Comprehensive Healthcare Simulation
Series Editors: Adam I. Levine · Samuel DeMaria Jr.

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Harshad G. Gurnaney, MBBS, MPH *Editors*

Comprehensive Healthcare Simulation: Improving Healthcare Systems

Springer

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This series focuses on the use of simulation in healthcare education, one of the most exciting and significant innovations in healthcare teaching since Halsted put forth the paradigm of "see one, do one, teach one." Each volume focuses either on the use of simulation in teaching in a specific specialty or on a cross-cutting topic of broad interest, such as the development of a simulation center. The volumes stand alone and are also designed to complement Levine, DeMaria, Schwartz, and Sim, eds., THE COMPREHENSIVE TEXTBOOK OF HEALTHCARE SIMULATION by providing detailed and practical guidance beyond the scope of the larger book and presenting the most up-to-date information available. Series Editors Drs. Adam I. Levine and Samuel DeMaria Jr. are affiliated with the Icahn School of Medicine at Mount Sinai, New York, New York, USA, home to one of the foremost simulation centers in healthcare education. Dr. Levine is widely regarded as a pioneer in the use of simulation in healthcare education. Editors of individual series volumes and their contributors are all recognized leaders in simulation-based healthcare education.

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Foreword: Comprehensive Healthcare Simulation: An Opportunity for Continuous Healthcare System Design

Improving healthcare systems is tough! As healthcare workers and leaders continue to struggle with improving work systems and processes while achieving high-quality and safe care, we clearly need new ways of thinking about healthcare improvement. *Healthcare systems are complex work systems* where clinicians, healthcare workers, patients, caregivers, and community actors work individually and collectively to **co-produce care** over time. When healthcare work systems are not adequately designed or changes are made to its function or elements, barriers and constraints are produced that limit the ability of all to co-produce high-quality and safe care. Simulation approaches can be used *to identify and characterize system barriers and constraints and to highlight the system factors (i.e., facilitators) that support patient safety*.

We need insights from a range of disciplines, approaches and perspectives working together, which is one of the goals of this book edited by Ellen Deutsch, Shawna Perry and Harshad Gurnaney. The editors invited teams of international experts in human factors engineering (HFE), healthcare and simulation *to provide a broad and deep view of the many opportunities healthcare simulation can provide for improving systems of healthcare delivery and their processes*. They have clearly made an effort to address *conceptual, methodological and operational perspectives* of a multiple of disciplines related to the use of healthcare simulation to improve work systems and avoid negative effects of potential interventions.

Emergent system changes sometimes produce surprises, but they must be expected as they are a property of all work systems and should be planned for when possible. Simulation can, therefore, contribute greatly *to continually enhancing the design of healthcare work systems* by providing insight into not only the impact of proposed changes on the work system, but also aiding in the avoidance of emergent or impactful disruptions from what may seem like small or "common sense" interventions. Chapters in the book describe how simulation can be used in the work system analysis phase to improve the design of potential interventions and provide interesting examples of how simulation can help *to imagine and test solutions* aimed at improving work systems. The benefits of using simulation for assessing the potential changes to the work of healthcare are incalculable if they avoid negative consequences for those for whom the system was designed—the patient.

This book will become a must-read for anyone interested in challenging the status quo of healthcare improvement through simulation. Healthcare improvement is not a project; it is **a continuous system design process that unfolds over time and requires commitment** from healthcare workers and leaders at all levels in collaboration with safety science experts from disciplines outside of medicine. This timely book provides a practical background necessary to engage in the long-term journey of embedding simulation in the fabric of healthcare improvement.

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Foreword: Assimilating Healthcare Simulation

There has been a steady increase in the sophistication of how we use simulation in healthcare. More recently, simulation has been used to improve the functioning of healthcare systems and thus plays a valuable role in advancing the field of patient safety and quality care delivery. By sharing the story of how my institution's simulation program has evolved, I hope to inspire readers to apply simulation for their own systems improvement. In this book, Drs. Deutsch, Perry, and Gurnaney have joined a diverse group of leaders in the fields of simulation, human factors, and safety to impart their expertise on this topic.

Initially, I used simulation as an educational tool to teach technical skills, such as airway management, to physicians. Then, I learned the value of including multiple professions in the same simulation session and incorporating training of communication and teamwork skills. The locations where these simulations could be conducted seemed unlimited. Effective debriefing models evolved in response to the complex interactions of the healthcare system. We now better understand how to translate our simulation education and research efforts to measurable outcomes at the patient level.

By rehearsing and debriefing medical emergencies with frontline staff in our intensive care unit, on hospital floors, and in our emergency department, I witnessed how people in each clinical unit had variations in their interactions with each other, their local environment, with other units, and even with us, the simulation educators. Different workflows, communication styles, and solutions had emerged in response to the challenges of the local patient population, and the capabilities and experience of the clinical staff, including their relationship to their leaders and upper management. The effectiveness of healthcare delivery, the successful adoption of new technologies and safety initiatives, is limited without attending to the humans who are central to the work.

Healthcare is a sociotechnical system. Prompt and successful translation of interventions and innovations from a theoretical or research environment to the clinical setting requires optimization of social integration at the microsystem level. As technology in healthcare has rapidly advanced, there is a need to jointly develop the social dimensions of care delivery for ideal system functioning. Simulation provides a mechanism for disassembling a work process to allow examination and refinement of the relationships of workers to their work system, including technical and non-technical aspects.

We found staff to be very receptive to simulations where the objective was process improvement or system safety testing within their microsystem. They were happy to problem solve together and I could see some felt relief as they finally had a receptive audience for their frustrations related to work inefficiencies. Positive change happened at a faster rate as solutions were able to be tested and optimized in a simulated environment prior to implementation with real patients. Using simulation in this manner facilitated inclusion of frontline staff's perspectives, and built a shared understanding of priorities and limitations for accommodating new technologies and protocols in their local clinical setting.

Because our simulation team serviced the entire institution, we were able to see recurring opportunities and needs across multiple settings. We could provide an avenue to exchange ideas/problems/workarounds at the microsystem level with management. We could make connections across clinical departments or between clinical and research departments so they

could collaborate, share resources, and work toward their similar goals. Our simulation program took on an informal role as a clearinghouse for the organization.

Integrating our simulation program into our hospital system makes our institution work better and contributes to achieving best outcomes for our patients. The chapters in this book are organized into four sections and designed to help others achieve similar success: Simulation and Systems the Big Picture, Practical Applications of Simulation for Systems Improvement, Resources for Translating Ideas into Actions, and Future Directions. This book will be a useful resource for all of us who are committed to preventing medical errors and improving care delivery and systems safety.

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Preface

Providing the best medical care and outcomes possible for patients is extremely rewarding but also quite challenging. Simulationists, individuals who are simulation professionals, make substantial contributions to these efforts. While the simulation community has developed many creative approaches to improving healthcare delivery, and simulationists often focus on optimizing the skills of individual providers and clinical teams, it has been less common for simulationists to intentionally seek a broader stance of understanding and improving the systems that surround and are fluidly interconnected with patient care. The systems we work within, around, and all too frequently despite can support or undermine the efforts of everyone involved—including patients and families, providers, administrators, and entire societies, with their values, priorities, and resources.

The tendency for simulation in healthcare to focus more on the individual and teams likely results from our difficulty with bounding or seeing the delivery of healthcare *in toto*. The scope and scale of medical work is difficult to envision or track, resulting in it often being addressed at extremes, either as a vast nebulous entity, i.e., "The System," or from a more myopic, reductionist perspective of a single patient encounter with a provider. No matter the stance, understanding how we deliver care is daunting, and as such, so is implementing change to improve it. With this book, we, the editors, seek to demonstrate that *simulation can be used as a powerful tool to explore healthcare as a system with component microsystems, and provide vital insights into what is needed to support, enhance, and improve medical care.* We deliberately invited multi-disciplinary writing teams to collaborate on each chapter, with differing domain perspectives and vocabularies to demonstrate the complexity of healthcare as seen through different lenses. This text has been designed to promote conversations between simulationists, healthcare providers, and experts from a range of other sciences and disciplines to stimulate discussion of new and innovative concepts. Some of our authors have been working toward similar goals for many years; some are just embarking on these explorations. Many of the authors, from nine different countries, did not know each other before they tackled their chapters, but were willing to take a chance and explore new and unique domains and relationships. Each author is an accomplished expert from the domains of human factors, systems engineering, psychology, education, simulation, informatics, architecture, organizational theory, industrial engineering, and a wide range of medical specialties including anesthesia, critical care, emergency medicine, pediatrics, surgery, prehospital services, and physical therapy. We greatly appreciate the expertise and time they contributed, and are humbled by their commitment to crafting such wonderful chapters.

Additionally, we were interested in reaching out to a variety of audiences. First, to stimulate healthcare simulationists to include work system analysis in their local efforts to support enhanced clinical expertise related to patient care and outcomes. Second, to encourage healthcare leadership and administrators to see simulation as much more than a teaching or training methodology, and also as an overlooked opportunity to explore the "hard-to-see" impact of decisions made for the front line of care. Every change to any system, whether purposeful or not, will result in intended and unintended consequences. Simulation provides a powerful tool to identify and address many of these phenomena proactively rather than reactively. Lastly, it has been our goal to demonstrate the value that experts and expertise from

other scholarly disciplines engaged in systems and safety science can contribute to simulation and clinical care. Close collaboration between simulationists, clinicians, and non-medical experts is even more vital now that the world and the conglomerate of elements known as healthcare has been forever altered by the COVID-19 pandemic which emerged during the gestation of this book. Our hope is that the ability of authors with diverse expertise to talk with each other will make their chapters accessible to a wide range of communities.

Simulation should be up front as a tool for understanding the new healthcare work system that has emerged as we enter 2021 and can be instrumental in shaping it to meet the competing goals and challenges ahead. We began this endeavor as an introduction to simulation for system improvement, and now also offer it as compelling material for medical work system design, assessment, re-assessment, and enhancement. To the best of our knowledge, this is the first text that integrates diverse perspectives of simulationists, clinicians, and non-medical experts on such a broad scale. We very much look forward to seeing what will grow from this effort.

Philadelphia, PA, USA — Ellen S. Deutsch
Jacksonville, FL, USA — Shawna J. Perry
Philadelphia, PA, USA — Harshad G. Gurnaney

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To my father, Stanley Deutsch, PhD, who through his work at NASA planted seeds for many of us involved in the domains of human factors and Simulation, including their integration to improve the nature of all types of work.

To my family – my parents, siblings, and children – each of whom provides inspiration, love, and support.

To my husband, Vinay Nadkarni, MD, MS, for his love and support, and for sharing many wonderful adventures.

Ellen S. Deutsch, MD, MS, FACS, FAAP, FSSH

To my mother—Marie Fuselier Perry, who *never* let me think there was anything in the world I could not do, even when the world told her she could not because of the color of her skin.

Shawna J. Perry MD, FACEP

To my wife and kids—Hema, Rohan, and Rhea, for their love and for always being supportive and understanding. To my parents and my family for their love and support.

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Part I

Simulation and Systems: The Big Picture and Overarching Principles

The Nature of Systems in Healthcare

1

Siddarth Ponnala, Rupa S. Valdez, Kerry McGuire, and Jose A. Valdez

What Is a System and How Does It Pertain to Healthcare?

Modern healthcare delivery takes place in system settings that are open, complex, and dynamic. *An "open" system, loosely defined, is a set of interdependent parts that work together to achieve some purpose, through the exchange of matter, energy and information within and beyond its environment.* In an open system, boundaries are set around the internal environment, or the system factors within the scope of analysis. Complexity arises due to the nature and interaction of the parts themselves – a conflagration of biological, technological, and social systems that have multiple, often competing, goals. Healthcare systems have many sources of complexity, including the roles of individuals and technology in the system as well as organizational, clinical, and patient priorities. *Systems are dynamic in that the elements, their interactions, and their purpose all change over time* [1, 2]. *Changes in the external environment predispose systems to being both dynamic and adaptable.*

Adopting a systems perspective provides both context and guidance for the assessment and improvement of healthcare delivery systems. To comprehensively understand systems:

- Clearly define system boundaries for analysis – e.g., patient, specific care settings, populations, larger industry/regulatory environments
- Identify the set of system objectives – e.g., improving health outcomes (actual and/or perceived), increasing throughput/utilization, reducing errors/costs – and any relevant targets or required standards
- Understand the linkages between the structures, processes, and outcomes of care delivery, including the mechanisms for feedback and control [3]
- Consider the temporal nature of systems, and thus the limitations of analyses conducted.

Within the related fields of human factors engineering (HFE), quality improvement, and patient safety, healthcare systems have often been described as uniquely challenging to improve based on their complexity, which is characterized by a multitude of interacting levels and components, fuzzy boundaries between system components, and multiple stakeholders often having competing objectives. Healthcare systems have been defined as having *four levels* consisting of the (a) *patient*, (b) *care team*, (c) *organization*, and (d) *broader environment* (e.g., political, economic) [4, 5]. The presence of these four levels and the injunction to consider all levels simultaneously only begins to capture the complexity of attending to multiple interacting levels and the components that comprise them [6].

To illustrate this point, consider a patient with multiple chronic conditions who breaks their leg while traveling internationally. Such a patient will likely be seen by multiple care teams abroad and at home, potentially across multiple healthcare organizations, thereby increasing the complexity of care received. Further, the patient's care will be impacted by additional external environments peripheral to the healthcare organizations (e.g., health insurance benefits or lack thereof; modes of transportation to return home). Using simulation modeling to improve a healthcare system requires clearly defining system boundaries, as seen with the above illustra-

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tion. Since the patient serves as the catalyst for healthcare delivery processes by presenting themselves to a healthcare system, the theory of an "open" system requires the acknowledgement of contributors to the patient's health that extend beyond the clinical care teams and organizations. This could consist of family members, friends, colleagues, neighborhood communities, places of work, in-home care professionals, places of worship, and in person or virtual patient communities [7–9].

One example to expand the perspective of healthcare as a large 'open' system would be to look at individual clinics where it is assumed within healthcare that they can be clearly defined as all of the patients, providers, and services associated with a particular clinic site. This can be useful for implementing very small scale change, however, systems improvement at a broader scale requires understanding that such systems are coupled or interrelated, rather than independently functioning entities or well circumscribed clinical microsystems [10]. The need for bounding the system in a targeted fashion for improvement beyond a single clinical microsystem is particularly evident when viewing healthcare from a patient-centered or patient-oriented workflow perspective [11]. For example, a patient who suffers a stroke interacts with multiple systems for care, yet, are generally considered independently for improvement—pre- hospital medical services, emergency department, inpatient stroke unit, rehabilitation hospital, and potentially long-term care facility. Improving health outcomes and enhancing the patient experience, would require not only creating improvement within each (sub)system, but also *considering spaces for improvement between and across these systems* [12]. In other words, *there is a need to define the system of healthcare work more broadly and inclusively to encompass all aspects of patient care, their relationships with each other and the larger system of healthcare work*.

Finally, systems improvement in healthcare is complicated by multiple stakeholders with objectives that are often competing or conflicting [13]. The range of stakeholders within a healthcare system is extensive and includes patients, informal caregivers, nurses, physicians, allied health professionals, insurance companies, payers, and government/regulatory entities, to name a few. Optimizing a healthcare system may have different meanings for stakeholders with varied perspectives. This is further complicated by each of the multitude of stakeholders having several objectives expected to be implemented simultaneously [14]. For example, the Institute of Medicine's (IOM's) seminal report, *Crossing the Quality Chasm: A New Health System for the 21st Century*, outlines six aims: [15] healthcare systems should be safe, effective, patient-centered, timely, efficient, and equitable. Similarly, the Institute for Healthcare Improvement (IHI) identifies four aims to optimize health system performance: enhance patient experience, improve population health, reduce costs, and improve the work life of health care providers [14–16]. In an *ideal* situation, it should be possible to simultaneously maximize across each of these outcomes. In *reality*, because healthcare delivery occurs in complex adaptive systems, tradeoffs are required, with certain stakeholders advocating more strongly to maximize one goal over another. For example, development of a simulation model may be motivated by low patient satisfaction scores, indicating a need to reduce wait times and have more clinical hours available in the evening. From a healthcare provider perspective, adding hours in the evening might reduce work-life balance and quality. Similarly, a model might show that if healthcare providers were to stagger their hours, more rooms would be available for each provider, further reducing wait times. However, the tradeoff might be that the quality of care is impacted by staggered hours if healthcare professionals regularly consult with one another about the patients they are seeing. Additionally, staggering provider work hours may reduce access to resources that could be beneficial for clinical care (e.g., if laboratory and radiology services close at 5 pm but clinic remains open until 9 pm). This example illustrates the particular complexity of healthcare and the need to clearly define priorities for any improvement effort while seeking to identify tradeoffs and associated risks.

Conceptual Frameworks of Systems

As described earlier in this chapter, healthcare systems require complex analyses of the work system, processes, and outcomes to holistically understand the barriers and facilitators to achieving desired outcomes. This is especially important in safety critical systems such as those around healthcare delivery, because significant harm may occur to both the patient and provider if systems are designed poorly. In this section we provide several conceptual frameworks that can be used to guide the analysis of a work system in general and health care in specific.

SEIPS and SEIPS 2.0

While it is known that systems are complex, it is also *important to understand how elements interact within a system to propel processes that result in outcomes*. This is particularly necessary while evaluating the quality of healthcare delivery. Donabedian proposed a *structure-process-outcome model* to illustrate the relationships between three main components of healthcare delivery [3]. Smith and Carayon proposed the balance theory which illustrates how elements within a system compensate for each other to maintain balance in a system [17]. The Systems Engineering Initiative for Patient

Safety (SEIPS) model provides a comprehensive framework, derived from Donabedian's quality model and the balance theory to understand the relationships among the structures, processes and outcomes in healthcare delivery [18]. In the *SEIPS model, work system is composed of six interacting elements: person(s), organization, tools and technology, tasks, physical environment, and external environment*. These interacting elements affect work and care processes which influence patient, employee, and organizational outcomes. Some of the strengths of the SEIPS model include: (1) focus on system design with respect to downstream effects on processes and outcomes, (2) high-level view of processes, and (3) in-depth description of interacting system elements. The SEIPS model has been applied to study many different healthcare processes including: safety in outpatient surgery [19]; patient safety in radio therapy [20], and patient safety in nursing homes [21] (Fig. 1.1).

