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Simulation Training in the ICU

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Because of an emphasis on patient safety and recognition of the effectiveness of simulation as an educational modality across multiple medical specialties, use of health-care simulation (HCS) for medical education has become more prevalent. In this article, the effectiveness of simulation for areas important to the practice of critical care is reviewed. We examine the evidence base related to domains of procedural mastery, development of communication skills, and interprofessional team performance, with specific examples from the literature in which simulation has been used successfully in these domains in critical care training. We also review the data assessing the value of simulation in other areas highly relevant to critical care practice, including assessment of performance, integration of HCS in decision science, and critical care quality improvement, with attention to the areas of system support and high-risk, low-volume events in contemporary health-care systems. When possible, we report data evaluating effectiveness of HCS in critical care training based on high-level learning outcomes resulting from the training, rather than lower level outcomes such as learner confidence or posttest score immediately after training. Finally, obstacles to the implementation of HCS, such as cost and logistics, are examined and current and future strategies to evaluate best use of simulation in critical care training are discussed. CHEST 2019; 156(6):1223-1233

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Simulation has been defined as "a technique…to replace or amplify real experiences with guided experiences that evoke or replicate substantial aspects of the real world in a fully interactive manner."[1] Because of a confluence of factors in health care, there has been an accelerated growth of health-care simulation (HCS) over the last two decades. The Institute of Medicine's report "To Err Is Human"[2] highlighted preventable deaths related to medical errors, leading to increased focus on using training modalities that minimize patient harm and emphasize patient safety. Simultaneously, clinical duty hour reduction for medical trainees, mandated in part to minimize fatigue-related risk of medical errors, has resulted in less instruction and fewer procedural opportunities.[3,4] In this context, HCS is an appealing solution for providing educational opportunities that fill gaps in training while minimizing patient risk.

ABBREVIATIONS: ACGME = Accreditation Council for Graduate Medical Education; CM = curricular milestone; CVC = central venous catheter; ECMO = extracorporeal membrane oxygenation; EPA = entrustable professional activities; HCS = health-care simulation; IPE = interprofessional education; MV = mechanical ventilation; POCUS = point-of-care ultrasound; QI = quality improvement; SP = standardized patient

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Because patients in the ICU require invasive procedures and efficient interprofessional team performance in a high-stakes environment fraught with potential complications, HCS is particularly well suited to safely learn and practice both technical and team skills needed for critical care practice. For example, consider a patient bleeding around and through their tracheostomy site while hypotensive and desaturating despite receiving 100% oxygen via bag-valve mask. Simulation can be used both to train ICU staff to work effectively as a team for this airway emergency and to allow each team member to practice appropriately performing their individual task, so they can best care for an actual patient in this life-threatening circumstance.

We describe the various applications of HCS relevant to critical care, clarify their appropriate use in ICU training, and review the role of HCS in learner assessment, decision science, and ongoing quality improvement (QI) of intensive care practice. When possible, we cite literature evaluating the effectiveness of HCS reporting high levels of learning resulting from the training, based on the Kirkpatrick model for evaluating the effectiveness of training programs (Table 1).[5]

History of Medical Simulation

Simulators were introduced in the aviation industry in the 1920s so pilots could receive standardized flight training without putting people's lives at risk.[6] The first documented use of HCS did not occur until 1960, when a group of anesthesiologists led by Peter Safar in the United States and Bjørn Lind in Norway collaborated with Norwegian toy manufacturer Åsmund Lærdal to develop Resusci Anne, a full-size manikin simulator of a pulseless dying victim.[6] Soon thereafter, Sim One, a computer-controlled manikin simulator used for teaching endotracheal intubation to anesthesia residents, was developed.[7] In the 1970s, Harvey, a computer-controlled manikin simulator named after the cardiologist renowned for teaching auscultation, was developed to teach bedside cardiovascular skills such as detection of heart murmurs and jugular venous pulsations.[8] Gaba and colleagues[9,10] advanced HCS another step forward, inventing their own high-fidelity anesthesia simulator to study anesthesiologist response to simulated critical events in the operating room and to teach crisis resource management to anesthesiologists. These advances serve as a basis for much of today's HCS focus on clinician performance and patient safety.

