechnical skills were equally improved in both groups. Overall, these studies demonstrate that HFS effectively allows for the transfer of skills from the simulation laboratory to the clinical environment for novice anesthesia providers (Blaine et al., 2018). Similarly, Jansson et al. (2016) assessed retained knowledge and skills after simulations and found that of the 17 critical care nurses that completed all evaluations of the 24-month study, skills retention was higher in the simulation group than in the control (classroom education) group at six months. One drawback that this study highlighted, however, was that at the 24-month retest period, improvements were found to be not statistically significant ultimately questioning simulation's long-term reliability.

Compelling realism is a cornerstone of HFS. When implemented well, HFS has lasting effects in learner outcomes and effectively translates both technical and non-technical skills acquired in the simulation lab into concrete practices in the clinical area. HFS often outperforms when compared to LFS however, LFS still has a major role in the education of anesthesia staff.

Low Fidelity Simulation

Low fidelity simulation incorporates a basic design of a limited number of educational points with an associated low financial cost. Multiple types of LFS task-trainers, or mannequins, are available for varying goals of education. One of the most commonly identifiable mannequins amongst healthcare providers is the cardiopulmonary resuscitation (CPR) mannequin that health care providers are required regularly to practice the administration of CPR. These mannequins consist of a head, torso, and chest which has a built-in, compressible spring that allows for a critique of the depth of chest compression (Chima et al., 2018). For epidural placement simulation, lumbar puncture models are available that mimic a patient's arched backside that consists of layered ethylvinyl acetate, polyethylene, plasticine, cork, and a fluid-filled, refillable, Penrose drain that aim to mimic skin and various layers of tissue (Rábago et al., 2017). Alternative anatomic-specific models exist as well. Arms and torsos lined with superficial tubes and solid structures that represent anatomically accurate bones are intended for arterial and central line placement simulation (Shin, Park & Kim, 2014). These various anatomically specific body segments allow anesthesia providers to practice potentially dangerous procedures with convincing fidelity all while removing the threat of patient harm at a fraction of the cost of many other types of simulators.

LFS has also gained significant popularity in the field of obstetrics. Obstetric simulators are now available with a wide array of common obstetrical physiological changes. According to Okuda et al. (2009), specific task trainers have even been developed with interchangeable, varying degrees of female anatomy depicting progressing levels of cervical dilation, mannequins that are capable of being assessed with ultrasound to determine conditions like amniocentesis, fetal station, and shoulder dystocia and even mannequins powered by motors that can move a second fetus mannequin through a birthing canal. Birnbach and Salas (2008) also reported that these obstetric-specific LFS can be useful in exploiting unpreparedness in obstetric operating rooms (ORs). LFSs are one example of cost-effective alternatives to expensive HFS that offer opportunities for learning outside of the anesthesia department.

Virtual Simulation

Another cost-effective form of simulation that is beginning to gain popularity is virtual simulation (VS). It offers an alternative to the costly price of HFS and the equipment and staff training required to maintain it (Erlinger, Bartlett & Perez, 2019). Using computer software, VS is capable of recreating a hospital environment that students can interact within using a computer.

Erlinger, Bartlet and Perez (2019) investigated how VS performed when compared to HFS. Using the recognition of intraoperative myocardial infarction (MI) as the scenario, both VS and HFS using the SimMan 3G© were utilized as methods. Thirty-nine SRNAs were randomized in the study into two groups. Nineteen students were in their second year of training and twenty were in their third year. One group participated in a VS first then a HFS second while the second group participated in a HFS first and a VS second. Each student participated in a randomized order of whether they received the intraoperative MI first or second. The students were also given other random critical events to minimize the possibility of information sharing between students. Confidentiality was requested by the study's creators. Erlinger et al. (2019) found that for second-year SRNAs, the recognition time of intraoperative MI was faster amongst the HFS group while among the third-year SRNAs, neither VS nor HFS reflected a difference in intraoperative MI recognition times. Of note, all of the second-year SRNAs were observed to not have had any experience with VS before where all of the third-year SRNAs had. This is a major limitation of the study as the potential an experienced third-year student to recognize an anomaly quicker from the software used rather than truly identifying the clinical derangement itself could occur. Overall, VS provided a less effective yet comparable mode of simulation to its costly counterpart, HFS.