An extension of the SEIPS model, SEIPS 2.0 sheds light on three novel concepts: (1) configuration, (2) engagement, and (3) adaptation [22]. *Configuration* is the idea that multiple components interact at an instance to shape processes and outcomes. *Engagement* is a concept that describes who is actively engaged in performing the process-related work activities. The work activities can be performed by professionals, patient and family members, or in a collaborative effort between the patient and professional. *Adaptation* is discussed as the dynamic feedback mechanism between the structure, processes, and outcomes, which can be reactive, intermittent, or short lasting. These three components are necessary additions to the SEIPS model because they include patients, and families as persons in the work system, which is consistent with modern views of healthcare work systems. SEIPS 2.0 has been applied to study Consumer Health information technology (CHIT) [23], elderly patients with chronic heart failure [24], and fatigue in hospital nurses [25] (Fig. 1.2).

Human Factors Engineering Paradigm for Patient Safety

The work system elements in the SEIPS model have also been reconfigured to illustrate a framework to aid design of complex work systems. *The human factors engineering paradigm for patient safety consists of four major components: performance inputs, transformation processes, performance outputs, and system redesign* [26]. In this paradigm, the elements of the work system (i.e., tools and technology, environment, and organizational factors) are the *inputs*. The *transformations, or processes*, are the actual acts of transforming inputs to outputs which can be cognitive, physical, or social/behavioral. The *outputs of the performance* can be either immediate (i.e., changes in provider or patient mental or physical state) or ultimate (i.e., patient safety and quality of care). The paradigm is cyclical because outputs are evaluated, and feedback is generated to inform system redesign for subsequent performance inputs. *The idea of system redesign configures inputs differently based on the*

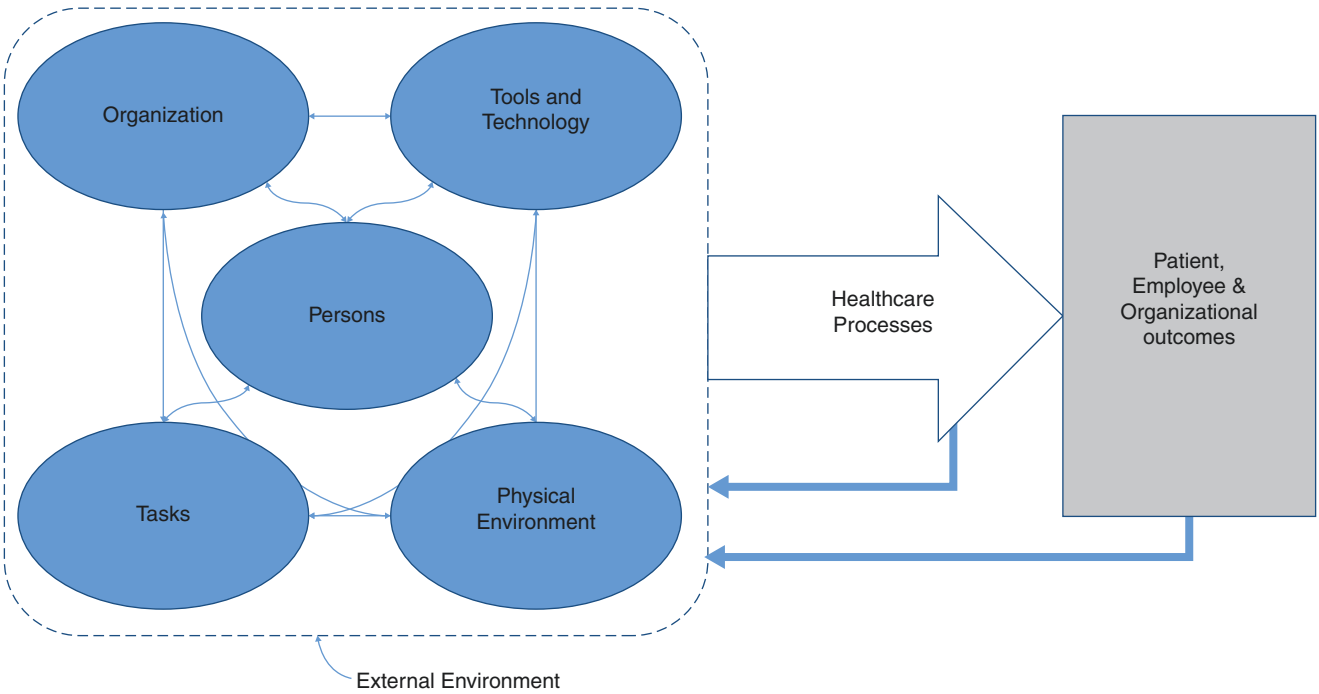

Fig. 1.1 SEIPS model redrawn from Carayon et al., 2006 [18] and Carayon et al., 2014 [42]

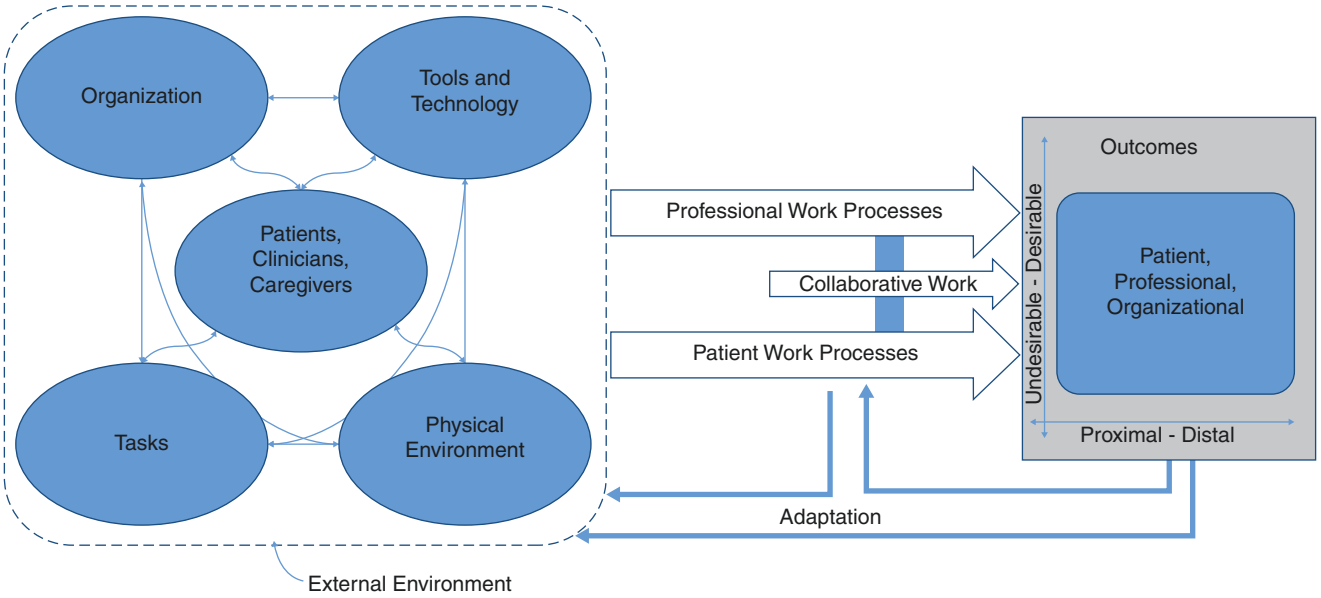

Fig. 1.2 SEIPS 2.0 model redrawn from Holden et al., 2013 [22]

performance process of interest. For example, cognitive processes may need a particular configuration of inputs, while physical processes need an alternative configuration to experience the desired outputs. The human factors engineering paradigm for patient safety has been applied for system redesign in many different contexts including health IT [27], burnout and fatigue in nurses [28], and clinical decision making [29]. Holden (2011) used the human factors engineering paradigm for patient safety to develop a classification framework that describes and identifies the cognitive performance altering effects of electronic medical records.

Patient Work System (PWS)

The delivery of healthcare is spread across many environments under unique circumstances. There is also great variation in the type of care provided and how individuals contribute to the care activities [30]. HFE has successfully demonstrated the use of a systems approach in conceptualizing professional work in clinical environments [18]. However, much of the care for chronic conditions is delivered in the community or patient's home by family members, volunteers, and other non-professionals [31]. Along with professional and collaborative work, scholars in HFE and other sciences consider this to be a third type of care known as *patient work* [22, 32]. ***Patient work*** *is defined as the health-related activities that require the energy by patients, their family members, and other non-professional individuals to fulfill the needs of the patient* [23, 32]. This component of patient care is often overlooked in healthcare delivery analyses, and as such, the way care in the home or community is provided, and the socio-technical circumstances that influence care delivery, are not well understood. In order to conceptualize the context in which the care is delivered, we use the Patient Work System framework.

The Patient Work System (PWS) was developed from one of HFE's fundamental tools, the work systems model, to study work performance [18]. Originally the PWS was applied to study the work performance shaping factors for self-care among elderly patients with heart failure and their informal caregivers [24]. In the PWS, work performance is shaped by four interacting components: *person, tasks, tools, and context.* The *context* can be further dissected into three categories: *physical-spatial* (i.e., weather and environment, distance and proximity), *social-cultural* (i.e., social influence, culture and socialization), and *organizational* (i.e., rules, roles, routines, financial and legal considerations) to identify specific factors contributing to work performance [24]. There have been several successful studies, which have applied the PWS to conceptualize work done by patients, caregivers, and other non-professionals associated with transitions of care, medication management, and chronic heart failure [33–35]. Since healthcare delivery is a continuum that occurs across various system boundaries, PWS provides a validated framework, which incorporates the relevant context, to identify barriers and facilitators to performance outcomes.

MacroErgonomic Analysis and Design (MEAD) Framework

While there have been many scholars who have developed valid conceptualizations of a system, Brian Kleiner and Hal Hendrick are among the pioneers who integrated systems thinking with HFE. Kleiner and Hendrick conceptualize a system using a macroergonomic lens focused on the interactions between organizations and systems, grounded in socio-technical systems theory. *MacroErgonomic Analysis and Design (MEAD) model portrays a work system composed of three elements: technical subsystem (interacting with technology), personnel subsystem (two or more persons working together), and the organizational and managerial structure* [36, 37]. These subsystems are characterized by a physical and cultural internal environment embedded in an external environment. In this conceptualization, the effectiveness of the work system is determined by *how well the technical and personnel subsystems are designed with respect to each other and the internal and external environments* [38, 39] (Fig. 1.3).

MEAD had been applied to identify variances in systems across several domains. The original purpose of MEAD was to provide a framework to support organizational design. *Organizational design* is composed of three core dimensions: *complexity* (differentiation and integration of segments in the organization), *formalization* (degree of standardization) and *centralization* (decision making and authority concentration) [38]. MEAD applies the notion that organizational design configuration occurs across these dimensions at a macro level (e.g., organizational policy, roles, and responsibilities) but then design is carried out at a micro level (e.g., human cognition and technology). In healthcare, MEAD has recently been applied to understand factors impacting patient care during Electronic Health Record (EHR) downtime [40]. The results of this research present opportunities for developing intervention strategies for hospitals to better cope with EHR downtime [41].

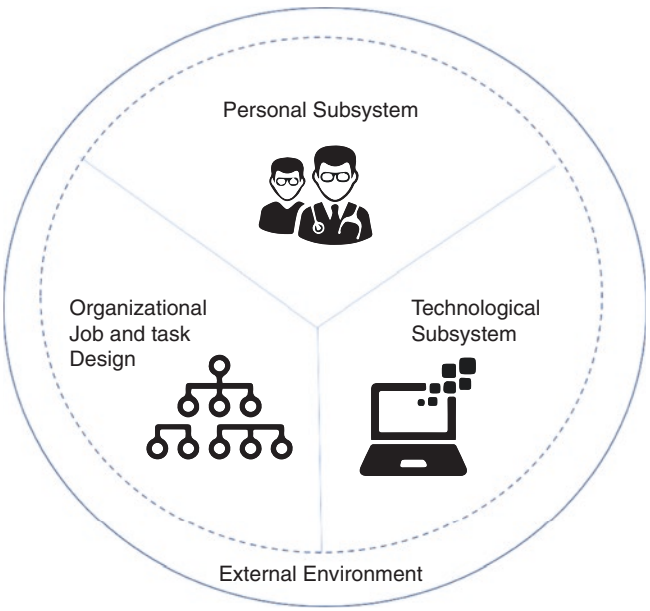

Fig. 1.3 Macroergonomics analysis and design (MEAD) framework redrawn from Kleiner (2008) [66]

Systems Engineering (SE)

Systems Engineering (SE) is a systematic, quantifiable, iterative, repeatable and holistic approach for the design and technical management of a system through its life cycles. This approach optimizes the whole design without being dominated by the perspective of a single discipline. Multidisciplinary teams in many different industries have used systems engineering as a way to look at the "big picture" and to meet customers' needs within opposing constraints. In healthcare, systems engineering has been used to improve the work processes and understand the needs of healthcare workers and patients [42].

Tools to Model and Communicate Systems Characteristics

Several of systems engineering frameworks have been reviewed thus far in the chapter. *Equally important are the tools to model and communicate system characteristics*. In this section, we discuss the various tools that may aid in the analysis and redesign of systems. The tools described in this section can be complimented with one or more of the frameworks presented in section "What Is a System and How Does It Pertain to Healthcare?" to operationalize the system analysis.

Work System Analysis (WSA)

Work system analysis enables healthcare administrators and clinicians to analyze units in their organizations, in order to develop robust interventions. There are essentially *10 steps in conducting a work system analysis* [43]:

1. Identify the subject of analysis
2. Produce a preliminary work system map

3. Based on the preliminary work system map, identify team members to lead analysis
4. Conduct initial scan of system with team member expertise
5. Identify system boundaries
6. Determine performance expectations for each step in the system
7. Begin formal data collection while iteratively updating work system map
8. Analyze collected data
9. Develop control strategies for identified hazards
10. Conduct system analysis of redesigned work system.

This method has been applied in various healthcare contexts including improving electronic medical records [44], bar coded medication administration (BCMA) [45], and radiology [20] systems. Holden et al., 2013 used work system analysis to study how BCMA affected nursing work and problem-solving behavior. The researchers were able to identify hazards and suggest three critical design needs.

Functional Resonance Analysis Method (FRAM)

FRAM is useful method to model complex socio-technical systems. *FRAM aims to develop a model of everyday system performance and then tries to identify variances in system performance and how they influence outcomes.* This model *acknowledges that healthcare delivery processes are not linear*, and can be applied to understand interactions between and across work systems to identify process barriers. *FRAM proposes a four-step process to identify these variances and design interventions* [46]:

1. Identify the functions that are required for everyday system performance
2. Characterize variability of the functions
3. Observe specific instances of the functions to identify unexpected outcomes
4. Propose ways to manage the occurrence of unexpected outcomes.

FRAM has been applied with resilience engineering to various contexts in healthcare [47]. This method can be used proactively for risk assessment, and retroactively to identify contributions and interactions impacting desired and undesired outcomes to redesign systems.

Cognitive Work Analysis (CWA)

Cognitive Work Analysis (CWA) is a Cognitive Systems Engineering (CSE) technique used to derive design requirements from complex systems. Compared to WSA, *CWA is primarily scoped to understand work is done and identify constraints that may affect it.* CWA is a toolkit that can be integrated with other analysis methods when the scope of study is broader. Applying CSE techniques within a traditional systems engineering provides a "realistic model of how the human cognitively functions" [48] within a system. This approach focuses on different users of a system and their skills and capabilities. The following *five components of a CWA toolkit* [49] can be used independently or with other tools: *work domain analysis, control task analysis*, *strategies analysis*, *social organization and co-operation analysis*, and *work competencies* analysis.

Network Analysis

With the overwhelming amount of data captured through electronic health records (EHRs) across healthcare organizations as well as community based sources, the application of network analysis has demonstrated promising returns in modeling system characteristics [50]. This section is intended to provide an overview of *three network analysis methods that have been used in healthcare: Social Network Analysis (SNA), Role Network Analysis, and Epistemic Network Analysis (ENA).* These three methods employ a form of mathematics such as matrix algebra, and graph theory to quantify relationships between different elements and display them visually.

SNA is used to study relationships between individuals and communities as they interact with each other [51]. *SNA is developed on the concept that individual or organizational behavior is fundamentally influenced by relationships* [52]. Individuals or collective units (i.e., healthcare organizations, communities) are defined as actors and distinct members of a network [51]. The connections between two or more actors are known as relationship ties. These relationship ties can be formal or informal and an actor can have multiple ties with others. SNA has been applied to study collaboration among healthcare professionals to understand the impact of team structure on care quality [50]. Wang et al., 2014 applied SNA to study relationships between clinical team structure consisting of surgeons, anesthetists, and assistants in the operating room. The study explored relationships between clinical team structure and efficiency metrics such as length of stay, complication rate, and medical cost. Several characteristics of team structure were captured including density (i.e., number of ties to each individual actor in the network over number of possible ties) and centrality (i.e., degree to which the network revolves around one actor). Surgeon centrality, or the position of the surgeon among all other team members in the network impacted all three efficiency metrics. SNA has also been used in community settings to model peer effects on binge drinking among adolescents [53].

Role network analysis takes a similar approach to system modeling as SNA, however *role network analysis focuses on the specific work roles associated with individual actors.* Role network analysis is used to model the work dependencies between different actors and elucidate how the work of one actor influences another [39]. In healthcare, role network analysis has been applied to study interactions between clinicians in the management of Venous Thromboembolism (VTE) Prophylaxis, a treatment intended to prevent pulmonary embolism and deep vein thrombosis [54]. This study helped model the clinicians' work flow for VTE prevention and management during patient's hospital admission and stay and prescribe design recommendations for clinical decision support.

In contrast to role network analysis, and SNA, Epistemic Network Analysis (ENA) does not specifically look at the relationships between people, but can be used to identify and quantify relationships among elements in coded data. *ENA relies on the patterns of association between knowledge, skills, and other cognitive elements to illustrate relationships among coded data elements in dynamic network models* [55]. ENA can be employed to investigate qualitative and quantitative research questions, where recognizing patterns of association in data are important. In healthcare, ENA has been applied to study task-allocation communication in a primary care team [56]. The results of the study found that physicians and unit clerk were most successful at allocating tasks compared to other team members. Additionally, the researchers also found that communication synchronicity of the sender and receiver roles were significant predictors of task acceptance. As demonstrated by this study, *ENA is a valuable tool to quantify qualitative data to understand care processes.*

Systems Engineering V

The systems engineering V model is a graphical depiction of the systems engineering process [57, 58]. The systems engineering V model is generally used to guide the development lifecycle of a system from defining the needs of the system to testing the designed system. The *left side of the V results in the creation of requirements and system specifications*. For example, when examining the design of an EHR, the left side of the V might list user requirements, organizational readiness, and hardware compatibility. *The right side covers the activities for testing and iterations of the requirements and specifications*. So, using the previous example of EHR design, the right side may include implementation goals and user acceptance testing before integrating into the healthcare practice. Using this approach assists in the reduction of total cost over the entire project life cycle, improves communication between stakeholders and reduces project risk through transparency and regular review of content throughout the project lifecycle (Fig. 1.4).