Today, health-care institutions worldwide utilize HCS to create experiential courses for health-care students and clinicians from numerous disciplines, including physicians, nurses, pharmacists, and respiratory therapists who work in the ICU. There are 665 self-reported simulation centers worldwide with 162 sites accredited by Society for Simulation in Healthcare in the fields of assessment, research, systems integration, and teaching/education.[11]

Simulation Modalities

There are several different simulation modalities available to an educator, from task trainers to human patient simulators, standardized patients (SPs), and virtual reality/augmented reality (Table 2). Task trainers and patient simulators vary in fidelity, the degree to which the simulation places learners into a realistic environment that elicits physical and psychological response. The appropriate simulation modality is determined on the basis of learning objectives that allow learners to achieve course goals.

TABLE 1] Kirkpatrick Levels of Training Evaluation

Level	Description	ICU Simulation Training Example
1	*Reaction:* Participants' perceptions of training	Survey of participant perception of value of communication workshop
2	*Learning:* Increase in knowledge and/or skills and change in attitudes. Evaluation during training demonstrates knowledge	Improved posttest score at end of ultrasound for resuscitation simulation course
3	*Behavior:* Transfer of knowledge, skills, and/or attitudes from training to job. Evaluation typically occurs on the job several months after training	Demonstration of improved ability to titrate PEEP at bedside 6 mo after HCS workshop on mechanical ventilation
4	*Results:* Final results that occurred because of participation in the training	Reduction in central line-associated bloodstream infections after mastery learning training in central venous catheter insertion

HCS = health-care simulation; PEEP = positive end-expiratory pressure.

TABLE 2] Simulation Modalities

Modality	Description	ICU Example[a]
Task trainers	Simulators that represent one body part or structure and can be utilized for high-volume basic skills training or devices designed just to train key elements of skill being learned Advantages: • Lower cost to purchase than full body manikin • Ease of setup • Allows students to practice specific skills repeatedly Disadvantages: • Need to replace skin/parts due to high utilization • Area of focus limited to task trainer region	Airway task trainer to practice intubation (by direct or video laryngoscopy) with high-fidelity option allows for intubation curriculum to integrate difficult airway by making tongue swell Examples: • https://www.trucorp.com/MedicalSimulationManikin/DifficultAirwayManagement • https://www.laerdal.com/us/doc/92/Laerdal-Airway-Management-Trainer Trainer to practice chest tube insertion Example: • https://syndaver.com/product/wearable-chest-tube-trainer/ Test lung that can be connected to ventilator to demonstrate effects of altering resistance and compliance on ventilator outputs and waveforms Example: • https://www.michiganinstruments.com/lung-simulators/adult-test-lung-simulators/
Human patient simulators	Full body manikins of various sizes, color, sex, and ages Low-fidelity version: Static manikins for a clinical situation or practice of a specific skill Advantage: • Less expensive than high-fidelity version Disadvantages: • Lacks realism • Unable to use for interpersonal skills High-fidelity version: Able to control the manikin's various bodily functions, vital signs, or hemodynamic parameters Advantage: • More realistic clinical environment than low-fidelity version Disadvantages: • Cost of purchase and continued maintenance • Training and knowledge needed to operate	Code Blue simulation to assess student's time to chest compression and visual assessment of quality of chest compression Incorporating high-fidelity: • Displays multiple life-threatening ECG rhythms • Blood pressure can be adjusted in response to learners' interventions • Provides objective data on quality of chest compressions, time to medication administration, and basic airway management Examples: • https://www.gaumard.com/hal-s3201 • https://www.laerdal.com/us/products/simulation-training/emergency-care-trauma/simman-3g/ • http://www.lifecastbodysim.com/
Standardized patient (SP)	Live person trained to realistically portray a role or specific condition Advantages: • Ability to adjust to the learners' level • Can teach physical assessment on actual people • Ability for SP to provide individualized feedback Disadvantages: • Cost of SP time • Logistics of recruiting and training SP • Coordinated scheduling of both SP and clinicians	Highly effective platform for communication curricula, such as goals of care discussions Standardized patient educators' website: https://www.aspeducators.org/
Virtual reality (VR)/augmented reality (AR)	VR: Computer-generated three-dimensional interactive environment that gives an immersion effect to the learner Advantages: • Does not require simulation space • Able to measure time to performance within VR program	VR case of decompensating, unstable patients Example: VR simulating patient with massive PE: • https://www.youtube.com/watch?time_continue=30&v=-3p5DljvZv4 Virtual bronchoscopy simulator allows learner to practice navigating bronchoscope through virtual