Johnson et al. (2014) conducted a quasi-experimental pre-post test convenience sample design to test the competency by self-assessment of graduate nursing students when using a mannequin or web-based training (VS). The SimMan 3G© was used for HFS and a web-based software training program that presents photographs of actors portraying ill patients was used for VS. What Johnson et al. (2014) discovered was that both groups had significant improvements after training in both observed performance and self-assessed knowledge. The mannequin group, however, scored significantly higher on the self-assessment scores than the web group in their post-training observed performance mean scores. Despite the HFS group demonstrating more improvement across these two categories, it is important to note that students in the VS group did demonstrate a significantly higher performance on posttest from pretest scores demonstrating its effectiveness (Johnson et al., 2014). This study demonstrates a powerful example of the effectiveness of VS when compared directly to HFS. Although VS makes sacrifices in fidelity, this study proves that it can have just as powerful of an educational effect.

Overall, the literature regarding VS reveals that it is another validated method for improving participant's observed performance, self-assessment of performance and intraoperative recognition of changes in status. However, these articles do go further to declare that HFS is a more effective method of achieving these results and other improvements as well. One theater where VS may have a role is medical education programs that require strict adherence to budgeting. For example, not all medical education programs may be able to afford the two-hundred fifty-thousand thousand-dollar HFS mannequins for retail. The VS simulations are estimated to cost five hundred dollars per case including regularly scheduled updates and access for an unlimited number of students to use at their own accord (Johnson et al., 2014). Ultimately, VS may not be as effective as interactive HFS, but can serve as a highly cost-effective educational resource for educational programs on a tight budget.

Low-Cost Immersive Simulation

Not all anesthesia delivery teams have access to the varying degrees of simulation technology available today. Depending on the fidelity of the mannequin, the cost of a single HFS can cost up to two-hundred fifty-thousand US dollars (Okuda et al., 2009). It is estimated that in order to open and operate a simulation center that the cost would reach upwards of over one-million United States dollars (Chima et al., 2018). This option is not realistic for the low-income countries that are estimated to require an additional one-hundred-forty-three million additional surgeries annually to address their emergency and essential surgical needs (Mossenson, Mukwesi & Livingston, 2019).

In search of a low cost, high-impact training method, Chima et al. (2018) focused on an underserved and underfunded anesthesia delivery team in Sierra Leon, Africa. Preceded by an 8-month assessment of surgical and anesthesia procedures, a two-week cross-sectional observational study of twenty-one nurse anesthetists was conducted by an expert panel of observers from Johns Hopkins University School of Medicine at the Princess Christian Maternity Hospital (PCMH) in Freetown, Sierra Leone. Simulations were designed around commonly observed at the hospital during the 8-month observational period and integrated equipment familiar to anesthetists in this region. This study did also introduce a universal anesthesia machine (UAM) into the simulations for which many of the anesthetists had never encountered. This machine also came with auxiliary oxygen tanks and computer-controlled cardiac monitors which were also foreign to these anesthesia providers. Data collection methods included a Likert-type scale developed and polled by 10 anesthesia physician experts at the director level of supervisor responsibility at each of their respective hospitals to measure the differences in practice.

Chima et al. (2018) concluded that simulation in the low-resource setting can be conducted at a fraction of the cost of the average simulation using medical equipment that is present and available at the training location. According to these authors, “These findings establish that contrary to accepted perceptions high fidelity in-situ anesthesia simulation is feasible in the low-resource environment” p.122 (Chima et al. 2018). The study also demonstrated that there are major safety and potentially life-threatening gaps in the performance of anesthesia providers in low resource environments (Chima et al., 2018). LFS can cost-effectively provide the necessary education to augment financially restrained anesthesia education groups to improve safety gaps in practice.