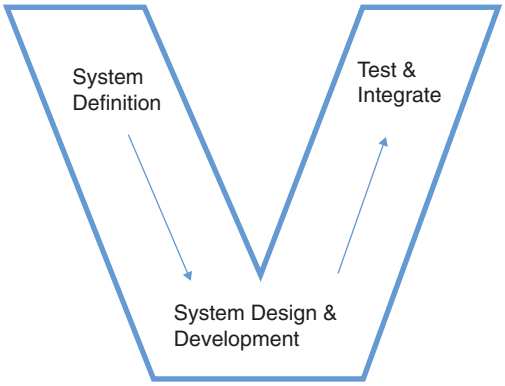

Fig. 1.4 Systems Engineering V framework for design

Analysis and Design Using MacroErgonomic Principles

While MEAD is a useful framework for conceptualizing the technical, organizational, personnel context of any system, it can also be applied to analyze sub-systems within existing functioning systems and identify variances. Kleiner prescribes a 10-step methodology to evaluate and design an effective work system [37]:

1. Scan the environmental and organizational design sub-system
2. Define production system type and set performance expectations
3. Define Unit Operations
4. Identify variances
5. Create the variance matrix
6. Create the key variance control table and role network
7. Perform function allocation and joint design
8. Understand roles and responsibilities perceptions
9. *Design/redesign support sub-systems and interfaces*
10. Implement, iterate and improve.

Analytical Tools to Capture Domain Expertise and System Interactions

Simulation and Model Based Systems Engineering

Simulation, an approximate imitation of a process or system through the use of physical or virtual representations of technical and non-technical elements can be incorporated into *Model Based*

Table 1.1 Example of FMEA matrix

	Process step	Failure modes	Failure effects	Potential causes	Process controls	Recommendations & action items	Severity (1–10)	Occurrence (1–10)	Detection (1–10)
1									
2									

Systems Engineering (MBSE). For example, consider a patient who is coding, or rapidly decompensating, and requires several resources to stabilize their vital signs. The process around codes in healthcare requires many individuals interacting with various technology and tools to work together in a confined environment. To study and improve the process around code response, simulation and model based systems engineering can be extremely beneficial. The book "Modeling and Simulation-Based Systems Engineering Handbook" documents how to incorporate modeling and simulation in systems engineering [59].

Model Based Systems Engineering (MBSE) is a formalized application of modeling to guide the full cycle of system redesign. MBSE typically starts with identifying system requirements to inform design and subsequently leads to the development of solutions, testing, and validation [60]. MBSE can be used together with the Systems Engineering V, which was presented earlier in this chapter, to illustrate the steps of model. Benefits of MBSE include allowing individuals to navigate the model for translating the relationship of system elements and their interactions. MBSE can also be used to aid in decision making by enabling teams to easily understand design impacts, assisting in examination of "what if?" scenarios, facilitating the understanding of how the elements of a system interact with one another and analyzing a system design before it is built.

Failure Mode and Effect Analysis (FMEA) and Success Mode and Effect Analysis (SMEA)

Failure mode and effect analysis (FMEA) is a method to identify and improve processes to ensure safe and desirable healthcare outcomes [61]. *This method can be used to identify and prioritize the failure modes that present most risk for adverse events in a particular process.* Often, the risk is associated with patient or provider safety. FMEA streamlines hazard analysis and enables healthcare personnel to readily apply it to their process improvement needs. The FMEA consists of five main steps, similar in process to WSA:

1. Define the FMEA topic
2. Assemble the team
3. Graphically describe the process
4. Conduct a hazard analysis
5. Determine actions and outcome measures

A matrix is provided in Table 1.1 to illustrate how to operationalize FMEA. This method has been applied to improve cardiac defibrillators [62] and in radiology oncology settings [63].

While FMEA is focused on identifying system and individual failures that may have been a precursor to an adverse event, *Success Mode Event Analysis (SMEA) conversely focuses on the success areas that a system plans to improve* [64]. Although not as common as FMEA, *SMEA is used to identify potential barriers and risks to achieving system goals*. For example, a health organization may identify financial goals to prove their system successful. SMEA can be used as a proactive tool to forecast any system barriers in accomplishing this goal.

Conclusion

Healthcare delivery occurs in complex and dynamic systems that require many interactions between work system components. If the work system is designed well, many of these interactions can yield desirable outcomes. However, we know from several reports [6, 15, 65], that there are many opportunities to study the work system, and improve processes and outcomes. In this chapter we have presented several conceptual frameworks that can be applied to analyze and design work systems. Further, we have presented several tools that can be used complementary to the frameworks to operationalize systems engineering. Applying a systems lens on healthcare delivery can improve outcomes related patient and provider safety, productivity and system efficiencies (Table 1.2).

Table 1.2 Summary of Conceptual Frameworks, Modeling, and Analytical Tools

Purpose	Name of Framework or Method	Application
Conceptual Frameworks of Systems	SEIPS and SEIPS 2.0	Widely used description of healthcare system components and their relationships, including work system, processes, and outcomes.
	Human Factors Engineering Paradigm for Patient Safety	Used to guide analysis that identifies work system inputs, transformation process, and outputs, which are used to inform system redesign
	Patient Work System (PWS)	Patient and caregiver centered systems model used to study and design for patient or collaborative work
	MacroEergonomic Analysis and Design (MEAD) Framework	Framework used to analyze variances in organizational, personnel, and technological subsystems to achieve joint optimization
	Systems Engineering (SE)	Interdisciplinary method to design, integrate, and manage complex systems
Tools to Model and Communicate Systems Characteristics	Work System Analysis (WSA)	Used to identify system boundaries and analyze the interactions between system factors to identify barriers and facilitators
	Functional Resonance Analysis Method (FRAM)	Used to model essential features and functions of a systems as well as their interdependencies
	Cognitive Work Analysis (CWA)	Focused on the cognition of human components of a system, including skills, capacities, and tasks
	Network Analysis	Used to quantify relationships between work system components and concepts based on qualitative data
	Systems Engineering V	Visual representation to map and guide phases in system redesign
Analytical Tools to Capture Domain Expertise and System Interactions	Simulation and Model Based Systems Engineering	Use to mimic an operation or system to analyze system failures or test interventions
	Failure Mode and Effect Analysis (FMEA) and Success Mode and Effect Analysis (SMEA)	Used to identify modes of failure within a system each process step, and prioritize action items based on risk of hazard

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Human Factors Applications of Simulation

2

Janet E. Anderson and Alastair Ross

Introduction

The potential of Human Factors for improving the quality and safety of healthcare is increasingly being recognised. In the UK there are efforts to embed Human Factors expertise in healthcare organisations and increase the Human Factors knowledge of healthcare professionals. Human Factors is a scientific discipline, also known as Ergonomics, but confusion has arisen from the common-sense interpretation of 'human factors'. The discipline has been taken incorrectly to be solely concerned with studying general cognitive attributes such as decision-making, or social/ interpersonal behaviours such as teamworking, or identifying human errors. Perhaps most problematic has been reference to 'the human factor'- implying that humans are viewed as unreliable and are often responsible when things go wrong. To compound the problem, Ergonomics is similarly limiting, being taken to refer to the design of chairs and other workplace equipment. So common is the misunderstanding about the profession that there have been several recent healthcare publications seeking to clarify and define its scientific basis and scope of practice [1]. Any discussion of Human Factors in simulation must similarly start by setting out clearly these foundational aspects.

Human Factors/Ergonomics

Throughout this chapter we use the term Human Factors/ Ergonomics (HF/E) to refer to the discipline. HF/E professionals study work systems to understand the interplay between the social, technical, and environmental elements of a system. The International Ergonomics Association defines HF/E as *"the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimise human well-being and overall system performance"* [2]. It is interdisciplinary and draws on the knowledge and methods of several disciplines, including cognitive and organisational psychology, engineering, physiology, industrial design, and information design. There is a strong focus on human safety and well-being. Although its use is embedded in other domains such as aviation, military and process control industries, its application in healthcare is at an early stage.

There are two tenets of HF/E that are central to its application in healthcare. First, it takes a systems approach to observing, analysing, testing, and understanding human work [3]. *Thus HF/E in healthcare will always be concerned with interactions between people, technology, processes, and the environment*. Safety and quality are viewed as emerging from the various interactions between these elements. Well known models for applying HF/E in healthcare already exist to make this explicit, such as the SEIPS 2.0 model [4]. Secondly, improvement and intervention are approached from a design perspective, which is more holistic than approaches based solely on education, behaviour, or psychology. *HF/E aims to design the environment, tasks, procedures, training, Information Technology (IT), equipment etc. to fit human capacities to make it easier to take the right actions.* Therefore, the context in which people act, make decisions, and communicate must be part of an HF/E approach to safety, quality, and health and wellbeing.

If health systems are to benefit from HF/E, and learn from other industries that have led the way in employing ergonomists and implementing HF/E principles for safety and improvement, this central theme of designing and configuring the world to suit human behaviour and abilities, as opposed to neglecting context and simply training people to 'behave differently', has to be embedded throughout its application to healthcare. A wide system focus, with an understanding of how tasks, equipment, processes, organisa-

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tions, and workspace configuration affect human behaviour, will lead to a better chance of success than a focus on the individual alone. This will also foster a just culture in which decisions and behaviours are understood in context. The benefits could be: more supportive, fair, and constructive investigations of adverse events; better regulatory oversight; better training modalities; insight for procurement of equipment and technology; improved staff wellbeing; and better outcomes for patients and organisations alike.

Brief Overview of Human Factors in Healthcare Simulation

Simulation is now a common feature of undergraduate, post graduate and ongoing professional training for many healthcare professions. Most readers will be familiar with the historical links to the aviation sector, where flight simulation is used for pilot training and accreditation. After high profile accidents attributed to inadequate cockpit communication and leadership, Crew Resource Management programs were developed to train these 'non-technical skills' through simulated practice [5].

Early healthcare simulation programmes were largely based on this model [6] and focused on closed settings that were similar to the working of cockpit crews, such as surgery and anaesthesia. For example, Anaesthesia Crisis Resource Management programs [7] were early examples of simulation in healthcare and focused on teamwork, leadership, communication, decision making and situation awareness. Such programmes became synonymous with HF/E amongst healthcare practitioners who were unaware of the wider systems and design focus of the discipline. This has arguably limited the benefits that could be realised from a HF/E approach.

Several professional bodies in simulation are careful now to define HF/E correctly. This has included distinguishing between CRM training, non-technical skills training and wider systems approaches and initiatives, as well as calls for faculty delivering human factors training to have a basic level of training in systems engineering (e.g. [8]). The HF/E focus on systems of care we would contend offers many possibilities with respect to using simulated practice to optimise care and well-being through the systematic study of the interaction between people, process, technology, and environment. But a limiting factor remains that simulation as a method has been historically synonymous with 'simulation training'- a constraint that leads to a singular focus on individual factors. We are by no means alone in recognising and grappling with this core issue for simulation and systems of care [9, 10].

Moreover, recent thinking in HF/E has emphasised the complexity and non-linearity of healthcare work [11]. In such an environment it is not possible to completely specify work processes because there are unanticipated challenges and problems that need to be solved, and competing priorities that require clinicians to make trade off decisions in the moment. Patients do not always neatly fit pre-determined procedures due to individual physiological factors and their own preferences and goals for treatment [12]. The technological and built environments also often do not align with the optimal design. Work goals are achieved in this messy, complex environment by adaptive actions that enable goals to be achieved despite these challenges. Systems that support adaptive capacity are termed resilient systems [13] and this thinking is now core to HF/E endeavours in respect to healthcare system improvement for safety and quality.

We argue that HF/E can build on the initial gains made through simulated practice, by providing tools, methods, and knowledge to analyse organisational work systems and how they constrain or enhance possibilities for action. The approach places emphasis on simulating the changing demands and fluctuating availability of staff resources, functioning equipment, physical space, bed capacity, and testing facilities, that characterise modern health systems. In such an environment, the ability to coordinate resources and adapt to challenges is an essential clinical skill [14]. We argue that HF/E offers a clear means to study practice and improve systems if we shift to this contextual focus.

In the rest of this chapter we discuss how the systems focus of the HF/E discipline, and its tools and methods can inform efforts to improve the design of healthcare systems and workplaces through simulation.

A Human Factors Approach to Simulated Practice

Designing, running, and evaluating simulated practice are not trivial or straightforward tasks. All aspects of the environment, task, team, and interaction must be considered while optimising fidelity to practice. HF/E, as a scientific discipline, has developed a range of tools and methods which can be helpful in this endeavour, adding rigour and a scientific basis for the aspects of everyday work from which good care emerges (or otherwise).

HF/E Analysis of Work Systems to Identify Skills

Healthcare skills are applied skills. People must understand how to perform skills and master techniques rather than simply retaining information about what to do. Present practice for designing simulation training appears to rely on clinical subject-matter experts to design the simulation scenarios, drawing heavily on clinical guidance and best practice. *HF/E can provide greater understanding of how task performance is influenced by contextual factors, individual and team characteristics, affordances in equipment and technology, and task demands*. HF/E practitioners employ a range of tools and techniques that could be used to inform this design process. This usually involves in depth analysis of performance under different conditions. Task analysis techniques, such as *hierar-*

chical task analysis [15], *cognitive task analysis* [16, 17] and *cognitive work analysis* [18, 19] have been used in many different domains [20]. They enable users to map task demands, identify the steps involved in successful task completion and describe alternative paths to successful task completion.

One example is a group of techniques that can be termed *cognitive task analysis* (CTA). These techniques can be employed to analyse the demands of tasks that involve the application of cognitive skills. This often involves stopping performance to ask what people are thinking, what they are trying to achieve, and how they are deciding on steps to take. This type of analysis is relatively rare in simulated practice but could be very informative for selecting tasks for simulation and specifying different options for task completion. Task analysis can be combined with systematic methods to identify opportunities for errors causing patient harm and their likelihood of occurring at each task step [21, 22]. Information about how experts recognise and recover from failures [23, 24] and learn to manage vulnerabilities can then be added to the analysis to inform simulation design. See Boxes 2.1 and 2.3.

Box 2.1 Task and work analysis methods

Hierarchical Task Analysis

This is a detailed method for breaking down tasks into a series of steps. The high-level goal of a task is identified. A task is then subdivided into a series of sub tasks that together enable that task to be completed. Sub tasks can also be subdivided, creating a hierarchy of steps required to meet the goal. This method often results in a highly detailed analysis of activity that can be used to analyse many aspects of work, such as the potential for error or alternative paths for success. The level of detail can be tailored to the requirements of the analysis.

Cognitive Task Analysis

This a form of analysis for identifying the cognitive activity required to complete complex tasks. It typically focuses on tasks that require cognitive skills such as decision making and problem solving, often under conditions of time pressure and high stakes. CTA is a collection of techniques rather than a single method and practitioners choose the best method for the requirements of the analysis.

Cognitive Work Analysis.

This is a method for analysing complex work systems to identify the cognitive requirements and demands of the work. It consists of several phases to analyse the work domain, the tasks required, strategies for completing tasks, social-organisational analysis, and worker competencies analysis. Together the phases build a complete picture of the work system, but not all phases need to be completed, depending on the aims of the analysis.

Process mapping [25] and *systems analysis techniques* [26] including *Cognitive Work Analysis* [27, 28] *can identify the contextual factors that affect performance*. These include such aspects as workflow, organisational policies and structures, equipment and technology, and spatial layout to ensure that simulation includes the full range of issues known to affect work performance. Considering a broad range of factors such as these is possible if it is based on empirical evidence of how clinical work is achieved under a range of conditions.

We can envisage a programme of simulation that, having spent some time specifying the work system(s) in question and systematically identifying the multiple factors associated with outcomes, could then rigorously explore and test interactions in simulation training. Many simulations already build in complexity, for example by including the transfer of patients from one department or clinical domain to another, allowing for physical and professional boundaries to be examined and barriers addressed. A further step would be to use the experience gained to formulate recommendations for process adjustment, design, use of equipment, and skills and behaviours of trainees, including difficult application of these skills under a range of conditions. Examples of such investigations are now emerging (Box 2.2).

Box 2.2 Example use of *in situ* simulation to identify system vulnerabilities in a new service before implementation [29]

In this study, *in situ* simulation was used to test a new endovascular aortic repair service in a new location prior to implementation. The aim was to identify serious issues that might affect safety or hinder work and correct them before implementation of the new service. A clinical scenario was designed around the process for a single patient case and used to test the new system. Observers used a checklist to evaluate each stage of the case from the pre-anaesthetic suite to anaesthesia, surgery, managing a crisis and post-operative transfer. Critical deficiencies were detected and corrected. They included: (a) equipment unavailability, (b) equipment layout making treatment impossible, (c) unclear team roles, (d) unclear blood product ordering processes and (e) unavailability of patient transport. Despite time and resource challenges, the exercise revealed many issues that had not previously been identified, allowing improvements to be made. This study shows how multiple aspects of the work system interacted to create patient safety problems.

Simulation training is often designed to simulate the conditions that led to an adverse event with the intention of providing practice in managing similar demanding clinical situations, such as “can’t intubate, can’t ventilate” anaesthesia crises [30]. But improving individual knowledge and skill in handling such situations is only part of the solution. Work system factors create

the conditions for adverse events to occur, for example through poor design of equipment and interfaces. These are often termed latent failures, or misalignments [12] and refer to vulnerabilities that are present in the design of systems. Some applications of simulation identify these vulnerabilities (see Box 2.2) and an important part of training should include developing the skills to identify and manage them. A major contribution of HF/E has been the development of tools and methods for analysing adverse events from a systems perspective [31, 32]. These methods systematically identify work system hazards that can be built into simulated practice in a structured way or may be identified for discussion when they extemporaneously emerge, for example during *in situ* simulation.

Scenario, Debrief and Analysis

Task, context, and systems analyses can maximise the value of simulation training by informing scenario and debrief design. Doing so broadens the aim of simulation training to include not just successful task completion, but to consider how clinical work can be effective under a range of conditions known to exist in healthcare work environments. Rigorously designed and evaluated, such data would then contribute to the knowledge base about human performance. Using basic HF/E knowledge, scenarios could be designed to test, for example, the working limits of response repertoires, the effect of *cognitive load* [33], *expert-novice differences* [34, 35], *fatigue* [36], the *effect of observers* [37] and *team cognition* [38]. See Box 2.3 for an example study.