(Continued)

TABLE 2] *(Continued)*

Modality	Description	ICU Example[a]
	Disadvantages: • Technical skills to operate software and equipment • Variability in quality of graphics and realism • Cost to purchase • Variable student physiological response to VR modality AR: Overlay of digital computer-generated information on real-world objects or places Advantage: • Allows student to be present in realistic environment with ability to enhance view for more detail Disadvantages: • Similar to those of VR	patient airways Example: • https://simbionix.com/simulators/bronch-mentor/bronch-platforms/ AR program of central vessel images combined with low-fidelity manikin for central venous catheter insertion training AR headset examples: • https://www.microsoft.com/en-us/hololens • https://www.oculus.com/?locale=en_US

PE = pulmonary embolism.
[a]The links to specific simulators are provided to illustrate specific uses of simulation for ICU training for the reader and do not constitute endorsement of any product by the authors, who have no financial relationships with any of the companies selling these simulators.

Uses of Simulation in Critical Care

Procedural Training

With the current emphasis on patient safety, the traditional "See one, do one, teach one" approach to procedural training has come under scrutiny. The empirical cognitive science evidence suggests that skill acquisition requires deliberate practice, a planned series of activities of increased complexity with opportunities for repetition that are guided by specific feedback to improve in a particular domain.[12] Developing expertise in performing procedures requires three-dimensional understanding of relevant patient anatomy, familiarity with the sequential steps and appropriate instruments for each step, as well as the psychomotor skills to perform the procedure.[13] Because they allow for practice in each of these domains, partial task simulators (either high or low fidelity) are particularly suited to procedural training.

A systematic review evaluating approaches for teaching bedside procedures found the strongest evidence for simulation as effective compared with other approaches.[14] A meta-analysis specifically evaluating teaching of critical care skills to medical students found simulation more effective than other teaching methods in skill acquisition.[15] Although much of the published data on HCS in procedural training measures effectiveness on the basis of lower learning level outcomes such as learner confidence,[16] we cite critical care studies with higher Kirkpatrick level evaluation. For example, a prospective randomized study found that improved endotracheal intubation performance on a simulator was sustained 4 weeks after HCS training[17] compared with traditional teaching in a group of residents. Prospective studies have also shown that new pulmonary fellows trained with virtual reality bronchoscopy performed better on their first patient bronchoscopies,[18] and demonstrated a more rapid improvement in clinical bronchoscopy performance[19] compared with traditionally trained fellows.

A working group for skills-based education in pulmonary/critical care medicine recommended that best practices for simulation for skill mastery involve deliberate practice with expert supervision prior to clinical performance of procedures.[20] Simulation-based mastery learning is one process that incorporates these principles. For procedural training, mastery learning involves learners taking a pretest, receiving instruction in the curriculum with practice on a simulator while receiving timely instructor feedback. When learners complete the curriculum, they are required to achieve a minimum passing score on a posttest and complete further simulation training until able to achieve a passing score. Since this rigorous process requires flexibility in both educator time and reserving simulation space, implementation of mastery learning is logistically challenging.[21] However, improvement in patient-centered outcomes with mastery learning implemented prior to performance of several ICU procedures suggests its value.

Residents who completed a mastery learning program in central venous catheter (CVC) insertion experienced fewer complications when inserting central lines in ICU patients than a traditionally trained cohort.[22] The ICU central line-associated bloodstream infection rate was significantly reduced after institution of a mandatory mastery learning CVC insertion program and was cost-effective.[23] In a randomized study of training for thoracentesis, internal medicine residents receiving mastery learning caused fewer clinically significant pneumothoraces and no hemothorax event[24] compared with residents who received traditional training. This emerging evidence base suggests that using simulation for mastery learning is not only an effective educational tool but may also be an effective QI strategy for procedural training.