Mossenson, Mukwesi, and Livingston (2019) also sought to bring highly effective simulation training to low-resource settings. Through a Level IV pilot training unveiling, the Vital Anesthesia Simulation Training (VAST) course was designed to enhance the practicality of simulation learning in under-developed areas while keeping costs at a minimum (Mossenson, Mukwesi & Livingston, 2019). In the deployment of the VAST program to Kigali, an under-developed region of Rwanda, the predominant learning method used was simulation complimented with debriefings. Skills stations are also presented as well as targeted case-based discussions that incorporate how ANTS can contribute to improved outcomes. Over three weeks, the total number of participants hosted was forty anesthesia providers, of which twelve completed the VAST facilitator course. One limitation of this study article was that no outcomes were obtained. As this was an initial program demonstration, further research is required that necessitates the degree of effectiveness of this program.

In summary, simulation technology is not only being developed for first-world consumers but third-world consumers as well. These low-cost immersive platforms aim to bring anesthesia communities in underserved countries up to speed in safety through cost-effective simulation. These LFS offer an effective alternative to HFS to both evaluate and educate students and current anesthesia staff.

Simulation to Identify Gaps in Clinical Practice

Simulation in recent decades has been specifically recognized as an effective tool to improve a provider's performance giving way to a new level of educational scrutiny. Simulation allows for the analysis and refinement of the human factor in education. This human factor is directly related to patient safety through productivity, task-management, leadership, decision making, communication, and efficiency, and is specifically addressed in simulation training (Higham & Baxendale, 2017). By mimicking scenarios, simulation allows for exposure and ultimately, education and improvement of a certain topic.

Another advantage of simulation is its unique ability to identify gaps in an individual's performance specifically regarding latent conditions that exist in the anesthesia work environment. Simulation-based education is essential for the evaluation and furtherance of SRNA's performance of both nontechnical and technical skill sets (Wunder, 2016). Similarly, Lowe and George- Gay (2017) found that latent conditions were present in 81% of the simulations of SRNAs they hosted. One feature that specifically HFS can offer is the ability to record an anesthesia student to be reviewed after the simulation in a post-simulation brief. These briefs offer educators to break down actions and latent hazards made by the learner to help correct behaviors to help hone technical and nontechnical skills sets. Post simulation briefs offer a new level of insight into student's performance and allow for reflection of latent conditions that hinder the execution of safe practices.

Lowe and George-Gay (2017) define latent conditions as "unforeseeable deficits in system design that are difficult to directly link to an adverse event because the consequential error is delayed" p.50. Latent conditions are considered hazardous and examples include inappropriately timed handoff, distractions, production pressure and non-interactive communication. In a Level II, retrospective randomized control trial, Lowe and George-Gay

(2017) examined sixty archived video recordings of anesthesia crisis simulations conducted at the Center for Human Research in Human Simulation at Virginia Commonwealth University. Focusing specifically on the handoff-report that occurred during episodes of latent conditions, the handoffs were scored on a scale of zero to ten and had a specific criterion to meet for each point awarded. Spearman correlation was used to analyze the results and concluded that an inverse relationship between latent conditions and effective handoff reports exists. As the latent condition scores increased, the quality handoff scores decreased. This correlation was further demonstrated with linear and curvilinear scatterplot which demonstrated the variability of effective handoff reports when latent conditions were high versus when latent conditions were low yielding a more concentrated cluster of handoff scores. Specifically, Lowe and George-Gay (2017) concluded that the lowest handoff scores occurred when three or more latent conditions were present when the highest handoff reports occurred when just zero, one or two latent conditions were present. Retrospective simulation examination revealed an inverse relationship exists between latent conditions and simulation participant's performance to provide adequate care.