Box 2.3 Example of using Cognitive Task Analysis to identify training requirements [39]

This study was motivated by the increasing complexity and ambiguity of emergency paramedical work in a resource constrained system. The aim was to identify how to better support practitioners using simulation to study differences between more and less experienced practitioners. Understanding how expert practitioners reason about cases and respond effectively is important for training and system design. A patient trauma scenario was designed to challenge diagnostic skills and resource and task management. Performance measures were carefully designed to capture diagnostic reasoning, risk management, planning and actions. More experienced paramedics: (a) performed more assessments and interventions, (b) switched attention between patients more frequently, (c) effectively interpreted information, (d) made more diagnostic inferences, (e) anticipated clinical developments, and (f) made better use of resources. The results inform the provision of training for novice paramedics, but also provide pointers to how the system can support the development of expertise through better feedback, and better design of equipment and processes to support expertise.

Managing the demands of the physical, environmental and organisational context is a skill that must be learned [14] by any worker in a complex system, and this is especially relevant in clinical work. *In situ* simulation, in which simulated scenarios are integrated into the clinical environment, is a powerful training modality [40] that aims to provide practice and training in the real-world environment. Studies show that it has benefits beyond individual skills, including better teamwork, improved quality and safety, better patient safety threat detection [41] and organisational learning [42]. Clearly full immersion in the relevant clinical context is powerful and *in situ* simulation has now become common practice. But it also has disadvantages, including the potential disruption to clinical care [42]. Additionally, contextual factors vary naturally and so may not afford exposure to the full range of important factors (Box 2.4).

Box 2.4 Example of simulation to provide practice managing workload over a full shift [43]

The in-situ simulation in this study was designed to run for a full 12 hour shift. Nurses cared for a standardized deteriorating patient alongside their normal caseload. The aim was to identify how nurses managed the case, whether they could identify signs of deterioration, and whether they could identify the cause of the patient's symptoms. The full shift design created greater realism and provided a basis for discussing prioritising and decision making. The study found that clinical decision making in relation to deterioration was slower than required when the patient was cared for alongside a full patient load in a busy word environment with multiple caregivers. The authors highlighted knowledge deficits that could be targeted with training, but the results also show how important it is to ensure that practitioners can practice skills in an environment with realistic demands that require accurate diagnosis under conditions of divided attention and competing demands.

Other opportunities for building context into simulation involve innovative designs such as including external staff, like the police [44], management staff, or transfers across organisational boundaries as well as the typical clinical speciality-specific episodes of care involving front line clinicians. The power of simulation lies in its ability to account for context and address real world problems [45]. Doing so systematically and informed by evidence about systems and human performance is required to gain the most benefit from simulation. HF/E offers a powerful knowledge and methods base to enable this.

Reflective practice is central to simulation as a training and teaching tool [46, 47]. Debriefing of participants facilitates interactive learning, situated in reflective practice [46] which has been shown to be an important augmentation of

more didactic clinical teaching methods [48]. *But the focus of reflection is often facilitated with little attention to organisational theory*. HF/E systems models could provide a framework for systematic examination of relevant contextual factors during debriefs. One example for structuring debriefs, Learning from Success [9], is based on recent developments in HF/E which emphasise adaptive actions as fundamental for safe, high quality care. Debrief discussions are focused on how success is achieved, with an emphasis on adaptive actions and the need to understand the system context when discussing actions. See Box 2.5 for a further example of HF/E informed debriefing.

Box 2.5 Example of systems-focused debriefing framework [49]

The PEARLS systems integration framework is based on systems engineering principles and the SEIPS 2.0 model (Holden et al. [4]). Health systems comprise multiple elements that interact to shape human behaviour and performance, including teams and people, equipment and IT system, physical facilities, policies, and work processes. PEARLS was developed to facilitate systems-focused debrief conversations to identify improvements in these elements. It provides a framework for identifying risks and hazards in systems through pre-simulation work to identify objectives, describe the system as experienced during the simulated practice, analyse the objectives and identify system risks and threats to safety.

Simulation as a tool to approach system complexity is now being advocated by improvement researchers [50]. Various approaches can be used, including analysis of professional interactions to identify the specific behaviours associated with better outcomes [51]. This approach emphasises the detailed analysis of naturalistic behaviour to inform interventions before the introduction of standardised programmatic interventions. The controlled nature of simulated practice and the common use of video recording in these settings facilitates detailed analysis of human behaviour [52], and the factors that shape human performance [53]. Results of such studies can inform clinical education, including group debriefs following simulation training, and increase our knowledge of human performance in complex systems. However, the control afforded by a simulated environment suggests that caution should be exercised in interpreting the results. Even in clinically realistic simulations behaviour is affected by other contextual factors and variability amongst participants [54], raising concerns about how generalisable the results will be. Nevertheless, such studies are important and crucial for generating hypotheses for further research and testing [50].

Identifying System Design Improvements

Despite widespread acceptance of healthcare as a complex sociotechnical system, improvement still often relies on interventions that target individuals. Knowledge of how systems work is often limited, even for people who work in the system [14]. *Lack of knowledge about the sources of complexity limits the ability to target interventions appropriately to improve the safety of systems.* Simulated practice can be used as a tool to study the clinical world and understand its complexity, and to test designs and effects of interventions. Although applications are limited, the use of simulation as a tool for improvement is being recognised. See Box 2.6 for an example.

Box 2.6 Example of identifying system design improvements with simulation [55]

In this study, high fidelity simulation was used to study how anaesthetists interacted with an anaesthesia machine during a scenario in which the oxygen and nitrous oxide pipelines were switched. The aim was to identify whether participants were able to identify this rare occurrence and investigate how the human machine interface design affected their ability to detect the problem. Multiple problems with the equipment were identified that inhibited participants in detecting the problem, including (a) confusing and undetectable alarms and (b) confusing colour coding that made it difficult to understand the gas source. Inappropriate reliance on the equipment when alternative sources of oxygen should have been used was also identified. The results highlight how important equipment design is and could be used to develop response strategies for clinicians, or to feedback to manufacturers in order to improve design.

Learning from success is a central tenet of resilient health care, but most simulation training focuses on learning about errors in front line staff [9]. There is now growing awareness in the simulation community that this focus neglects opportunities to improve healthcare systems by understanding fully how good performance emerges [9]. Perhaps the clearest recommendation we could make in this regard is to extend the body of simulation participants beyond clinical staff and standardised patients to people with expertise in all important areas that affect system performance. These include but are not limited to managers, those involved in procuring and maintaining equipment, technicians, lawyers, and ethicists, etc. Broader participation would facilitate cross-learning and deeper understanding of the multiple influences on human performance and how to 'make it easy to do the right thing'. Ensuring that the conditions most

likely to produce good performance are present is a neglected but necessary element if simulation is to aim to produce high performing healthcare systems.

Testing Interventions

Introducing and studying interventions in a clinical environment is difficult. It is challenging to establish comparison groups and control exposure to the intervention. The clinical demands of the environment mean that changing even one aspect of practice presents practical and ethical difficulties. Simulated practice provides an opportunity for piloting or studying interventions in a controlled environment. Lame and Dixon-Woods [50] provide a useful outline of study designs suited to testing interventions in simulated practice, including quality improvement studies, effectiveness studies, process evaluations, qualitative studies, and economic evaluations. They provide an overview of such studies that have tested, for example, a new checklist, new drug packaging systems, an intervention to minimise distractions and interruptions, and a telehealth system.

Introduction of new devices and technology into healthcare practice requires usability testing to identify the best design through the development process. *Simulation studies are common for equipment testing* [56]*, but it is not clear whether such testing includes all the demands present in the clinical environment.* For example, devices are often used when time and resources are limited, interruptions and distractions are common, and stress and fatigue may be present. Devices should be designed for safe use in these conditions using HF/E principles, not only under laboratory conditions. Testing device interfaces to identify the optimal layout to provide easy error free use is an obvious use for simulated practice especially given that badly designed interfaces are associated with quality and safety incidents [57, 58]. Expanding such testing to include the contextual, task and individual variables likely to affect real world performance is necessary, and a development suited to HF/E expertise.

Larger applications such as testing how new space configurations might affect work processes and team interaction are also possible [59]. In a study of the move from a hospital with multi-bedded wards to a new building with all single rooms, the new layout required major adjustments to practice which were embedded after multiple iterations that took place in the new building [60]. Simulated practice in a single room layout might have identified some of these problems in advance and made it possible to test implementation of new processes in advance of the move [61]. See Box 2.7 for more examples.

Box 2.7 Three examples of testing interventions in simulated practice

There are increasing numbers of studies reporting the use of simulation to test interventions for healthcare improvement.

Geis et al. [62] used simulation in a new pediatric emergency department to determine optimal staff roles and workload, refine the scope of practice and identify latent safety threats before opening the new service.

Rousek and Hallbeck [63] studied how the layout of a code cart medication drawer affected time to locate and select medication during simulated emergencies. Results showed that using human factors to improve visibility, group and organise the contents improved performance.

Finally, Trafton et al. [64] developed and evaluated a clinical decision support system for the safe and effective use of opioid therapy for pain. Simulation based testing was used prior to clinical testing to evaluate the usability of the system and gather user feedback. Results identified improvements to the user interface to increase clarity and ease of use, improvements to the tool itself, including organising, prioritising and highlighting information, and challenges for integrating the tool into clinical practice.

Conclusions

The time has come to embed HF/E approaches more firmly in all aspects of simulation design, operation, and evaluation to optimise learning and to identify how healthcare systems can be improved and how workers can be better supported. We need a coherent approach to improving care quality and safety. Simulation has an important role in the understanding and subsequent application of HF/E (i.e., systems science) in the workplace to optimise professional practice within the increasingly complex and resource constrained clinical environment. This can help improve system performance, through studying interactions between technical and non-technical skills and wider work system factors, such as the design of medical devices, information technology, working environments, and the policies and procedures that underpin everyday practice.

It is likely that the multi-disciplinary approach that typifies HF/E projects in other industries will have the most success. Different departments, specialities and care systems in healthcare have different problems requiring different solutions. Clinical experts, managers, patients, HF experts, psy-

chologists, designers etc. can together form a coherent HF programme to build healthcare-specific simulations, engage with HF/E theory and methods, and learn from everyday clinical work in context.

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Cognition and Decision Making in the Real World

3

Peter Dieckmann, Jan Bernhard Schmutz, and Lillian Su

Introduction

Cognition concerns how humans perceive and process the world – with their perceptions being the base for understanding a situation, some decision-making and possible action. Depending upon the decade and domain studying it, cognition and decision making have often been discussed as occurring in a linear, sequential fashion with 'proper decision making' consisting of a set of recommendations, or actually prescriptions, on how to make "good decisions". This would mean, to first identify the options available, then to assess the cost and benefits of each option, to select the one that is the best, and then to implement it [1].

Critics of this approach, argue that the amount of assumptions that would need to be fulfilled to successfully use a linear, algorithmic analytical approach within healthcare, especially clinical practice is unrealistic [2–4]. In healthcare, the problems are ill-defined, occur simultaneously, are messy, and full of uncertainties [5]. It is simply not feasible to identify all possible alternatives and often there is not enough time to even try. In some cases, it would take too long to do this and the patient might suffer from the delay. The problem is made more difficult in several ways: Human beings have difficulties in retaining and interpreting statistical information embedded in such models, [3, 4] and often lack the relevant information about assessing the results of clinical decisions over time. Consider for example, a clinician who treats a patient for some time, while a different healthcare professional will see the patient afterwards (e.g. after hospital discharge). Information from both encounters are relevant to this patient's care and they intersect in ways not necessarily reflected in a medical chart or even verbal communication. Without such process of having complete and comprehensive communication of all that occurred in both encounters, complex decision models cannot unfold their theoretical strengths of computing large amounts of data – simply because the relevant data is not available (some information was lost during the discharge) or would not be possible to obtain in a timely manner and with the resources at hand.

While prescriptive models for sensemaking and decision-making may have a role in some settings, the application in high risk domains such as healthcare is less straight forward and the models applied have difficulty predicting future events [3, 4]. Gigerenzer investigated decisions in many contexts and found that such deductive reasoning and the use of algorithmic thinking do not describe how decisions are *actually taken in a large proportion of clinical practice* [3]. Human activity is guided by multiple motives (e.g. treating the patient optimally vs. learning a new procedure), implemented in goal-oriented actions, and constantly adapted to ever changing contexts [6]. Not all decisions taken along the way might be considered "logical", showing, for example what could be seen from the outside and with hindsight as inconsistencies or contradictions.

As in any work domain, wherever there are many options, uncertain tests to assess them, and where the outcome is connected to the decision on the basis of probability and not certainty, there are a number of cognitive approaches that can be used for sensemaking and understanding. One model involves *heuristic decision models*

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which use rules of thumb to support decisions especially when there is a high degree of uncertainty associated. Those rules of thumb rely less on gathering large amounts of immediate information and instead seek to mitigate uncertainty associated with the decision, by focusing available information selectively [7–10].

This chapter will sketch a small variety of theoretical and practical approaches about cognition in the real world (i.e. macrocognition [11, 12]) that are relevant to healthcare simulation and its use for system improvements. Their aim is to take the messy conditions of actual care into account, in describing, analyzing and optimizing high quality and safe care for patients. This chapter will explore how these models can inform simulation practice in terms of design, conduct, and debriefing. It will also describe how simulation can be used to analyze meta-cognitive processes. With a case example, the focus shifts to demonstrate how meta-cognitive processes can become relevant for an entire hospital as a system. The chapter closes with practical reflections about simulation practice to stimulate the further theoretical conceptualization.

Naturalistic Decision Making and Sensemaking

Traditionally, researchers started investigating decision making and cognition in the laboratory using standardized settings like puzzle solving tasks. It became clear that the results from these isolated experiments were hardly generalizable to decision making situations in real life settings [12]. In the "field", individuals or teams often have to make decisions under complex, uncertain conditions, time pressure, and the decisions involve high stakes and high risks (e.g., nuclear power, space travel, patient safety). Research investigating cognitive processes like decision making in the natural setting—as it naturally occurs—is termed *macrocognition or naturalistic decision making* (NDM). [13–15] It is important to note that these macrocognitive functions can be achieved by individuals, teams and organizations [12].

When the USS Vicennes accidentally shot down Iranian Airbus [16] in 1988, the field of macrocognition was ignited by the US Navy deciding to initiate a program of research on decision making, the Tactical Decision Making Under Stress program [17]. In 1989, a group of 30 researchers met for several days and a few naturalistic decision making (NDM) models were discussed including the *recognition primed decision model, cognitive continuum model, image theory, the search for dominance structure, and the skills/rules/knowledge framework* and *decision ladder*. A central goal of NDM is to demystify intuition by the identification of cues that experts use to make their judgements [18].

Decisions Are Distributed

An additional layer of complexity results from the interplay between humans and other humans, and the interplay between humans and the physical and social environment. Humans are not completely predictable beings and therefore can never be completely knowable. Decisions evolve in a discussion with colleagues, while reviewing charts and algorithms that might (mis-)guide attention, in situations that are set up to trigger fixation errors, [19] where interruptions are frequent, and where "work as imagined" in the guidelines does not reflect "work as done" on the floor [20–22]. Processes described in procedures are not always the processes as they unfold in practice – Fig. 3.1 is an illustration of this. *Decisions, or more generally, cognition is distributed between a whole range of actors in a network, and within the dynamics of the interplay between the nodes in such a network.*

Figure 3.1 illustrates the difference between 'work as imagined' and 'work as done', by contrasting the walking patterns as planned (the official paths) and the actual work, the shortcuts.

We emphasize that such heuristic approaches, often labelled more or less implicitly as weakness, are a fundamental part of what makes humans so successful as problem solvers and decision makers. *It is human ability that compensates for glitches in the interplay between humans,*

Fig. 3.1 Illustration of the gap of "work as imagined" (the paved pathway curves to the left) vs. "work as done" (the well-worn shortcut curves to the right)" [21]. (Picture taken by Lillian Su and printed with permission)

technology, and organizations [6, 23] *and that helps to generate positive outcomes in a very variable clinical world.* We are interested in models that are useful in such contexts.

Recognition-Primed Decision Making

Healthcare professionals (HCP) make hundreds of decisions every day, often under time pressure with incomplete information. Under controlled circumstances, HCPs would make a decision by generating alternative options, evaluating all options, assigning probability and utility estimates for all different course of actions and evaluating them in decision trees. Clearly, this process is time and resource intensive and mostly not applicable in a complex, time sensitive setting. NDM research in military settings, with firefighters and HCP revealed that they rarely employ systematic evaluation techniques [13]. Rather they base their decisions on their experience in the form of repertoire and patterns, often intuitively [24]. The *recognition-primed decision (RPD) model* explains the process of making a decision without consciously evaluating options and consists of two components: *pattern recognition and mental simulation*. Patterns represent mental representations of the most relevant factors and their relationships within a given situation. Psychologist Daniel Kahneman would call this "system 1" or "fast" thinking [25]. These patterns also suggest typical types of reactions in the situation. The decision making process consists of matching a situation with prelearned patterns rather than a deliberate evaluation of options. If a match is found, the most typical reaction will be carried out. Experts are then defined as people who have learned numerous different patterns, are able to act upon small differences in the patterns, and are therefore able to make extremely rapid decisions. This process can be seen as a mental shortcut and often happens intuitively. Experts in crisis situations sometimes report that they had a "bad feeling" about a course of action even before having all of the critical data and therefore took early countermeasures that later appeared to be the right decision. A classic example in healthcare is the "gut" instinct of experienced neonatal nurses who can detect the onset of severe infections in babies prior to any sort of confirmatory laboratory test or vital sign change. This requires a strong response to a weak signal [26]. It takes experience to both detect the weak signal and also to have the confidence to act on those weak signals. This can be explained by the unconscious recognition of a pattern and the corresponding potential for negative consequences. However, RPD making does not mean that all decisions are made intuitively. Kahneman describes this as both fast (system 1) and slow (system 2) thinking and real expertise depends on knowing when to rely on which system and how to combine processes from both [18, 25]. After a pattern has been recognized, the future course of action will be anticipated by mental simulation, which is the process of imagining how the intervention would play out within the specific context. When system 1 goes unchecked, most of the time, things go well and it is said that an expert used good heuristics to come up with effective, intuitive decisions. In some cases, however, the actions taken in situations where system 1 goes unchecked are not good, leading others in hindsight to call the underlying processes "biases", but those processes often are not different from the processes that lead to good decisions. The picture is more complex than 'good' cognitive processes leading to good decisions and 'bad' cognitive processes leading to bad decisions. There might be "simple" errors (calculation errors for example) that can be clearly marked as wrong, but, in the messy conditions of actual care, it is more difficult to draw the lines of right or wrong so clearly.