Other Technical Skills

Data also support the use of HCS in improving other technical ICU skills, such as using test lungs to teach management of mechanical ventilation (MV) and use of simulators to train in point-of-care ultrasound (POCUS). Although management of MV is a fundamental technical skill in critical care medicine and a curricular milestone for all critical care-based training programs, there is a paucity of data regarding best practices in MV training for critical care providers. The only two studies of MV education that demonstrate improved patient-related outcomes were simulation-based, showing that residents trained with HCS prior to ICU rotations performed better on bedside assessment of mechanically ventilated patients compared with traditionally trained residents.[25,26]

POCUS has become an indispensable tool in the ICU, guiding resuscitation of critically ill patients and clarifying etiology of shock states among other uses. HCS has been shown to improve the critical care POCUS learning curve. A hybrid educational workshop with web-based learning followed by HCS on critical care POCUS improved learner confidence, knowledge, and technical skills of novice learners.[27] First-year residents from anesthesia, emergency medicine, and internal medicine training programs had more efficient hand motion and less time to insertion of ultrasound-guided CVC after taking part in an HCS POCUS workshop.[28]

Communication Skills

Simulation with SPs has long been used to teach clinicians' communication skills for a variety of patient interactions. In critical care training, developing communication skills related to serious news disclosure, empathic support, eliciting patient values, cultural sensitivity, and shared decision-making are vitally important in guiding patients and surrogates through critical illness. A study of a 4-day communication workshop for 115 medical oncology fellows from 62 different institutions found that fellows used more effective communication skills in postworkshop SP encounters compared with preworkshop.[29] Three-day simulation-based workshops to train critical care fellows in these communication skills improved both adult and pediatric critical care fellow perception of their skills as well as confidence in leading these discussions.[30,31]

One study assessing pulmonary/critical care fellows on their communication skills in actual family meetings before and after a 12-month communication curriculum (based on psychologist rating) found that fellows improved their skills in family meetings after the training compared with a historical control group of fellows who received usual education.[32] However, no trial to date has shown benefit of simulation-based communication workshops in ICU training on patient or family perception of communication. A large trial measuring patient-reported quality of communication about end-of-life care showed no difference in effect of simulation-based communication training compared with usual education on 1,866 patient and 936 family ratings of communication.[33]

Interprofessional Team Performance

As health-care teams recognized that communication breakdown, systems error, and lack of coordination within patient care teams are implicated in adverse clinical outcomes more often than lack of skills or knowledge,[34] the field of crisis resource management in health care emerged. Crisis resource management is an approach to managing critical situations that emphasizes the importance of human factors such as hierarchy, fatigue, culture, and expected errors in highly stressful environments by training nontechnical skills such as leadership, communication, mutual support, and task management to improve outcome.[35] Since these skills require teamwork, interprofessional education (IPE), defined as "two or more professions learning about, from, and with each other to enable effective collaboration and improve health outcomes,"[36] of teams of physicians, nurses, and other providers has been emphasized. Since HCS is the most effective method of training in IPE, it is not surprising to see considerable recent growth of simulation in IPE.[37]

Prior studies of simulation-based team training have occurred in areas in which multidisciplinary, interprofessional teams must work together effectively to care for critically ill patients such as operative and obstetric emergencies, trauma resuscitation, and cardiac arrest. Systematic reviews and individual studies show improved overall team effectiveness, communication, and coordination of care after team training.[38,39] One study of critically ill trauma patients demonstrated that team training not only improved teamwork but also efficiency of actual patient care, as measured by decreased times from patient arrival in hospital to intubation, CT scan, and operating room.[40] Team training improved team performance in simulations of post-pediatric surgery cardiac arrest, with a sustained increase in use of teamwork concepts 3 months after training.[41] Another important use of team training has been to empower clinical staff to activate emergency protocols, such as rapid response teams. Team training for non-ICU nurses lessened self-perceived anxiety and increased their confidence in activation and utilization of the rapid response team.[42]

Debriefing to Learn

A discussion of HCS is incomplete without emphasizing the importance of debriefing. Simulation training is based on the constructivist learning theory, which suggests learners gain knowledge and meaning on the basis of their experiences. In high-fidelity simulation scenarios with multiple learners, each participant gains different knowledge, based on their experience. This knowledge acquisition occurs not only during the simulation case but also during debriefing with feedback, which has been shown to be the most crucial aspect of simulation training.[43]