Chima et al. (2018) also identified gaps in clinical practice using simulation, specifically about individual practice. While performing simulation abroad in the austere environment of Sierra Leone, this study, examining twenty-one nurse anesthetists and found that 42.86% of its participants did not prepare an endotracheal tube and laryngoscope to prepare their anesthesia setup. Additionally, 76.19% did not perform a suction check. These two grading points by study designers were predetermined to have a 100% agreement that a patient will die or be injured as a result of failure to perform this specific task. Another 53% of nurse anesthetists did not check if the machine was turned on, rated an 80% risk of patient harm. Of the many results of this study, one finding of the simulations was the ability to identify major safety gaps in basic anesthesia preparation (Chima et al., 2018). One limitation of this study was the introduction of the UAM may have increased bias since many anesthetists were unfamiliar with it. Additionally, despite all of the nurse anesthetists having graduated from the same national program, experiences gained since graduation may have influenced their preparation and anticipation of certain events, reflecting the scores of certain simulations (Chima et al., 2018). Simulation revealed major safety gaps in anesthesia provider's setup for obstetric cases and general cases. These gaps pose major safety risks that carry with them high risks of harm and thus the potential for medical errors.

Simulation to Combat Medical Errors

With increasingly acute comorbidities, advancements in medical technology and changes in working routines with the adoption of electronic health record systems, the day-to-day work environment of an anesthesia provider has changed greatly over the past few decades. Along with this evolving scene, the high pressure to make fast, significant medical decisions under institutional production pressures further challenges the anesthetist, all while avoiding error in practice (Higham & Baxendale, 2017). As a result, the field of anesthesia has looked toward simulation to refine the science of the human factor in an attempt to reduce errors.

Non-technical skills are defined as "the cognitive, social, and personal resource skills that complement technical skills and contribute to safe and efficient task performance. They are not new or mysterious skills, but they are essentially what the best practitioners do to achieve consistently high performance and what the rest of us do on a good day" p.109 (Higham & Baxendale, 2017). In their systematic review of the use of simulation to enhance training and patient safety in anesthesia, Higham and Baxendale (2017) found that clinical simulation, along with scientific advancements, clinical governance, and standardization of practice, have all contributed to this improvement in patient outcomes. With its exponential technological development and increased market availability, simulation is identified as the key method for increasing safety through teamwork training, technical skills development, non-technical skills development and didactic knowledge assessment that can simultaneously be integrated into an academic curriculum.

Non-technical skills such as team working, task-coordination and communication, account for up to 70-80% of medical errors in healthcare (Mossenson, Mukwesi & Livingstion, 2019). Starmer et al. (2014) described miscommunication as a leading cause of medical errors and as the source for two out of every three sentinel events, the most serious events reported to the Joint Commission. In their case-control study evaluating medical management scenarios in an interdisciplinary training environment as a means to evaluate the impact of team-based skills and attitudes, Motyca et at. (2018), listed the 5 major sources of medical errors as communication breakdown, context, omission, error of commission and diagnostic error. As communication is the major culprit of all of these sources, their control study involved a total of 48 students from pharmacy, medicine and nursing programs at a local medical center, all collaboratively participating in four simulation scenarios that mimicked common clinical medical errors. Five major modalities were assessed including team structure, leadership, situation monitoring, mutual support, and communication. Amongst all the groups, communication was the only category where students of all three programs were most improved based on the pre and post-test means. Simulation also improved nursing students' structure category results, leadership and pharmacy students monitoring category and support category improved as well. Simulation was demonstrated to have a profoundly prevalent effect on communication potentiating advantageous secondary effects as communication is a major element of medication errors.

Birnbach and Salas (2008) conducted a systematic review analyzing simulation of labor and delivery events that included a range of different types of simulators capable of assessing multiple anesthesia crises of labor and delivery such as maternal hemorrhage (antepartum and postpartum), failed intubation, failed neuraxial block, cardiac arrest, anaphylaxis, seizure, shoulder dystocia, and cord prolapse. However, despite many of these events revolving around the anesthesia provider, the authors discovered that oftentimes more than one team member will be blamed and that medical teams can assuage this issue by practicing interaction through simulation to improve closed-loop communication and overall team synergy. Birnbach and Salas (2008) recognized that simulation is an effective method to combat poor communication as it has been demonstrated to improve communication in a crisis.