Due to the increasing complexity within healthcare, decision making in a lot of situations is not an individual process anymore but rather a team level process. Information from members with different backgrounds and expertise needs to be processed and integrated in order to make the right decision. The next section will therefore look at the team level in decision making.

Team Sensemaking and Team Reflection

Another relevant macrocognitive process is *team sensemaking*. This process is described as the processes by which teams manage and coordinate their efforts to explain the situation they are in and to anticipate future situations, typically under uncertain and/or ambiguous conditions. Basically this describes *the collaborative efforts of a team to make sense of a situation* [27]. The basic assumption of team sensemaking is that a team establishes a frame or a mental model about the situation based on environmental data. The team then continuously tries to fit new emerging situational information into the frame, and if newer data does not fit to a frame, the team "re-frames" and adapts the existing model. A frame can be a working hypothesis from which emerging information will be evaluated and added. At a certain point the working hypothesis might not hold true anymore and it has to be reformulated. The basic steps of team sensemaking are:

- *Formulating a frame* (e.g. team member announces his or her frame; consider a team leader's belief that a trauma victim has a low hematocrit (blood count) because of bleeding in the abdomen),
- *Questioning a frame* (e.g. speaking up if the current frame seems inappropriate; consider a team member questioning the diagnosis of blood in the abdomen because the initial ultrasound of the abdomen was negative),
- *Reframing: offering alternative frames* (e.g. team discusses other areas where the patient could be bleeding),
- *Reframing: creating new frames* (e.g. a team member raises new ideas that lead to a complete review and rein-

terpretation of the situation; consider noticing that the left chest has a large bruise and the breath sounds are diminished), and
- *Elaborating a frame* (e.g. looking for data that contradicts, confirms, or extends an existing frame; consider getting a chest x-ray to confirm a hemothorax) [24, 27].

Team sensemaking as a collaborative process is, of course, more difficult to accomplish than individual sensemaking. It requires significant coordination efforts within a team and this effort needs to be encouraged and trained. A study investigating shared mental models in operations, showed, for example, how difficult it can be for the different people involved in an operation to form a shared assessment of the patient and to note challenges in the team processes, like recognizing that other team members might have a problem in their task management [28]. The importance and complexity of sharing the right amount of information with the right people in a team is also emphasized by a review work [29].

Another macrocognitive process that overlaps with the principles of sensemaking and has gained increasing attention in healthcare and healthcare simulation is *team reflection* (TR) [30–32]. TR is defined as a team's ability to collectively reflect on group objectives, strategies (e.g. decision-making), processes (e.g. communication), and outcome of past and current performance and ultimately adapt accordingly [33]. Through the reflective process, teams recognize discrepancies between actual and desired circumstances and adapt accordingly to reach their goal. TR includes looking back and *seeking information* (e.g. "Can we summarize what we have done so far?"), *evaluating* information in order to acquire a deeper understanding about a process, situation or action (e.g. "Why did this treatment work/ not work?") and finally looking forward by *planning* what action(s) to take based on the evaluation made previously (e.g. "What are our next steps then?", "What will we do differently next time?"). Depending on when teams engage in TR, it takes on different forms and varies in scope enabling different outcomes (for a recent framework see [30]). Teams can reflect either before, during or after patient care. Especially brief reflective moments during patient care (e.g. situation assessment or a team time out) help a team to assess and evaluate all relevant information during the process. As a result, a team is then able to collectively make a unified decision with a shared understanding of the rationale behind the decision by all members of the team.

Simulation as a Tool to Support the Building of Macrocognitions

Simulation is a powerful tool to enable macrocognitive processes and therefore effectiveness of teams and the organization as a whole. There are some major ways that simulation can contribute here.

Simulation creates an opportunity for repeated exposure to patterns and cues necessary for pattern recognition. In the RPD model, decisions made swiftly and accurately depend on patterns and cues and these need to be learned through repeated exposure. Such patterns can be learned to some extent by lectures or reading, but context is important since context is one of the factors that triggers recognition of a pattern,and small differences in the contexts and patterns allows persons to develop their skills. Isolating which "cues" are most important to support this learning function, plays a role in determining the fidelity needed for the simulation [34]. Those differences between the simulation and clinical situations that make a difference in pattern recognition need to be investigated with respect to their influence on the recognition of a pattern.

The building of experience seems to support pattern recognition, meaning that healthcare professionals need to experience a wide range of situations in order to build a pattern repertoire that then can function as effective RPD [35]. Simulating relevant situations in a setting with teams of actual work colleagues will help health care professionals build a wide range of patterns that will then help them to make fast and accurate decisions, especially for situations that are low frequency but high risk. Due to the rarity of these situations it is almost impossible to learn specific patterns without simulation [36]. This potential of the experience can be supported by effective reflections during debriefings.

A unique feature of medical simulation that could support pattern recognition and improve anticipation is the ability to pause a simulation scenario. Simulation educators can pause a scenario and let the team members speak out loud and reflect their current considerations, and how the process will continue. During the pause, trainees will deliberately articulate and consider the patterns they perceive. This explication might increase their decision-making skills in the future. This way, simulation can be used to expose teams to repeated scenarios where they learn which cues to focus on and which to ignore despite the increasing numbers of distractions built into the scenario [37].

Simulation as a Tool to Practice Behaviors Related to Team Cognition Such as Team Reflection and Sensemaking

Simulation training and a debriefing represent powerful tools to train all aspects of team sensemaking and reflection. During a debriefing questions like *"How did you make sense of the situation as a team?", "What was your working hypothesis (frame)"* and *"Why and how did you change your working hypothsis (frame)"* represent the very core questions for analyzing the team sensemaking process during a debriefing. All aspects of the team sensemaking process can be discussed in the debriefing in order to improve this process in a team. This can be seen as a way of combining the

different skills that individuals in healthcare teams need to function in collaboration with colleagues.

Repeated emphasis on behaviors that promote team cognition may have an effect on institutional culture. Taking a reflective stance in repeated debriefings may model reflection and may cultivate an atmosphere where such behaviors are encouraged in real clinical events. The TALK tool is one approach that tries to use ideas from simulation-based debriefings in clinical practice [38]. Simulation-based training can prompt certain psychological and behavioral processes by recreating real world events and allowing assessment of a range of possible performance outcomes [39]. As such, simulation-based training can be used to develop task-related team mental models that can then be generalized to any team configuration [40]. Simulations can also build specific skills, such as proficiency in prebriefing and debriefing, that support the development of team cognition, particularly in settings with low levels of team member familiarity [41].

Simulation as a Tool to Investigate and Optimize Work Systems

Simulation can be used in a diagnostic approach, as well as in an interventive approach [42, 43]. The interventive approach typically focuses on improving the performance of individuals and teams and was discussed above.

The diagnostic approach focuses on describing and understanding how the system functions and how the individuals within the system function [44]. This could, for example, be the adaptive capacity of a system to absorb unexpected events. Based on such analysis, determinations can be made as to whether changes would need to address human abilities, the material aspects, or the social and organizational rules of interactions. This use of simulation can thus have a direct impact on the work system and can also serve as a needs analysis for further training. If, for example, training shows systematic misunderstandings of devices, the basic introduction to those devices might be improved, or other devices more compatible with the work might be acquired. In-situ trainings can also expose "latent threats" and can direct technical and organizational improvements [45].

So far, this chapter has discussed elements of cognition that could be described as "outside" of the simulation programme. This chapter will now focus on how the adaptation of simulation actually can be seen as part of changes in cognitive structures of individuals and organizations.

Improving Organizational Operations Through a Comprehensive Hospital Wide Simulation Curriculum – A Case Study

In 2013, two simulation enthusiasts and members of a pediatric ward in a regional hospital in Switzerland decided to introduce simulation based team training (SBTT) to their hospital. They knew that just buying a simulator is not a sustainable strategy because the long term goal was a hospital wide introduction of SBTT. In order to make this initiative work they started lobbying for their cause and got the support of key players from different wards as well as the hospital leadership. After that they slowly started training staff in debriefing techniques and simulation design, first just in one department and later on others. A few years later the majority of departments in the hospital had their own assigned specialists for simulation. In order to facilitate cross department exchange simulation experts from different departments were exchanged and information how trainings are conducted in different departments was shared. Also, they agreed that the focus of the SBTT should be crew resource management (CRM) [46] in relation to diagnosis and treatment. This common conceptual basis allowed, for example, a debriefer coming from a pediatric ward to debrief a team from a surgical ward. In addition, the simulation educators from all departments had a variety of professions from different disciplines (e.g. nurses, surgeons, anesthetists etc.).

Today, healthcare professionals from the whole hospital report that this introduction of a hospital wide simulation curriculum lead to significant changes in the system. The increased cross department information exchange through simulation activities lead to more interactions between departments, increasing collaboration between a whole range of departments. Also, the interdisciplinary character of the trainings helped to decrease hierarchies and created a more open and positive organizational climate. In addition, different departments established a shared understanding of teamwork principles like speaking up, the 10-seconds-for-10-minutes principle [47] or closed loop communication. Although this evidence is primarily anecdotal, this illustrates how the introduction of a SBTT might have a wider influence on the hospital system that can eventually benefit patient care.

The case example demonstrates, how macrocognitive models and principles can evolve not only on the level of individuals and teams, but can actually impact an organization as a whole. New collective ways of sensemaking are established, norms, values, and beliefs change, practice is impacted, and with this, most likely the results and outcome of the operations in simulation and clinical care is impacted.

Practical Considerations for Simulation Practice

Beyond the ideas mentioned above, we see several practical implications for utilizing simulation-based education and training to understand the cognitive processes of the team members and the effects of various elements on cognition such as culture and psychological safety [48]. By examining certain elements of the simulation including the debriefing and simulation design, you can gain insights into institutional culture.

- Analysis of jokes that are told during debriefings. Jokes tell quite a bit about stereotypes, perceptions of the others and ways of seeing co-operation [49–51]. These aspects are important elements influencing perception, cognition, and decisions. The simulation setting is a good place to see jokes in operation and to reflect on them in the debriefings.

- Analysis of the selection of scenarios and the composition of participants to play in them can provide insight. Who attends simulations? Who is given the opportunity to participate? Who isn't? Why are certain scenarios selected over others? Are there unifying themes that can be seen? In the debriefings, who speaks up the most? These aspects provide insights into the motives and goals that guide decisions and actions.

- Analysis of scenarios that are considered and which are not considered. Is the focus on emergency situations? How much is regular practice simulated? How much attention is paid to slowly developing situations that occur often and are performed by many? Such an analysis can point out blind spots in terms of the types of decision situations that are considered. Even though time pressured decisions have big impact on patient safety, day-to-day decisions with less time pressure also have their challenges and should be investigated and trained.

- Analysis of debriefing discussions: what are the messages that are sent about the work system? What is seen as important and by whom? What should you do and not do? What "is" good "leadership", "decision making", "team working", etc.? The views around these topics will influence which arguments count for which option in a decision situation.

- Understanding how procedures or incidents are changed in order to turn them into a simulation? What is left out, what is added, what is changed? What do these adaptations tell about the work system and how it is functioning? Insights in these processes will aid the understanding of the "active ingredients" of decision making situations.

- Using simulation to investigate and optimize the system. For example, in disaster readiness simulation of a whole system, explore work systems and how they function in practice, by describing the typical challenges that a certain target group has during specific simulation scenarios. This way, awareness for decision making and its challenges can be raised in the organization.

Conclusion

Models of macrocognition take the messy conditions of healthcare into account and therefore hold great promise to inform the design, conduct, and debriefings of simulations. They can also provide the theoretical basis that can inform the design of debriefings which utilize simulations to understand the cognitive processes of participants. Models of macrocognition point to the interplay between humans, technology, and organizations and therefore to the distributed nature of cognition. These models can be scaled and contextualized to investigate and optimize the individual, a team, and even an organization. Models of macrocognition can help bridge the gap between 'work as imagined' and 'work as done', not only in clinical practice, but also in the training of personnel and the design of work systems.

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Overview of Simulation in Healthcare

4

Marjorie Lee White and Aditee Ambardekar

Introduction

Healthcare simulation is a rapidly developing field. An understanding of the core concepts and language used by simulationists can help to navigate this field. One commonly quoted definition is found in the Society for Simulation in Healthcare (SSH)'s Dictionary: simulation is "a technique that creates a situation or environment to allow persons to experience a representation of a real healthcare event for the purpose of practice, learning, evaluation, testing or to gain understanding of systems or human actions" [1]. This definition provides a framework for this chapter. What follows is a discussion of general simulation terms and a review of core concepts for the use of simulation in education, research, and systems improvement.

Overview of Simulation

How Are Simulations Characterized?

Simulations are generally described in terms of purpose, location, simulator modality, and other key terms. The purpose of the specific simulation is of primary importance and varies based on learner, setting, and opportunity. Simulations are developed and deployed for learners of multiple ages, level of experience, and needs. Opportunities for interprofessional simulations in which two or more types of professions learn together in the simulated setting are particularly valuable. Common purposes include learning, formative or summative assessment, and process understanding and improvement. Simulations may take place either in simulation facilities: "in sim," or in actual clinical or other patient care settings: "*in situ*." The nature and character of simulation facilities varies broadly. Listings of some simulation facilities can be found on the Society for Simulation in Healthcare and the International Nursing Association for Clinical Simulation and Learning websites [2, 3].

The spectrum of available simulation modalities is broad. These range from simulations which take place on computer screens to those which take place in immersive environments, such as real or simulated patient care rooms, using either manikins, humans, or constructed systems. The manikins used in healthcare simulation also vary across a spectrum of technology – in which the characteristics and features of the technology vary in their depth and breadth. The use of humans within simulations usually involves standardized patients (SPs). Standardized patients, who have traditionally been used for early learners in the development and perfection of clinical skills such as obtaining patient histories and performing physical exams, receive specific training and are coached to portray their roles. However, standardized patients are increasingly being used in an integrated fashion to test patient care systems. Some institutions use standardized patients as "secret shoppers" or *in cognito* patients to gather important patient experience data.

An additional spectrum of modalities is also used in procedural simulation. For this purpose, task-trainers are designed to allow the learner to focus on procedural skills. These may range from a simple piece of tissue used to practice suturing to a high-technology, virtual-reality trainer used to perfect complex surgical procedures. In addition to single modality simulations, one also sees hybrid, mixed-methods and other types of simulations. In a hybrid simulation, two modalities may be combined to enhance the simulation experience. An example of a hybrid simulation might be to use a standardized patient with a plastic hemi-pelvis for an obstetrical delivery simulation. In mixed simulations, multiple modalities are used simultaneously. Other types of

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simulation modalities include role play, tabletop exercises and multi-participant widespread drills such as for mass casualty or disaster preparedness.

Simulations should be tailored to target learner or learner groups. Often procedural training is focused on the acquisition and development of individual skills. Team-based training may have different purposes including focus on team functioning, nontechnical skills, or choreography. Systems-focused simulations may be targeted to understand or improve a process, such as an institution's response to a mass casualty.

Depending on the intent of the simulation, opportunities may be scheduled, which provide some convenience, or unscheduled, such as when the intent is to evaluate or improve an emergency response. Simulations can also occur in either a massed or distributed fashion. Often scheduled simulation sessions take place at key transition points in healthcare practitioner careers such as bootcamps during orientation or when new responsibilities are bestowed. Distributed skill training with the use of just-in-time, just-in-place training is a timing strategy that is increasingly popular as well; these simulations are often very brief and allow warm-up practice especially if task or technique oriented, such as simulated laparoscopic surgery, intubation techniques, or chest compressions [4].

What Are the Parts of a Simulation?

Healthcare simulations designed for teams generally follow a standard cycle, which include a *pre-brief* and *brief*, a simulation, and a *debrief*. Often the *brief* informs the instructor/facilitator and the team that will carry out the simulation. The *pre-brief* includes the participants and provides an introduction to the simulation environment and an explanation of the manikin's capabilities; delineates the rules of simulated environment and promotes psychological safety; and describes faculty expectations of the participants. The *debrief* is a distinct exercise in reflection, discussion, and feedback that usually occurs after the simulation session. In healthcare simulation, an emphasis is placed on the structure and function of the *debrief*. The model of "debriefing with good judgement" by Rudoph *et al* is widely used [5]. There is emerging support for co-debriefing (e.g., the facilitation of a debrief by two or more educators) and for translation of debriefing practices from the simulated setting into clinical event debriefing [6].

Key roles in simulations include the facilitator, the simulation operator, the embedded simulation participant(s) when appropriate and the debriefer. The facilitator is often the person who has developed the simulation and ensures that the simulation goes as planned. The simulation operator may be the person who runs the manikin or ensures that any technology being used functions well. If used, an embedded simulation participant generally is aware of the details of the simulation and serves to keep participants on track, clarify confusion generated by simulation artifact and provide information as needed to contribute to simulation flow. The debriefer is responsible for the reflective *debrief* session. When plausible, one individual may serve multiple roles. For example, the simulation facilitator may also facilitate the *debrief* after the simulation session or may function as the simulation operator in lower-fidelity or realism scenarios.

Some additional, important concepts in healthcare simulation include fidelity, realism, reliability and validity. *Realism* in simulation reflects how closely the simulated experience reflects the actual clinical environment. *Fidelity* is the measure of the realism of the experience of the learner and is often described on a continuum in terms of degrees. *Reliability* and *validity* are constructs which allow for reporting on reproducibility and generalizability. These concepts albeit controversial among simulationists are important when considering the use and structure of simulations in education, research, and systems improvement.

Education

Why Should I Use Simulation in Healthcare Education?

Simulation has become a widely used adjunct to the typical didactic and clinical experiences in health professions education. Accrediting bodies such as the Accreditation Council for Graduate Medical Education (ACGME) have made simulation-based education a mandatory component of the core program requirements while the National Council of State Boards of Nursing (NCSBM) has recently determined that simulation-based curricula are just as effective as clinical experiences in the acquisition of nursing competencies and clinical care [7, 8]. The authors do not advocate the replacement of clinical training experiences with simulation rather that simulation can be used as adjunctive experiences in skill and competency acquisition. Historically medical education and nursing training relied on an apprenticeship model whereby the phrase, 'see one, do one, teach one' was the paradigm of acquiring skills and clinical acumen. The not-so-recent shift in patient safety culture and Medicare funding has required health professions educators to consider a patient-centered learning environment rather than the age-old, learner-centered environment [9]. Furthermore, changes in Medicare funding requirements for medical education as well as public scrutiny on duty hour regulations have diminished the quantity of patient contact for trainees. These changing paradigms in health professions education support the use of simulation to fill the gaps in exposure, training, and clinical experiences.