Simulation debriefing strategies emphasize the facilitator guiding the learner to self-discover and reflect not only on their critical thinking processes but also emotional response, and actively reflect on actions performed in this safe environment. Although learners and facilitators often identify specific undesirable actions or decision points, it is more challenging to determine the reason why they occurred. The mental model of the knowledge, assumption, and feelings that drive the learner's actions has been described as the frame that facilitators seek to discover. The goal of debriefing is for the learner to self-identify the gaps in knowledge, attitude, and emotions in the clinical scenario that contributed to the performance gap. Rather than merely explaining the relevant clinical skills, an effective debriefing guides learners to think through their actions and reactions, allowing learners to incorporate the simulation session into their prior experiences (scaffolding) and conclude with take-away actions or knowledge.[44,45]

Simulation educators need to set realistic objectives for the simulation session, based on participants' training stage, to effectively facilitate further learning. While setting prescenario objectives for students and clearly identifying key concepts to review during debrief are important components of HCS, the way an educator facilitates learners' self-reflection is crucial to optimal learning. Although there are several different debriefing strategies (Table 3), all incorporate elements of active participation and focus on learning and improvement, discussion of specific events, and input from multiple sources.[46]

Simulation for Assessment/Maintenance of Competency

Milestones in Critical Care Training

The current Accreditation Council for Graduate Medical Education (ACGME) accreditation system incorporates entrustable professional activities (EPAs) and milestones to provide meaningful trainee assessment to learners.[47] EPAs are tasks that trainees are expected to perform independently on graduation while milestones are competency-based development outcomes that can be demonstrated progressively from beginning of residency or fellowship to graduation.[48]

Milestones and EPAs exist for all ACGME specialties. In 2014, a working group of medical educators representing each of the relevant critical care societies published specific EPAs and curricular milestones (CMs) for both pulmonary/critical care and critical care medicine fellowship training.[49] Simulation can be used to assess fellow competence related to specific CMs by providing structured training opportunities for fellows to reflect on their performance; faculty further enhance training by delivering timely feedback on specific observed behaviors.[50] Six training programs successfully implemented a high-fidelity simulation program to assess CMs related to trainee resuscitation of critically ill patients.[51] Assessment of fellows' ability to work effectively and respectfully with other members of the interprofessional team are ACGME CMs for critical care,[52] and since HCS is a preferred modality for IPE, these CMs can also be assessed with simulation.

Summative Assessment

Two common methods used to evaluate training are formative and summative assessment. Although

TABLE 3] Facilitator-Guided Debriefing Tools

Debriefing Method	Description	ICU Example
Debriefing with good judgment	Utilizes three-phase conversational structure that consists of reaction, analysis, and summary. This method, in particular, allows for the learner to have an initial "reaction" in order to explore their emotional reaction to their simulation experience. The analysis phase focuses on what happened during simulation and why the learner performed the way they did. The summary phase focuses on the participants describing what they learned and how they would apply those lessons to future performance	An assigned critical care team leader participates in a simulation with a standardized patient diagnosed with sepsis requiring admission and invasive procedures, but the patient refuses because of issues at home. The facilitators lead postsimulation debrief allowing for the leader to "react" to the emotional stress of dealing with patient's refusal of treatment
GAS	Three-phase conversational structure: Gather, analyze, and summarize Gathering phase encourages all learners to recap simulation events to establish a shared mental model. Analysis of learners' actions is performed by utilizing self-reflection and, finally, a summary of teaching points and lessons learned during simulation	A critical care fellow participates in a difficult airway simulation. During debrief, the learner outlines the events, reflects on and analyzes actions performed, and finally discusses learning objectives and what they can take away from the scenario to their practice
PEARLS	Promoting Excellence and Reflective Learning in Simulation Expands on three-phase methods to incorporate an additional description phase meant to identify major clinical problems or key events with the goal of developing a shared mental model	An interprofessional ICU team participates in end-of-life care discussion simulation. The members identify major clinical problems with the patient as well as address concerns of the patient and family, using a shared mental model postsimulation
Plus-Delta	This method is derived from the "plus" and "delta" (Greek symbol for change) signs. Learners identify positive aspects of simulation under the plus sign and things they would have changed under the delta. A group-based reflection covers what went well, what the learners need to change to improve care or practice, and what did not go well. The focus is not only on patient outcomes but also on identifying structures or system processes that may have contributed to the outcome	An ICU simulation for a patient requiring initiation of a massive transfusion protocol. Learners can identify what went well and what did not. They then reflect on how they can improve practice as well as identify structures and processes that contributed to the outcome
TeamGAINS	A hybrid debriefing model that incorporates elements of team-guided self-correction, advocacy-inquiry, and systemic-constructivist approaches to debriefing. In this model, the focus is on individuals within their respective system and the interactions and relationships of the team rather than individual behavior	An in situ facility mock cardiac arrest simulation in which the facility's Code Blue team jointly performs resuscitation efforts with the interprofessional team currently caring for the patient. Learners reflect as a group on team communication and skills, with facilitators voicing performance gaps and using circular questions to reflect on team behavior