Similar findings of communication’s correlation to medical errors can be found in the retrospective study of anesthesia crises video recordings by Lowe and George-Gay (2017) who concluded that when active failures and latent conditions occurred together, adverse events occurred. Communication failure specifically during anesthesia handoffs were the main focus of this study. Lowe and George- Gay (2017) concluded that latent hazards like distractions and interruptions, which were present in 81% of their simulations, detrimentally affected handoffs most notably during the induction and emergence phases. The authors further stated how the presence of noninteractive communication was the most consistent predictor of poor handoff scores and that communication failures are common during task-dense activities. Simulation was used to exploit the relationship between communication and latent events and noninteractive communication failure was a prominent predictor of poor hand-off reporting which could potentially lead to risks in patient harm.

In the Level II, quasi-experimental, retrospective study, Wunder (2016) not only used simulation to assess, but then also demonstrated simulation's ability to enhance the nontechnical skills of nurse anesthetist students. Thirty-two first-year student registered nurse anesthetists (SRNAs) were ultimately surveyed by videotaping performances and later rated as they performed six simulated crisis scenarios; three before the intervention and three after. The intervention consisted of a three-hour educational instruction of non-technical skills through a computer presentation. The Anesthetists' Non-Technical Skills assessment (ANTS) scoring system was used to assess the student's nontechnical skills and the Key Action Scoring system was used to assess technical skills. The ANTS system focuses on Situational Awareness, Decision Making, Teamwork, and Task Management while the Key Action system scores participants based on their response time to initiate 6 key actions based on the scenario. The Mean posttest scores of the ANTS assessment were greater than the pretest scores. Additionally, nontechnical skills mean gain scores were significantly greater than technical skills which scores did not change in the posttest. Wunder (2016) concluded that simulation-based education is essential to developing and evaluating SRNA's technical and nontechnical skills as nontechnical skills are often the cause of human error in healthcare. Wunder (2016) effectively used simulation as both an assessment tool and also as the media to improve nontechnical skills that are known to be the root cause of medical errors and breaches in patient safety. Simulation's ability to evaluate and educate was productively demonstrated with the adjunctive use of the ANTS system.

Ross, Kodate, Anderson, Thomas, and Jaye (2012) conducted a Level I systematic review of simulation's use in anesthesia journals. Of the thousands of simulation papers that were found, a total of three-hundred twenty papers containing primary data were included for analysis about nontechnical skills that simulation provides an opportunity to explore behavioral aspects of healthcare whilst still allowing the participant to reflect on the experience which can then translate into technical skills development. By conducting post-simulation briefing before then reattempting, the students benefit from the repetition of the simulation and also the opportunity to correct the areas of error. Largely, simulation has a high degree of effectiveness on communication. By correcting this major pillar of the medical error's root cause, simulation can have a profound effect on reducing medical errors and improving patient safety.

Simulation's Effect on Patient Safety and Reduction of Medical Errors

As previously mentioned, the study conducted by Bruppacher et al. (2010) demonstrated the valuable effects of realism in simulation training. Bruppacher et al. (2010) also were able to demonstrate direct, beneficial increases in patient care outcomes regarding the weaning of CPB by using simulation. The simulation group outperformed the seminar group in time interaction and also outperformed the seminar group in both post-test and retention tests (Bruppacher et. al., 2010). The authors further suggested that simulation's ability to improve patient outcomes despite the complexity of CPB may translate to other critical concepts like ACLS. Here, the value of simulation safety benefit is amplified by its participants bringing experience into a critical, intricate situation instead of the long-established, current methods of on-the-job training (Bruppacher et al., 2010). This study successfully provided specific examples of how its simulation improved patient outcomes.