What Are the Theoretical Underpinnings for Simulation-Based Education?

Simulation-methodologies, whether they are used for task-training or team-training purposes align well with several accepted theories of adult learning. Yardley and colleagues summarize the relevance of experiential practices in medical education based on the work of adult learning theorists like Dewey, Knowles, and Kolb [10],who recognized that learners have to be actively engaged within their surroundings to acquire knowledge. John Dewey maintained that the personal experiences, interests, and motivations of the learner were a necessity to any curriculum designed for adult learners. Malcolm Knowles expounded on this theory and asserted that learning happens best when there is partnership between the learner and the educator, the learning is personal and relevant, and the education is problem-centered rather than subject-centered. Task-based or skill-based expertise is no exception. Deliberate practice, as described by Ericsson, should begin with learner's motivation to improve followed by an experiential activity that is designed at the right level with clear instruction prior, targeted feedback immediately after, and, finally, a clear assessment of his/her performance [11]. David Kolb built on the relevance of these personal and concrete experiences and suggested that reflections on the personal experiences and activity are an integral component of the assimilation of new knowledge [12]. This reflective component helps to abstract new skills and knowledge and affects one's personal experiences when similar situations are encountered later.

How Can I Incorporate Simulation-Based Education?

Simulation curricula, whether they are task-based or team-based experiences, are designed in a way that satisfies the tenets of adult learning theory. Most scenarios are built around a clinical problem, such as the insertion of a urinary catheter or the management of a manikin with hemodynamic instability. Educational content can vary widely based on the needs of the learners. They can generally be thought of as content-based curricula or team-based curricula. Learning objectives for content-specific curricula center on medical knowledge and patient care decisions. This type of curriculum is very useful when considering the needs of the novice learner like a medical or nursing student or even a junior resident. Examples of such content include the improvement of high-fidelity scenarios into an organ system-based medical school curriculum. Students would be responsible for the diagnosis and management of septic shock or tension pneumothorax during their cardiovascular and pulmonary blocks, respectively. Similar curricula for nurses have been developed to teach the difference between clinical stability and instability [13].

Team-based, simulation curricula can be used at all levels of learners but are particularly useful for advanced learners and multi-disciplinary groups. As was introduced in the Institutes of Medicine report entitled "To Err is Human" and corroborated by many publications in the literature since then, team-based training and communication skills are an important part of keeping our patients safe within the health system [14]. As such simulation-based experiences whose focus is on the non-technical aspects of patient care are an ideal way to improve communication and team skills. The goals of such a curriculum are to teach, practice, and demonstrate the importance of good team dynamics, especially in the face of a crisis.

Team dynamics in healthcare and clinical crises have been compared to concepts in the airline industry. These principles of crew resource management were first described in the aerospace literature and adapted nearly 25 years ago as crisis resource management by David Gaba and his fellow anesthesiologists [15]. Today a commonly used teamwork system designed for health care professionals is TeamSTEPPS® [16]. It is an evidence-based system rooted in 20 years of research by the Department of Defense and is widely used in healthcare systems to teach multi-disciplinary teams of professionals [17]. Team-based curricula often use constructs like TeamSTEPPS® to guide and teach teamwork principles in simulation. Examples of teamwork exercises include a multi-professional mock code during which participants learn how to apply principles of the American Heart Association's Advanced Cardiac Life Support in the setting of a crisis in the operating room or critical care unit, or as part of a rapid response team [18–20].

Curricula exist, of course, that encompass clinical decision-making, technical and non-technical skills. Specific and measurable learning objectives should then include each of these areas. After the hands-on portion of the experience, a debrief is facilitated to reflect, discuss, and provide feedback to the learners on all objectives delineated. If the learner relates to the task or scenario, participates in the activity, and engages in the debrief she/he is more likely to assimilate new knowledge into her/his current practice. A deliberate and situated curriculum developed around measurable objectives and synthesized by a sound debrief satisfies the needs of an adult learner.

It is important to distinguish formative simulation from summative simulation in order to maintain a productive environment for learners. The presence or absence of an assessment should be made very clear. Formative simulations are used for educational purposes, thus a safe environment in which learners can make mistakes, ask questions, and improve their knowledge and skills is imperative. Summative simulation is used to measure and report competency. In

summative simulations, reliable and valid assessments are necessary and while reflection of one's actions may ultimately provide value to one's learning, it has no bearing on the grade or score achieved.

Research

Simulation research can be described as two broad areas: (1) research about simulation and (2) research with simulation. Research and healthcare delivery are often conceptualized in a spectrum starting from basic science progressing through translational, patient-oriented or clinical to outcomes and healthcare delivery research. Research about or with simulation can also be organized in the same way. Simulation-based educational research has also been framed to categorize results as achieved in the simulated setting (T1) transferred to the patient care arena (T2) and finally leading to improved patient and public health at the system level (T3) [21].

Significant research has addressed the best methods for deploying simulation [22–24]. In addition, great progress has been made in standardizing how simulation research is conducted and reported [25]. Simulation research networks such as the International Network for Simulation-based Pediatric Innovation, Research, & Education (INSPIRE) have also demonstrated success in moving simulation research forward [26]. In addition, a body of work exists to inform simulation practitioners on appropriate simulation methodologies for particular areas [24].

Systems Improvement

Beyond education and research, healthcare simulation is also useful in the domains of patient safety and quality improvement. Although patient safety and quality improvement are distinct concepts, healthcare simulation can be used interchangeably in both. Whether healthcare simulation is used for systems testing, new space planning, or testing newly implemented process improvements, the use of simulation fits naturally within the complex system that is healthcare [27–29]. Complex systems are those that have many moving components that interact in an intertwined manner. In healthcare this includes consumers (i.e. patients), the employees (health professionals and staff), the governing bodies and regulations that provide oversight to healthcare, the technology and equipment, and the ever-changing understanding of diseases and treatments for the human body [30]. Mass casualty and disaster drills are large healthcare simulations that consider these complex systems and how they intertwine.

Healthcare simulation can be married to patient safety through many avenues within a healthcare system or hospital. For instance, serious breaches of patient safety often call for an investigation, such as a root cause analysis (RCA). During the RCA, healthcare simulation can be used to recreate a real clinical event in order to study it and see why something went wrong, perhaps including the original care team and leadership from the unit or department to participate and observe, respectively [31]. Similarly, to improve patient safety within a healthcare system, quality improvement projects are often implemented. Healthcare simulation can be a useful tool in the quality improvement process, specifically by being a safe way to test process changes before they are implemented in the real clinical environment. This is one phase of the commonly used quality improvement tool, the Plan-Do-Study-Act (PDSA) cycle, namely, the "Do" cycle. To simulate what might happen if a hospital were to change a process can provide invaluable insight into the consequences, without putting any real patients or staff in harm's way [32, 33].

Additional ways in which healthcare simulation can be integrated into the complex system of healthcare are the use of simulation during onboarding of new hires and for standardization of best practices, clinical procedures, customer service, and many other processes that are often standardized across healthcare organizations [34–37]. One aspect of system improvement simulations within healthcare that is worth noting is that these simulations often happen *in situ*; that is, outside of the confines of the simulation center and within the real patient and healthcare environment. Mock resuscitations often take place in real patient rooms, just as space or facility simulations can take place in new or repurposed clinical spaces, while tabletop simulations may take place in staff conference or break rooms [38].

Summary

Healthcare simulation with proven value encompasses a range of simulators, which can be used in a variety of settings to address a multitude of skills. With a bit of creativity, applications are nearly limitless. Attention to the purpose and structure of simulations enhances effectiveness and can be divided into pre-simulation, intra-simulation and post-simulation activity. Simulation's uses in health professions education are vast and effective. Simulation-based research includes both research about simulation and research using simulation, supporting utilization across the clinical and translational research spectrum. Systems-improvement simulation, the focus of this text, is rooted in patient safety theory and practice. This chapter has provided an overview of definitions and deployment to assist with understanding and implementing healthcare simulation.

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Foresight: How Simulation Can Promote Resilient Performance

5

Christopher Nemeth and Garth Hunte

Introduction

Efforts to ensure safety in healthcare have traditionally focused on error detection and mitigation, looking back at what happened rather than preparing for possible future challenges. Hollnagel's "Safety II" approach instead focuses attention on what goes well in spite of challenges, and uses insights from that effort to protect against future challenges by building on success [1]. From the view of safety, resilience is "the intrinsic ability of a system to adjust its functioning prior to, during, or following changes and disturbances, so that it can sustain required operations under both expected and unexpected conditions" [2]. Resilience engineering (RE) is a safety management approach used to develop systems that can continue to operate in the face of unforeseen challenges. RE translates Safety II into action by understanding and managing risk in high risk socio-technical systems, which are assemblies of people in various roles who work interdependently with equipment and information [3].

The study of everyday work in complex high risk sectors such as healthcare can reveal how individuals and teams cope with surprise and create safety through flexibility and improved capacity to adapt. Flexibility is the inherent capability to accommodate and successfully adapt to changes in the environment. When circumstances are uncertain and changing rapidly, workers in complex socio-technical systems can act interdependently to adjust to expected and unexpected demands and conditions and make it possible to continue operations [4]. This ability to adapt and sustain performance under stress, and to maintain continuity in the face of change, is evidence of resilient performance. We can find the potential to continue to act while coping with uncertainty in multiple high-risk systems. The multilevel response to the 2013 Boston Marathon bombing and the 2018 Tham Lung cave rescue of the Wild Boars soccer club in Thailand are examples of resilient performance; so is everyday practice in healthcare.

Resilient performance is evident in everyday work in high risk units in healthcare, such as emergency departments (ED), critical care areas (ICU) and operating rooms (OR). In these settings, care providers make effective decisions, develop treatment plans, and refine care management over time. They work together to ensure safety for patients by anticipating and mitigating threats and hazards. Threats in these settings can include inaccurate, late or missing data (e.g. lab results), critical equipment (e.g., vital signs monitors) that are disconnected from other related gear (e.g., respirators), databases without connections needed to share patient data, and inability to see trends in data that could be used to start therapies sooner and be more effective. These can contribute to adverse outcomes (termed "patient safety events" [5]) in most care settings, but present a more immediate concern in high-risk units.

Simulation can be used to promote resilient performance in healthcare teams and systems. It can be used to carefully study what goes well, by cultivating adaptive skill and capacity through methodical analysis and design. Simulation can help providers and systems improve their adaptive expertise by exposing gaps in care continuity, presumption, bias, and realizing the implications of trade-off decisions. It can also help to learn about, anticipate and respond to, risks that are part of any socio-technical system [6].

This chapter shows how simulation can be used as a tool to analyze and design care systems that promote resilient performance. The example at the end of the chapter shows how simulation can be used to evaluate the usability of a clinical decision and communication support system and its potential to contribute to the resilient performance of a Burn ICU.

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How RE Can Improve Healthcare

Traditional views of safety consider threats to be discrete, identifiable by methods such as root cause analysis [7], and easily interpreted and eradicated [8]. However, complex socio-technical systems such as healthcare are dynamic assemblies of many elements that interact in variable and nonlinear ways that are not obvious [9]. These interactions produce results that are routinely successful, but occasionally are not.

RE research has identified and described resilient system performance and patterns of adaptation in multiple high-risk sectors through observation, interview, and artifact analysis. More recent RE practice focuses on analytic methods to assess resilient performance, and design and development to create and support resilient performance [10].

Hollnagel has developed two methods that are specific to RE that practitioners can use to analyze system resilience. The Functional Resonance Analysis Method (FRAM) can be used to represent a system's functions rather than just its components [11]. The method reveals interdependence and variability by showing how the functions connect and interact with each other, which is typical of socio-technical systems. Each hexagon is labeled as a function included in the procedure. Each hexagon has six aspects: Input (I), Output (O), Requirements (R), Precondition (P), Control (C), and Time (T). For example, "Initiate abdominal surgery" output (O) relates to input (I) for "Excise tissue sample." Figure 5.1 shows the functions and interactions during a surgical procedure that resulted in a sponge being left in the wound at closure. The method shows links among aspects of "Complete surgical procedure," "Count instruments and materials (Before Surgery)," "Count instruments and materials (After Surgery)," and "Suturing the wound" that would enable an investigator to more accurately trace the possible sources for this undesired outcome.

The Resilience Analysis Grid (RAG) [12] can be used to map four abilities of resilient performance in a system over time. They include the potential to anticipate and monitor what might happen, to respond to what happens, and to learn from what happened. The insights they lead to can be used to foster a conversation about safety and performance in a clinical team or unit that can lead to adaptive action.

The RE perspective makes it possible to better understand how clinicians routinely engage the "regularly irregular" [13] challenges of everyday operations. It also provides insights into how threats from outside of and within a healthcare setting can be mitigated to minimize harm.

Simulation in Healthcare

Using the RE perspective in clinical simulation helps to understand how to develop and expand expectations of obvious and latent risk, and improve the ability to anticipate and counter threats. The value in simulations from the RE point of view, though, is that both success and failure can provide an excellent learning opportunity.

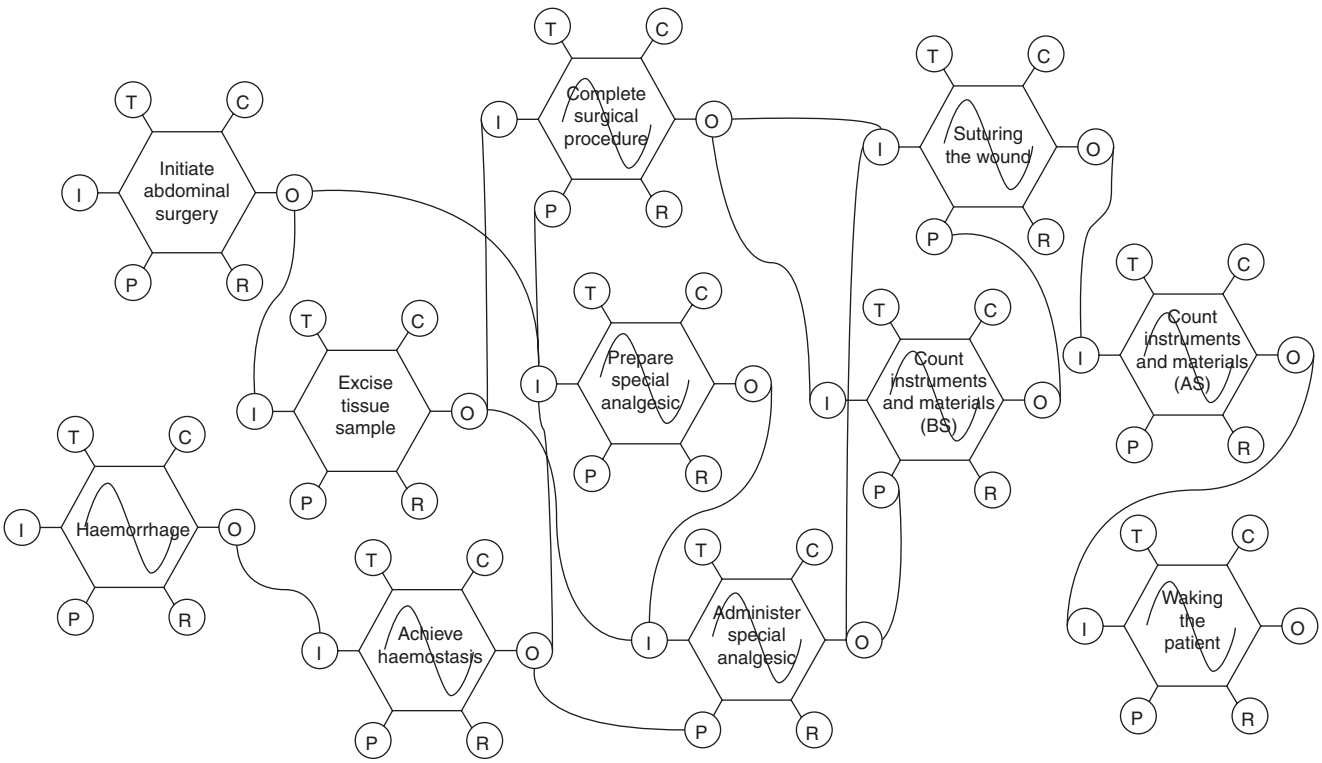

Fig. 5.1 FRAM model of a surgical incident. (Reproduced with permission of Ref. [11] (p. 107))

We suggest a number of ways that simulation can be used to improve resilient performance.

To confirm what goes well Creation of simulations can serve as a kind of audit by reconfirming how a system such as a unit or procedure was originally conceived and what about it remains valuable. It can also reveal nuances such as how clinicians and staff adjust ("tailor") what they do, or create informal shortcuts.

To explore possibilities New strategies are experiments that can be tested in pilot simulations. Running a simulation can test presumptions about new approaches from policies to procedures.

To understand an undesirable outcome Simulation can reveal what fails, when it fails, and invite consideration of why. Post-event reenactment is one traditional approach to understand how an undesirable result happened. Simulation can also be used to deliberately "break the system" by deliberately forcing failure. The tactic can be used to clarify the boundaries of safe performance, understand what safety margin may exist, reveal hidden interdependencies, learn where systems are brittle, make trade-off decisions evident, and anticipate how future challenges might compromise performance.

To build resilient performance Thinking about possible future events requires imagination. Envisioning the future is a deliberate effort to stretch perceptions and expectations to anticipate challenges. This is what Adamski and Westrum [14] term "requisite imagination." Simulation makes this kind of exploration possible and can be used to understand and apply resilience principles to care systems.

Resilient team and system performance can be enhanced by developing surprise scenarios that can be run on short notice by small teams. Individuals and teams use them to find out what happens when key features such as time of day and care specialties change. Reflection on how the scenario led the participants to anticipate, monitor, respond, and learn will lead in the direction of resilient performance. Results can demonstrate what goes well, and what may need to change. The deeper understanding that comes from these events can make a strong case to an organization's leadership for making more resources available to use simulations more often.

The following section describes how two types of simulation made it possible to evaluate how well a decision and communications support system for Burn ICU clinicians supported the variation, and at times unpredictable/surprise elements, of their high-risk work.