GAS = gather, analyze, summarize.

formative assessments that assess learner performance for a skill or task are common in HCS, simulation can also be an effective tool for summative performance assessment at the end of educational units, such as high-stakes evaluation for promotion or certification. Since summative assessments require prioritizing validity evidence emphasizing standardization and objectivity, they are sometimes criticized for lacking clinical relevance. A well-designed simulation-based assessment is appealing because it has both strong validity evidence as well as clinical relevance.

Several studies support the validity of simulation-based assessment in assessing acute care skills of graduating medical students,[53] acute anesthesia skills in anesthesiology residents,[54] and nurse anesthetists.[55] Various simulators have been incorporated into summative simulation assessments in HCS including SPs, task trainers, and high-fidelity manikin simulators.[56] Summative simulation-based assessment has been incorporated into the American Board of Surgery's required Fundamentals of Laparoscopic Surgery course[56] and a national anesthesiology board examination.[57] The American Board of Anesthesiology now allows certified HCS courses to meet its Quality Improvement Maintenance of Certification requirement. However, simulation-based assessment is not currently used for critical care certification, with the fear of interfering with the simulation learning environment "safe space" given as one reason.[58]

Simulation for QI

Simulation for Health-Care System Support

A highly reliable health-care system requires a culture of safety, and leadership committed to process improvement.[59] Effective QI processes for health-care systems include having clinical team members practice together, with simulation serving as an effective way to learn and rehearse so teams can prevent adverse events, or improve after their occurrence. Communication errors during handoffs between teams or at shift change are common and an area of QI focus. Simulation has successfully been used to practice effective handoffs between providers at shift change, and to mitigate hierarchy-related medical error.[60,61] An electronic health record-based ICU rounding simulation has been successfully used to understand the effect of team dynamics on recognition of patient safety issues in the health record.[62] A strategic framework to effectively use HCS to rigorously investigate and learn from safety incidents to benefit hospital quality and safety programs has been proposed.[63]

High-Risk, Low-Volume Critical Care Events

Simulation has also been essential for health-care systems to rehearse safe care of patients with rare, emerging infectious diseases such as Ebola that require clinical staff to provide care without violating their appropriate personal protective equipment and risk acquiring the infection.[64]

Today, there is increased utilization of advanced mechanical and resuscitation techniques such as extracorporeal membrane oxygenation (ECMO) and extracorporeal CPR that require system resources spanning multiple disciplines and locations in managing critically ill patients. HCS has been shown to be effective in training and retraining teams to implement these programs in hospitals. An interprofessional simulation workshop enabled initiation of extracorporeal CPR flow within 30 minutes that persisted at 3 months posttraining.[65] Even with groups such as pediatric ICUs that are accustomed to clinical management of ECMO, introduction of a high-fidelity simulation education program of quarterly retraining for ECMO emergencies reduced time to manage air embolism and change oxygenator in actual patients receiving ECMO.[66]

Simulation in Decision Science

Simulation has also been used in decision science to assess biases in provider choices. Serious games, simulations of real-world events, or processes designed for the purpose of solving a problem, have been used to both teach and assess provider decision-making, which can be negatively influenced by cognitive load inherent to caring for critically ill patients. Physicians randomized to different types of active serious games with structured feedback demonstrated reduction of undertriage of severely injured trauma patients compared with control or text-based educational intervention.[67]

Since improving diagnosis has been identified as a patient safety imperative,[68] there has been growing interest in simulation as a modality to study clinical decision-making. Observational in situ simulation with interprofessional teams has been used to study adherence to treatment protocols and to assess readiness in pediatric diabetic ketoacidosis and cardiac arrest.[69,70] Simulation has been used to assess physician mental models during conversations surrounding prognostication and decision-making for intubation.[71] Simulation has also been used to test and validate a model to study clinician-surrogate conflict, whereby different strategies between intensivist (task-focused communication) and palliative medicine specialist (relationship building) communication strategies were observed.[72]