The Level II systematic review by Park (2011) further correlated simulation with the improvement of patient outcomes by presenting three simulation-based studies that directly affected patient safety outcomes. They categorized their data into three tiers: T1, T2, and T3. T1 represents a phase in which simulation in the laboratory occurs to attempt to bring treatment to the clinical phase. The T2 phase enters the clinical phase and attempts to measure clinical performance while the T3 phase extends the clinical performance to achieve improvement in patient outcomes. Three T3 studies are described by Park (2011). This first example describes a study focusing on outcomes of deliveries with shoulder dystocia that were analyzed both before and after a simulation intervention was provided. Brachial Plexus injuries dropped dramatically as a result of the simulation intervention and overall demonstrated a clear progression from T1 to T3 (Park, 2011). The second study that Park (2011) presented achieved a T3 outcome that linked five-minute Apgar scores and rates of hypoxic-ischemic neuropathy (HIE). Before a single-day obstetric emergency simulation course, rates of HIE were obtained. After the course was implemented, rates of HIE on low Apgar scores were obtained once more and demonstrated HIE rates dropping by close to 50% (Park, 2011). The third T3 outcomes study found that after simulated catheter-insertion training sessions, catheter-related bloodstream infections decreased dramatically (Park, 2011). This author strengthened the argument for simulation's improvement of patient outcomes with three articles of differing power.

Next, the systematic, Level II review by Shear, Greenburg, and Tokarczyk (2013) cited literature where residents were randomized into two groups to analyze central venous catheter (CVC) line insertion. A simulation group and a conventional apprenticeship training group were established, and the simulation group was found to have higher success at first cannulation attempt in addition to overall success rate thereafter (Shear et al., 2013). Another successful

CVC simulation study was found by Shear et al. (2013) and found that complications during CVC placement by who had trained in simulation versus residents who had received no such training demonstrated less arterial punctures, less overall needle passes and overall higher success rates at passing CVC catheters (Shear et al. 2013). Here, CVC placement, a task which anesthesia providers are required to perform, is demonstrated to have improved outcomes after a simulation session.

Shear et al. (2013) reviewed a simulation study on a hospital-wide scale. This study occurred across the Veterans Affairs (VA) facilities nationwide and entailed medical team training programs consisting of nurses, surgeons, and anesthesiologists that utilized CRM, a fundamental concept of simulation. In the facilities that held this team training CRM program, an 18% decrease in mortality was noted. The authors concluded the trend in simulation studies is beginning to both quantify and validate translation of simulation benefits into patient outcomes. This last example provided a high-powered data point as a nation-wide study that demonstrated a profound impact on patient outcomes, specifically, mortality.

Overall, simulation was proven to improve CPB outcomes in the cardiovascular surgery setting, lessen brachial plexus injuries in the occurrences in the obstetrics setting, improve incidence of HIE, decrease catheter-associated blood-stream infections, decrease CVC insertion complications and decrease mortality in VA hospitals. Simulation has been found to improve patient safety across a wide domain of patient care fields and settings.

Limitations to Simulation

The premise of evidence-based research is based on understanding that all methods have limitations. Simulation is no different. Geeraerts et al. (2017) encountered this when conducting their study by using videotaped simulation performances and a self-assessment using a numerical scale and salivary amylase concentrations of its participants, a level II observational study of twenty-seven anesthesia and critical-care residents. The study found that the mean degree of stress, when placed on a numerical scale, was equal before and after the simulation scenario. Conversely, salivary amylase, an indirect estimation of stress, was also evaluated before and after and was found to be significantly higher after versus before the simulation session. The authors note however that stress can also lead to an unexpected reaction that can negatively alter the performance and further provide examples of stressful simulations that impaired healthcare worker's performances (Geeraerts et al., 2017). Although this negative effect of stress was not encountered in this study, it is an important factor to consider when studying simulation performances.