Case Study: Cooperative Communication System (CCS)

The Burn ICU (BICU) where the study was performed is located in a new wing of federally funded and built 450-bed tertiary care military academic medical center. The 16-bed unit is widely considered to be one of the best of its kind in the country. Two of the ICU beds are reserved to serve as a post-anesthesia care unit (PACU). Another bed is dedicated to support the center's Extracorporeal Membrane Oxygenation (ECMO) program. A nearby step-down unit, dedicated operating room, and an outpatient clinic support the BICU. The typical census averages around 8 patients but rose as high as 13 during the study. This unit's role as a regional tertiary care unit attracts patients who have the most severe affliction from burns or burn-like skin diseases. Twelve clinical roles including nurses, intensivists, surgeons, respiratory therapists, occupational and physical therapists, wound care specialists, dieticians and more collaborate to provide care for fragile patients whose length of stay ranges from days to over a year.

The Cooperative Communication System (CCS) was developed to support real time decision and communication by clinicians in this BICU [15]. Figure 5.2 shows one of many views that assemble a variety of patient data sources into a single comprehensive view. Organized by body systems, each tab includes a label, data and arrows that indicate trends for key variables. The user can arrange graphs and tables within the central frame to suit his/her preferences, and change time scale to show all data from the present back to time of admission.

The four abilities of Hollnagel's RAG described earlier in this chapter make it possible to understand how the CCS contributes to resilient performance. Use of machine learning (ML) in the CCS enables clinicians to view care trajectory and outcomes of prior patients on the unit who had similar traits. ML algorithms are based on validated clinical models (e.g. Sequential Organ Failure Assessment: SOFA) and can invite attention to vital sign trends. For example, indicating a decline in patient condition before a clinician would notice it can buy precious time to prevent the onset of shock. In the context of the RAG, this is *anticipation*. Watching current patient condition and response to treatment based on that context is *monitoring*. Real time display of all variables in the way an individual clinician prefers to see them supports a well-considered *response*. Understanding the patient trajectory over time that the system captures and retains makes *learning* possible, and contributes to the patient cohorts that other clinicians may study.

We used simulations to assess how the CCS affected clinician performance and compared it to their performance using

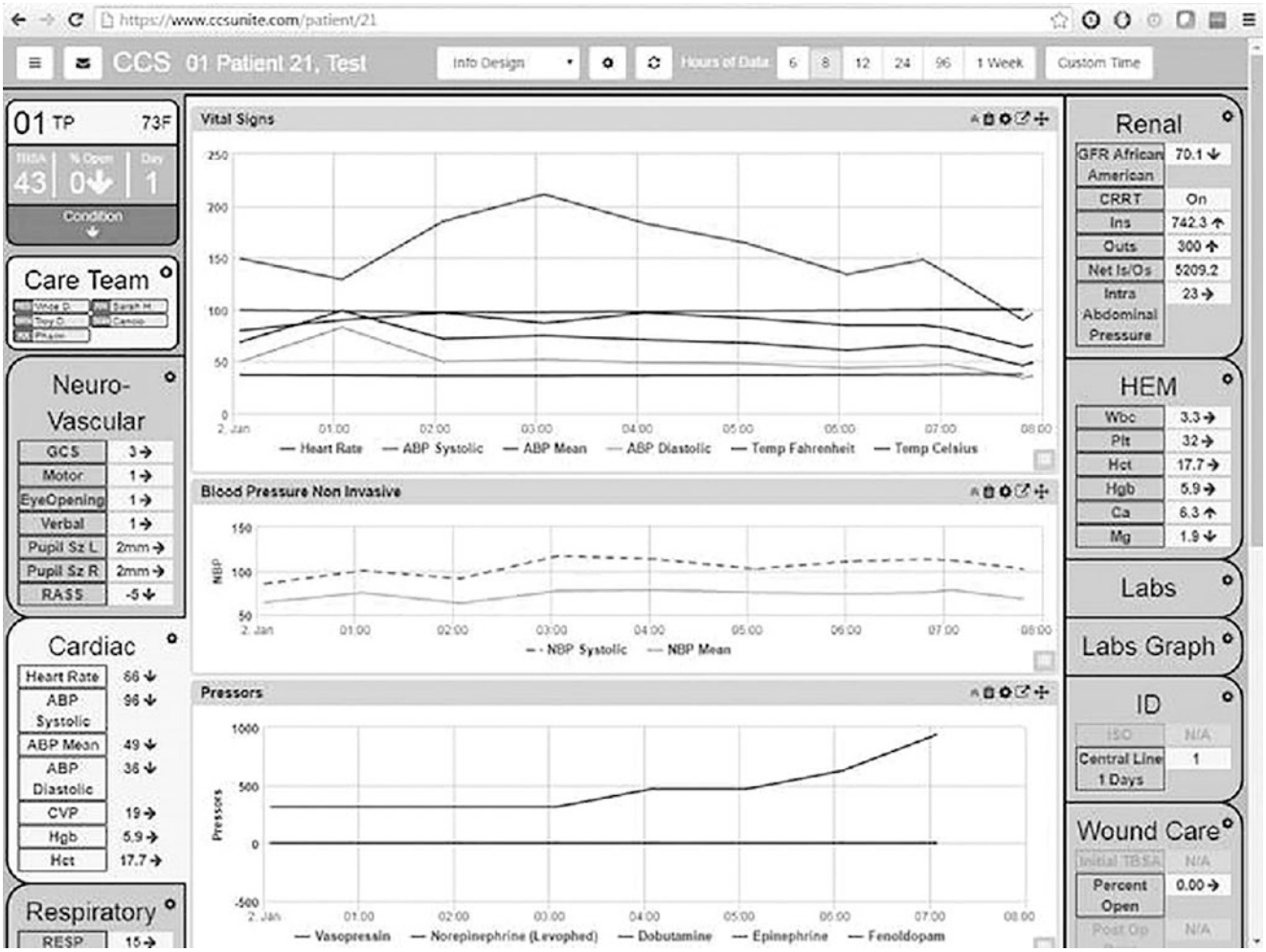

Fig. 5.2 CCS Patient View. (Copyright © 2019 Applied Research Associates)

a legacy electronic health record (EHR). This was one way to translate RAG principles into RE practice. We measured the CCS' effect on team performance during high fidelity simulated patient care using two approaches to determine how well a new IT system supported clinician decision making and communication: a usability assessment and a validation assessment [16]. The validation test in particular used the RAG's principles to determine whether the CCS could improve clinician ability to anticipate, monitor and respond to changes in patient condition.

Simulations to Evaluate a New System

The usability assessment (Fig. 5.3) was relatively simple and low cost. Clinicians were asked to perform two essential tasks using the CCS on a laptop with a video camera looking over their shoulder to record navigation and capture comments. This approach was appropriate because we needed to gauge whether the basic design of the CCS was acceptable to users. We evaluated individual clinicians' acceptance of the system and its ease of use while clinicians used it to make certain predefined clinical decisions (e.g., is the patient ready for surgery?). Forty-one burn intensive unit (BICU) clinicians (11 physicians, 20 nurses, 10 respiratory therapists) participated. Each used the CCS to find essential information needed to admit a new patient to the burn intensive care unit (BICU), and to prepare a BICU patient for surgery. They were asked to "speak aloud" and report information they considered, how they found it, and how they interpreted it while observers recorded the time it took to complete tasks. Participants also used a 7-point scale to rate their confidence in their overall usability experience and confidence in decisions using the novel system, and the novel system's ability to support the cognitive work as compared to the legacy system. Each easily completed 6 information search and decision-making tasks and rated the experience favorably compared to their experience with the legacy EMR [17].

We designed the validation assessment (Fig. 5.4) to determine how teams performed using all CCS features and how

Fig. 5.3 Usability Assessment. (Copyright © 2019 Applied Research Associates)

Fig. 5.4 Validation Assessment. (Copyright © 2019 Applied Research Associates)

results would compare with use of a system that had already been operating in the BICU for years. The assessment was an immersive patient care scenario, involving inter-professional patient care teams, using high-technology manikins, conducted in an actual patient care setting. The simulation setting on the unit and the scenarios were designed to be as close as possible to the actual care setting to minimize the need for teams to "play roles." Two 3-member BICU teams (attending burn surgeon, bedside nurse, resident physician) completed two 4 to 6-hour diagnostic and treatment scenarios: acute respiratory distress syndrome (ARDS) and intra-abdominal sepsis.

While Team 1 had more overall experience than Team 2, experience in the BICU work setting was equivalent. The Team 1 attending physician had 10+ years in practice and 10+ years working in the BICU, and the resident had 4–6 years in practice and less than 1 year in the BICU. The nurse had 10+ years in practice and 1–3 years working in the BICU.

Team 2's attending physician had 10+ years in practice and 7–9 years working in the BICU. The resident had less than 1 year in practice and less than 1 year working in the BICU, and the nurse had 7–9 years in practice and 1–3 years working in the BICU.

Each team used the legacy system and the novel system, counterbalanced to avoid learning effect. Both teams cared for simulated patients (SimMan 3G, Laerdal®, Stavanger, Norway) in an actual BICU patient room. Detailed simulation scripts laid out how scenarios might evolve depending on clinician decisions, including variations in procedures, lab values, imaging, notes, patient care needs, and changes in patient condition. For example, earlier detection of sepsis enabled a team to avoid the surprise of a patient going into septic shock. Unlike traditional pager, phone, and face-to-face discussion, the CCS messaging feature supported efficient and distributed decision making by making flexible and asynchronous communication possible within the system. Its messaging feature made it easier for team members to check patient or test status, request consults, and order medications, and each team used the feature differently. Team 1 had 11 communication threads, 82% of which received replies. This experienced team communicated directly (one-to-one) in 9 of these. In contrast, Team 2 broadcast information to their team (one-to-many) for 70% of their 10 threads. Despite brief training in use of the CCS, clinicians preferred it to the legacy system and found in some instances it outperformed the legacy EHR [18].

Conclusions

Simulation in a variety of forms can be used to foster and promote resilient performance in healthcare, offering the potential to practice adaptation and cope with surprise.

Development of new methods such as using a variety of simulations to explore the boundaries of healthcare system performance will lead to new insights. Collaboration

to develop new approaches and use them will rely on original thought to expand how we understand healthcare as a system.

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Simulation in Healthcare: A Concept Map

6

Robert K. Armstrong Jr.

Introduction

Several years ago, upon transitioning to the realm of healthcare education and training from the defense training industry, it seemed important to account for the myriad relevant applications of simulation. Motivated thusly, these application areas are represented in a concept map (Fig. 6.1) that is similar to a "mind map" but is focused around providing an answer to the question, "where can modeling and simulation tools be applied throughout the healthcare industry?" The diagram captures an understanding and appreciation – at an obviously high level – of where modeling and simulation has use, when applied specifically and particularly, throughout the industry.

The industry can be broken down into several sub domains, which helps to organize ideas and thoughts regarding the varied uses of modeling and simulation therein. These ideas and thoughts are the author's alone; there is likely no defense of these categorizations, other than – given a new perspective of the healthcare industry and a tendency towards systems thinking – they appear generally accurate.

- Administration, Business, and Management
- Practitioner and Patient Safety
- Theory and Science
- Logistics and Physical Process

This chapter assumes the reader knows a bit about modeling, simulation, and analysis, and the related fields impacted by or complementary to modeling and simulation, including (but not limited to) data analytics, operations analysis, systems engineering, and prediction.

There are many references, websites, and organizations that might be helpful if the reader wants to dig deeper into the theories informing modeling and simulation and healthcare simulation specifically. Here are a recommended few (links provided in endnotes):

- Society for Modeling & Simulation International (SCS) [1]
- *Simulation Modeling and Analysis*, Fifth Edition, Averill M. Law, Ph.D., McGraw-Hill, 2015 [2]
- *Modeling and Simulation Fundamentals: Theoretical Underpinnings and Practical Domains*, Editor(s): John A. Sokolowski PhD, Catherine M. Banks PhD, 2010 [3]
- Introduction to Modeling and Simulation, IEEE XPlore, J.S. Carson, 2004 [4]
- *Best Practices For The Development Of Models And Simulations*, NSAD-R-2010-037, Johns Hopkins University Applied Physics Lab, 2010 [5]
- Department of Defense Modeling and Simulation Body of Knowledge [6]
- Association for Computing Machinery SIGSIM (Special Interest Group (SIG) on Simulation and Modeling (SIM) [7]
- Computer Modeling and Simulation, National Institute of Health [8]
- The Society for Simulation in Healthcare (SSH) [9]
- A list of global healthcare simulation societies [10]

These definitions of modeling, simulation, and analysis are used to construct the concept map:

- **Model**: A representation of an object, concept, event, or system; models can be physical models, computational models or theories of function [11].
- **Simulation**: A method for implementing a model over time [12].
- **Analysis**: A detailed examination of anything complex in order to understand its nature or to determine its essential features: a thorough study [13].

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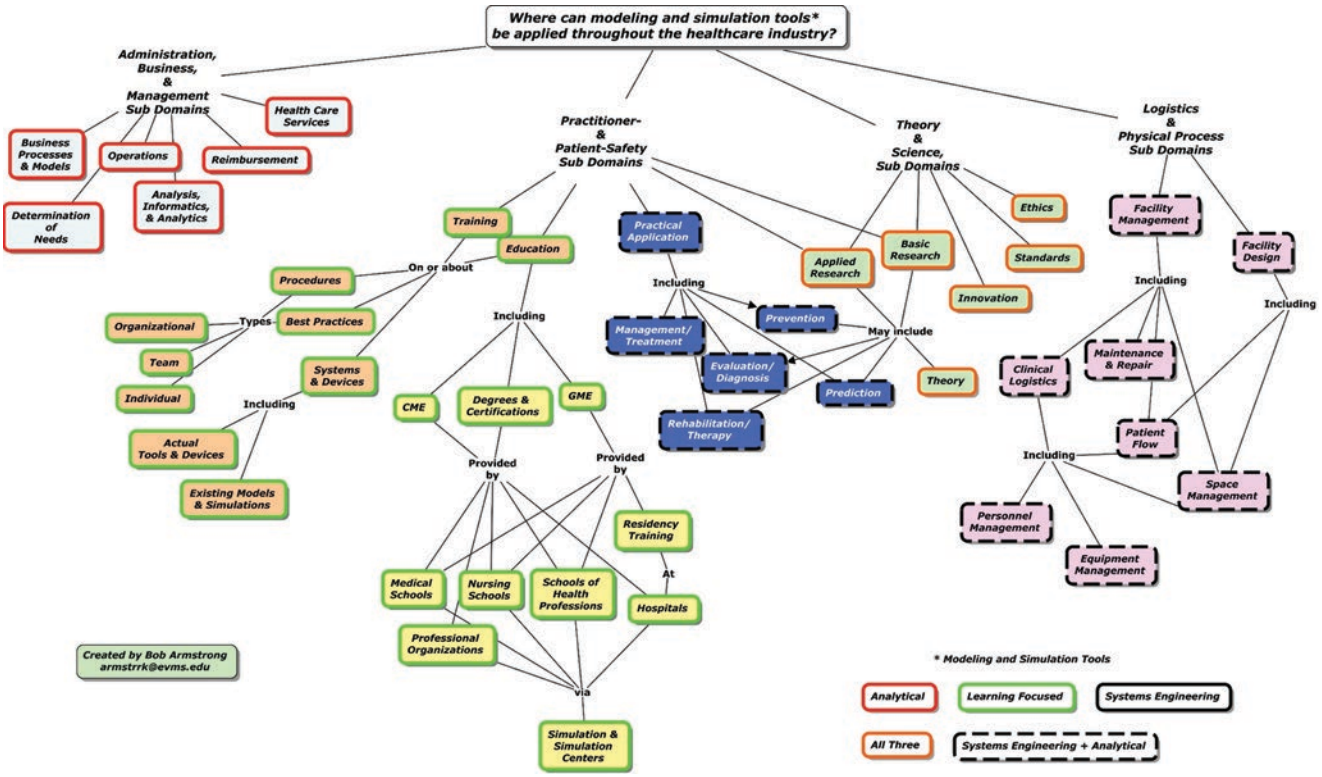

Fig. 6.1 A Concept Map to answer the question, "Where can modeling and simulation be applied throughout the healthcare industry?" For an interactive experience with the Concept Map, go to www.MedSimCmaps.org

Relying on these definitions, valuable healthcare industry insights are derived from any model that is carefully built and appropriately simulated. It is important to acknowledge that complex models are very difficult to build, and seldom accurate. The statistician George Box made popular the idea that "All models are wrong, but some are useful." More from Box:

> *Now it would be very remarkable if any system existing in the real world could be exactly represented by any simple model. However, cunningly chosen parsimonious models often do provide remarkably useful approximations. For example, the law PV = RT relating pressure P, volume V and temperature T of an "ideal" gas via a constant R is not exactly true for any real gas, but it frequently provides a useful approximation and furthermore its structure is informative since it springs from a physical view of the behavior of gas molecules.*
>
> *For such a model there is no need to ask the question "Is the model true?" If "truth" is to be the "whole truth" the answer must be "No." The only question of interest is "Is the model illuminating and useful?"* [14]

The point, relevant here, is that model and simulation developers can create models as a simplification or an approximation of reality – so they are NOT a reflection of all reality – but they are useful to help us understand aspects of reality in a supportive, valuable way. A manikin approximates a human body and is useful to represent certain specific features and characteristics of the body or of a patient. A business model approximates the successful operation of a business, setting basic metrics used to measure historical or predict future performance. A facility model approximates the space, utility, and environmental needs required to create a fully functional workspace. In all three of these example models, it is possible to change factors (treatment, costs, and number of people, respectively) and see the resulting impact of the changed factors – thereby providing "illuminating and useful" information.

The Administration, Business, and Management Sub Domains

The Administration, Business, and Management Sub Domains depicted in Fig. 6.2 show those areas within the healthcare industry that deal with the strategic management of a healthcare enterprise. In this case, the enterprise need not be large, only overseeing care functions. Think C-Suite level engagement. These models are typically analytical and mathematical, and involve things that can be measured numerically. They are most useful to find trends and hidden insights in historical and current data sets, or to perform "what if" analysis to better prepare for, understand, and predict future conditions.