Regarding the patient with hypoxemia and bleeding from the tracheostomy site discussed previously, periodic interprofessional simulation to practice rapidly mobilizing the involved teams and resources (bronchoscopy, difficult airway adjuncts) while working through the differential diagnosis and then debriefing performance gaps prepares the health-care system to maximize success when the actual emergency occurs. Additional training benefits could be derived from individual practice in difficult ventilation and airway hemorrhage scenarios with simulation after learners have reviewed educational content reinforcing best practices. Utilizing simulation in this manner is an effective system quality assurance strategy that has been used effectively to improve root cause analysis after adverse clinical outcomes.[73]

Areas of Uncertainty and Future Directions

We have highlighted many benefits of simulation to ICU training (Table 4). However, the cost of the educational or performance improvements gained from simulation must be acknowledged. High-fidelity simulators are expensive and require maintenance. Dedicated simulation staff must schedule, set up, and run scenarios and aid educators who require assistance throughout the simulation process. Hiring SPs for communication programs or examinations can also be costly. Additional costs may be incurred related to faculty development in facilitation and protection of learner's time for training. While health-care institutions confront these budgetary realities, they must weigh these costs with local needs when deciding what to teach with simulation.

Since there are many practical questions that remain unanswered regarding best practices for simulation in ICU training, and the cost and logistics of organizing learners and educators for simulation are important real-world considerations, future research that evaluates higher Kirkpatrick level outcomes should be prioritized when possible. Fortunately, groups are collaborating to systematically study important simulation questions with enough participants to evaluate meaningful outcomes. The International Simulation Data Registry contains data from hundreds of simulation sessions that can be used to benchmark QI practices to evidence-based standards and conduct translational research that relates educational theory and patient care.[74] The International Network for Simulation-based Pediatric Innovation, Research, & Education (INSPIRE) has developed a collaborative process to study effects of HCS, with ongoing studies related to effect of resuscitation training on improving code team performance and outcomes and bundled interventions to improve cardiac arrest outcomes, among others.[75]

As more high-quality web-based learning resources are available and medical education moves away from the traditional lecture, simulation can be used to maximize in-person learning for those training in the ICU. One can envision an ICU curriculum that includes trainees completing a mastery learning process before performing common ICU procedures on patients; and practicing cardiac arrest scenarios with physicians, nurses, and other team members followed by team debriefing. We hope continued HCS research further clarifies best use of simulation in ICU training to improve patient care.

TABLE 4] Summary of Various Uses of Simulation in the ICU and Supporting Evidence

Use of Simulation	Brief Description	Critical Care Examples	Evidence of Benefit
Technical skills	Procedures and other technical skills are part of daily ICU practice. Task trainers commonly used to train	Central lines Intubation Pleural procedures Mechanical ventilation Ultrasound	Mastery learning associated with decreased patient complications[22-24]
Interprofessional team training	Interprofessional team of physicians, nurses, respiratory therapists practice ICU scenarios together, using high-fidelity simulator, and entire team debriefed by facilitator	Code Blue Difficult airway Massive transfusion Decompensating patient on ventilator	Improved teamwork[38,39,41] Improved efficiency of care[40]
Communication	Effective communication with team members and patients critical in ICU. Standardized patients often used	Determining goals of care Handoff between operating room and ICU teams for postoperative patient	Improved caregiver performance in leading goals of care discussion[32] Improved handoff communication[60]
QI	Practice ICU processes that are new to system or identified as high-risk or common sources of medical errors	Training for high-risk, low-volume critical care scenarios QI maintenance of certification in anesthesiology	Testing of clinical decision tools prior to implementation[62] Ebola training[64] Decreased time to manage ECMO emergencies[66]
Assessment of competency	Objective method to determine whether learner is meeting CM or provider competent in specific domains	Fellow competence in interprofessional teamwork CM	Objective assessment of trainee CM with critical care resuscitation scenario[51]

CM = curricular milestone; ECMO = extracorporeal membrane oxygenation; QI = quality improvement.

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