Assessing other physiological markers, Baker et al. (2017) found that when measuring heart rate variability (HRV) amongst anesthesia trainees for a during rapid sequence intubation (RSI) simulation, there was no significant difference between average objective stress levels across all time points. Between clinical (theatre setting with live patients) and simulation environments. Overall Baker and colleagues' study determined that there their research was unable to accurately replicate the stress of the technical procedure. This study has several limitations, however. The first limitation is that only eight individuals participated in the study. The second lies in the overall structure of the study. RSI is indicated in most emergency intubations and can be a major source of stress amongst anesthesia providers. They do not always correlate to emergency situations however and are regularly performed in anesthesia (Baker et al., 2017). Failure to replicate stress may stem from a poorly designed study that would not illicit levels of stress as other more well-constructed stressful scenarios.

A further limitation of Simulation is noted by Shin, Park, and Kim (2015). A Level I meta-analysis of twenty articles meeting the criteria regarding the effectiveness of simulation in nursing education was carried out. They report that many of the studies performed on simulation were conducted with relatively small sample sizes of participants and given that simulation research stage is still in its emergence, that making recommendations for its true effectiveness and drawing conclusions might be premature. Despite this, Shin, Park, and Kim (2015) overall determined that simulation education could improve learning outcomes with medium-to-large effect size, compared with either no intervention or traditional education. Adding to this argument is the Finnish study conducted by Jansson et al. (2016). This study used a small sample size of a total of seventeen critical care nurses who were found to have improved outcomes at the six-month interval. “A serious lack of robust evidence (including variations in the research designs) and a universal method for outcome measurement (e.g., a constructivist vs behaviorist approach in designing learning and assessment, and a lack of standardized instruments, measurements, and follow-up times).” p.14 (Jansson et al., 2016). Uniformity in simulation design and assessment are needed to further the investigative and diagnostic depth of simulation.

Mariani and Doolen (2016) conducted a Level III descriptive, qualitative study to assess perceived gaps in nursing simulation across the globe. After poling the one thousand, eight hundred eleven members of the International Nursing Association for Clinical Simulation and Learning, ninety members responded with a completed survey that aimed at identifying gaps in simulation research and obstacles to conducting research. One major gap that respondents frequently identified was small sample sizes of simulation research, similar to what Shin, Park & Kim found in their meta-analysis (Mariani & Doolen, 2016). Overall, simulation studies regarding simulation design and setting along with outcomes were all well addressed according to the surveys (Mairina & Doolen, 2016). This study presents many limitations, however. First, the study only obtained ninety of the one thousand, eight hundred eleven members respond. Second, the questionnaire was an open-ended tool allowing for the ambiguity of responses with no numerical scores to be obtained. This study dealt with mere perceptions that are not able to be used as scientific indicators. Furthermore, this questionnaire was only sent to members of a specific organization within the nursing community, of which, not all are to be expected to have the same, let alone, sufficient, grasp of simulation literature.

Another limitation to simulation was presented by Cumin, Weller, Henderson & Merry (2010) when they conducted a Level II systematic review that focused on the standards for simulation. The authors stated that manufacturers have experienced issues with product quality resulting in an unrealistic experience undermining the entire simulation. To combat this recurring issue, Cumin et al. (2010) pointed out that The Society for Simulation in Healthcare (SSH) listed standards that outlined the criteria for key aspects of simulation-based teaching, assessment and research accreditation for the promotions of patient's safety. The authors discovered that there was no indication as to what serves as an appropriate indicator to meet these key aspects. The world of simulation has a plethora of factors beginning with the participants, to the environment, to the educator and ultimately the simulator. To standardize all of the details surrounding these factors would be near impossible so the authors offered that the simulators themselves be standardized into categorical levels of realism. They propose "S' as specific, realistic and interactive, "R" representing present and recognizable and "A" for absent entirely (Cumin et al. 2010). This would allow manufacturers to filter details on their mannequins to entirely include or exclude features that would even offer further clarity when used. Lusciano & Talbot (2012) also determined that fidelity was an issue amongst simulation review articles. "Fidelity to the actual clinical environment was considered a key in developing the specifics of the simulation scenario" p.27 (Lusciano & Talbot, 2012.)

In their systematic review, Lucisano and Talbot (2012) also found that of 129 studies reviewed regarding simulation, only 15 were considered for their specific goal of researching advanced simulation for airway management. The authors also note a significant gap in researchers' ability to evaluate the potential or actual effects of training on patient safety and the translation of skills from the laboratory into clinical practice. Furthermore, the authors found objective measures such as checklists and/or time completed for a task were the most common method that simulation was used to detect learning. As simulation encompasses a broad spectrum of media to educate its participants, homogeneity is rare among research articles regarding simulation. Overall, they state a need for the evaluation of trainer skills translating to patient safety.

A limitation of this proposal deals with the logistic of implementing and regulating international companies to an international standard (Cumin et al. 2010). Refining this proposal even further, this study is its recommendations are purely illustrative emphasis and have not been physically attempted in any way. Importantly, the authors though reiterate that standardization within the simulation community has begun to direct the field of simulation as a whole, in the safest direction. This standardization of simulation is vital to ensure its validity as a reproducible and thus reliable product.

Discussion

Additionally, of the 34 studies reviewed, only four studies were able to demonstrate a direct increase in patient safety. One of these, a systematic review, provided several examples. Many of the studies reviewed focused on the improvement of a non-technical skill like closed-loop communication and the development of technical skills like airway establishment. Four of these studies assessed clinical outcomes in the clinical setting after this implementation and demonstrated direct positive outcomes. More studies must be conducted to confirm that simulation translates to a reduction in medical errors and an increase in patient safety.

Simulation is not without limitations and barriers, however. Simulation has been demonstrated to reduce medical errors and increase patient safety across many sectors within anesthesia. Medical errors are multifactorial and often the result of multiple system breakdowns and human failures. Some models of simulators can reach tens of thousands of dollars which causes accessibility and affordability as major issues. A lack of fidelity within the field of simulation can lead ultimately derail the effectiveness of the lesson. Also, poor simulation execution by educators can fail to elicit a significant stress response changes in students, ultimately leading to a question of simulation's effectiveness.

Simulation's ability to positively affect communication, teamwork and skills competencies is well described in the literature. Specific examples of simulation having a direct effect on patient safety and the improvement of patient outcomes are less populous. In order to further validate simulation's effect on patient safety and its ability to reduce medical errors, more standardized and homogenous implementation and assessment techniques are needed.

Conclusion

Simulation is widely regarded as an effective method for training and teaching students throughout the interdisciplinary world of medicine, especially in anesthesia. Simulation offers many advantages to traditional classroom education including the development and enhancement of a multitude of highly technical/high risk and non-technical skills. One of simulation's core advantages is the ability for the participant to gain experience without the risk of patient harm. The ability to focus on one learner or convey a subject to a multitude of learners in just a single session also is a strength of simulation education. High-risk, low-frequency events are particularly valuable for anesthesia providers to participate in. Simulation has been proven that it can reduce medical errors and increase patient safety. The gravity of the establishment of high-risk, technical skills before first attempting on live patients is especially important within the anesthesia education community as well.

Simulation also has demonstrated outcome specific accomplishments. Simulation has been proven to improve outcomes regarding CVC placement and infection rates. During difficult labor, simulation decreases brachial plexus injury in newborns. CPB weaning outcomes by anesthesia providers improved in cardiovascular ORs after simulation implementation as well. Mortality rates across an entire hospital network decreased after simulation training exercise.

Additional research is needed to further validate simulation's importance in education, specifically, its ability to reduce medical errors and improve patient safety since this literature is low in volume. Simulation therefor should continue to be used by medical education programs throughout the world to convey important concepts, skills and knowledge to their students.

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