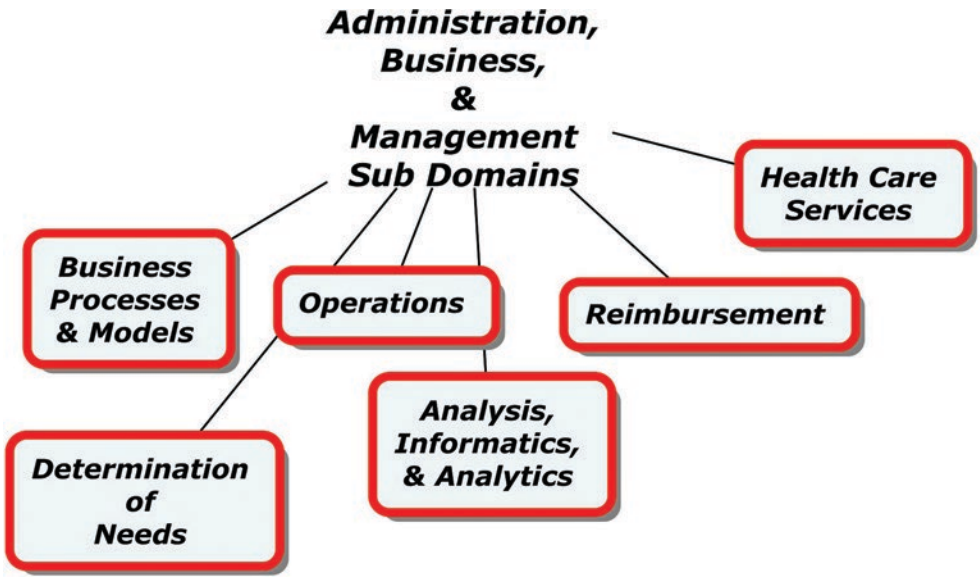

Fig. 6.2 The Administration, Business, and Management Sub Domains

A simple example: Consider a 10-hospital system that is merging with an eight-hospital system, and that needs to analyze the impact of merging electronic health record (EHR) systems. The EHR merge model would include capturing key factors and changes such as bed counts, patient flow, existing system costs, federal mandated performance standards, training costs, volume discounts, pending and ongoing system upgrades, infrastructure costs, and employee impacts.

Representing all the above factors would be challenging, and likely overcomplicate a predictive or analytical model of the EHR merger. In its most simple form, the model could represented thusly:

$$X = 10 - \text{hosp system EHR patient count}$$
$$Y = 8 - \text{hospital system EHR patient count}$$
$$Z = \text{total patients needing support in the new system}$$

So, $X + Y = Z$ is a very simple mathematical model to represent the need. This model, however, does not capture factors such as costs, patient growth projections, savings from combining systems, or any other critical business consideration.

This is a very simple model, obviously; a more extensive model is beyond the scope of this chapter. The point, though, is that it is possible to build a simple model to help provide additional insight into the intricacies of a complex administrative problem.

Practitioner and Patient Safety: Training/Education Sub Domains

The Practitioner and Patient Safety: Training/Education Sub Domains in Fig. 6.3 include those areas that are most often associated with healthcare modeling and simulation. They are intrinsically learning-focused models and simulations. The Society for Simulation in Healthcare (SSH), The Society for Simulation in Europe (SESAM), The International Nursing Association for Clinical Simulation and Learning (INACSL) and many other societies and organizations focus on the use and promotion of healthcare simulation throughout the industry.

In this sub-domain there are significant existing uses of models and simulations, all typically found in academic environments as well as in clinical facilities. Nearly all these models have a physical component to them, although in many cases there is a mathematical/computerized model that serves to generate relevant physiology data or visualizations. These models and simulations serve as replacements – *or approximations* – of human anatomy and physiology. Physical interaction is intrinsic to basic healthcare, hence the proliferation of physical approximations. These models help to create a safe learning environment with minimal potential for physical and emotional harm to patients - since the patients are not "real." Failure results in learning opportunities not harm.

Examples of type and use are myriad. Task trainers act as physical models of limbs and body parts, approximating aspects of the human body so that safe and effective learning can occur. Simple models, such as peripheral intravenous therapy trainers, allow a learner to realistically yet safely learn and practice the common yet often challenging task of safely inserting an intravenous line. Sophisticated models such as virtual models might support the simulation of laparoscopic surgery, where accurate visuals and force feedback generate a more refined experience for the advanced learner. Medical devices such as intravenous pumps are modeled so that users can learn proper function and use prior to real-world application.

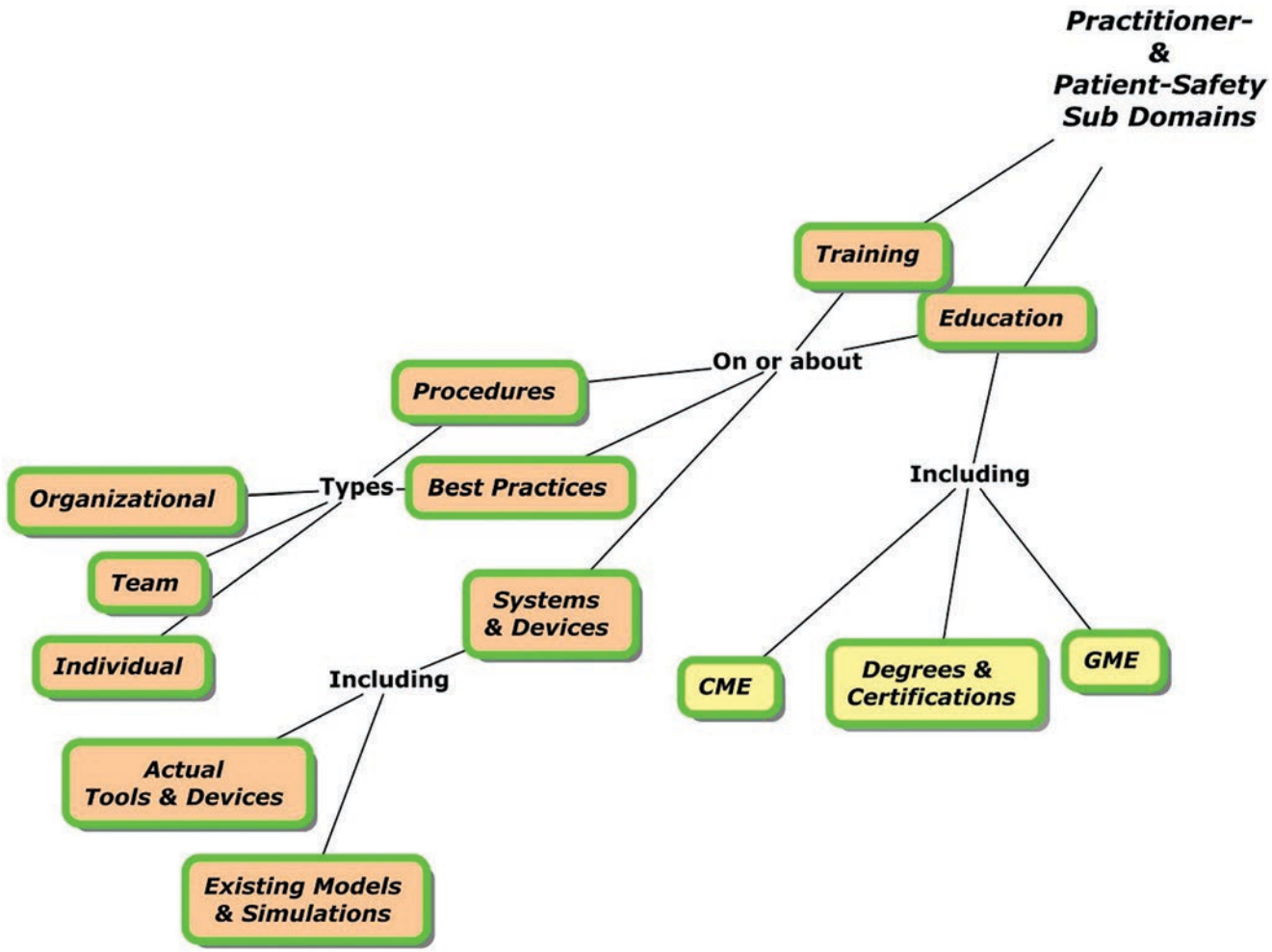

Fig. 6.3 Practitioner & Patient Safety: Training/Education Sub Domains

Learning environments are created that approximate the workplace, supporting both individual and group training and learning – again, without potential to impart harm upon the patient.

It is important to note that, as stated previously, *none of these models and simulations are completely accurate*. It is critical that faculty, practitioners, and learners understand that adding technology and fidelity to task trainers does not guarantee an improved or more accurate learning experience. When in doubt, one must place their faith in the model and simulation that best meets their learning objectives.

It is also important to note that what is missing from a model or simulation may be result in negative learning. Negative learning in this case can occur when a model's discrepancies contribute to inaccurate knowledge and actions in higher stakes settings.

An interesting example of a human-based model and simulation is the standardized patient (SP). According to the SSH Healthcare Simulation Dictionary [15], an SP is

> *An individual trained to portray a patient with a specific condition in a realistic, standardized, and repeatable way and where portrayal/presentation varies based only on learner performance; this strict standardization of performance in a simulated session is what can distinguish standardized patients from simulated patients.*

An SP, then, conforms as a role-player and potentially as an assessor to create a simulated experience for a learner focused on achieving specific learning objectives. The SP themselves, and the symptoms/problems they are portraying, make up the complete model. The simulation is the act or portraying the role of the patient. It is a fascinating capability used extensively in healthcare education to great effect.

Practitioner and Patient-Safety: Practical Application & Research Sub Domains

The Practitioner and Patient-Safety: Practical Application & Research Sub Domains depicted in Fig. 6.4 include those areas where models and simulations are intended to help

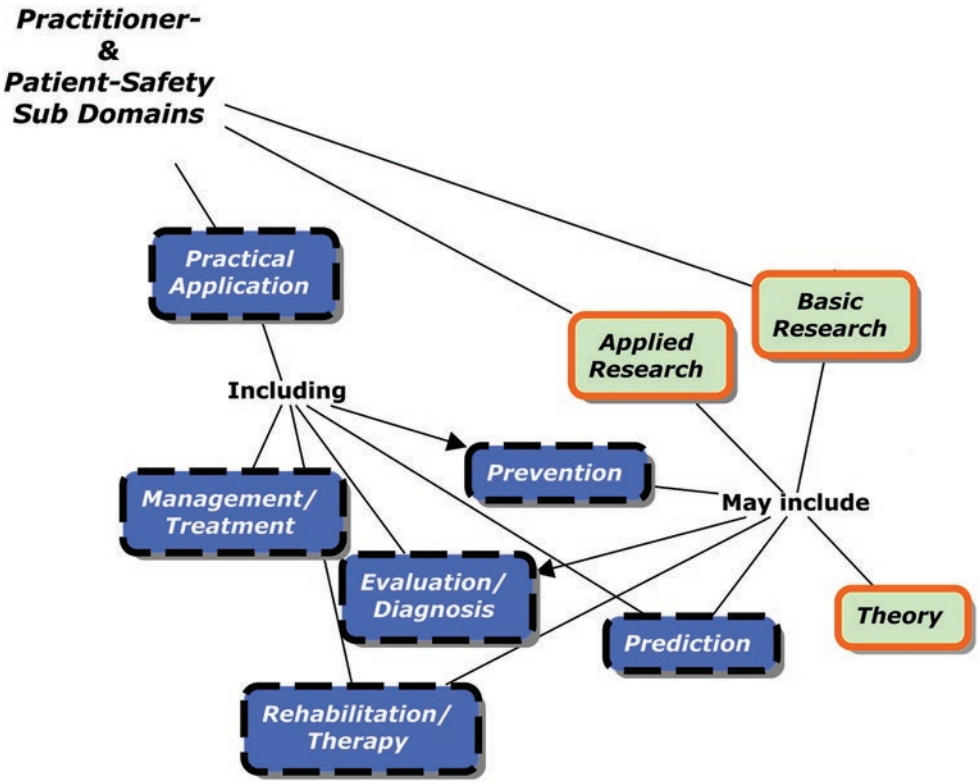

Fig. 6.4 Practitioner & Patient Safety: Practical Application/Research Sub Domains

treat and manage patients (practical application) and to support basic and applied research relevant to patient care.

Today, models and simulations supporting practical application of caregiving tend to fall into the systems engineering and analytical categories. According to the International Council on Systems Engineering (INCOSE), "Systems Engineering is an interdisciplinary approach and means to enable the realization of successful systems."

> *A system is a construct or collection of different elements that together produce results not obtainable by the elements alone. The elements, or parts, can include people, hardware, software, facilities, policies, and documents; that is, all things required to produce systems-level results. The results include system level qualities, properties, characteristics, functions, behavior and performance. The value added by the system as a whole, beyond that contributed independently by the parts, is primarily created by the relationship among the parts; that is, how they are interconnected* [16].

The system/systems in question relevant to practical application tend to have multivariate problems – those with a large number of "inputs" combining in unobvious and unknown ways to create an "output" that is sometimes good, sometimes bad. Complex relationships between multiple variables are well suited to a systems thinking approach, supported by a well-crafted model and analytical simulation.

Models, simulations, and analyses convert healthcare data into information that directs both population health policies and legislation. The same tools help to show both correlation and causality between disparate factors within the caregiving arena. Patient safety interventions came from these types of analyses, bolstered to a degree by models of the caregiving environment.

Consider wrong site surgery, a very serious patient safety issue that continues to persist [17]. Many factors and conditions must converge in order to create an environment where a surgical team might perform surgery on the wrong knee, for example. Investigators utilize root cause analysis [18] to help uncover the multiple factors that contribute to these types of surgical errors. The best analysis involves generating a model of relevant system inputs and outputs, decision points, and communication mechanisms to find the primary and secondary causes of a surgical mistake.

A mature organization might take a root cause analysis one step further and improve the analytical model to determine what best to monitor, measure, and assess in order to ensure the error never happens again. Administrators can use these same models to continually root out inefficiencies, process choke points, barriers to effective communication, and unacceptable risk conditions throughout their system.

In time, these types of models and simulations will be essential to personalized and precision medicine, wherein the system simulated may be a patient-specific physiology model. These types of complex precision system models will provide the ability to predict – for an individual – such things as interventional success, cancer growth rate, proclivity towards chronic illness, and metabolic response to treatment. These same models might one day serve as our primary med-

ical record, where historical, current, and predictive data will come together within the model, helping to explain the causes of health changes.

Theory and Science Sub Domains

The Theory and Science Sub Domains, depicted in Fig. 6.5, overlap with the Practitioner and Patient-Safety: Practical Application & Research Sub Domains. Here, we are focusing on the use of models and simulations to approximate a patient, a population, a hospital system, a drug regimen or other intervention, a new medical device, environmental health impacts, and the like. This area is bound only by the imagination.

An example: Harvard University's Wyss Institute has created "organs-on-chips" with a near-term focus on eliminating the need to test pharmaceuticals on animals. These are microchips lined with living human cells, which may eventually "revolutionize drug development, disease modeling, and personalized medicine." [19].

> *Wyss Institute researchers and a multidisciplinary team of collaborators have adapted computer microchip manufacturing methods to engineer microfluidic culture devices that recapitulate the microarchitecture and functions of living human organs, including the lung, intestine, kidney, skin, bone marrow and blood-brain barrier, among others* [17]. *These microdevices, called 'Organs-on-Chips' (Organ Chips), offer a potential alternative to traditional animal testing.*

This example demonstrates how physical and mathematical models might converge to create an acceptable approximation of a complex system, thereby providing valuable, trustworthy insights into a system – in this case, an organ or organs.

Logistics and Physical Process Sub Domains

The Logistics and Physical Process Sub Domains depicted in Fig. 6.6 closely align with the Administration, Business, and Management Sub Domains in part because they apply to activities essential to, but not directly focused on, caregiving. These models and simulations tend towards system engineering and analytical models, because one may observe and measure the majority of the critical factors within the selected system(s).

An example model to which most can relate is the physical layout of a hospital. Over the life of a hospital, space use requirements change, departments move, and new wings and new buildings are built; navigating the passageways of a hospital becomes challenging. This is a common problem. Patient and family caregiver confusion during hospital visits generates frustration and, ultimately, poor patient satisfaction. (Note that the Centers for Medicare and Medicaid Services administers the Hospital Consumer Assessment of Healthcare Providers and Systems survey mechanism, which tracks objective measures of hospital quality; these measure-

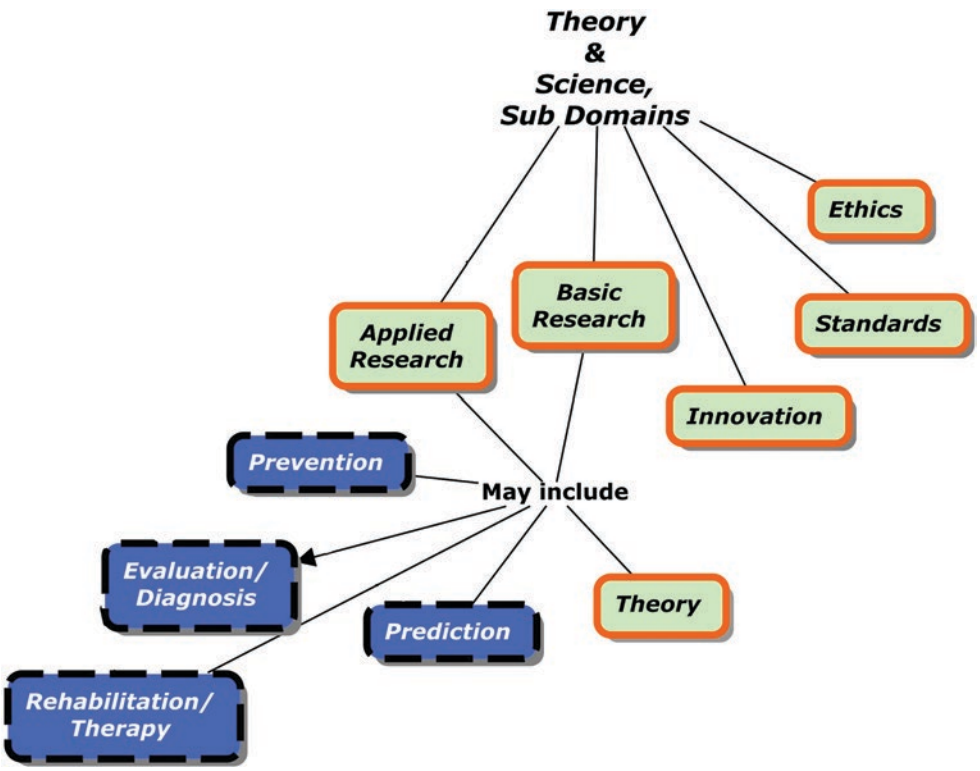

Fig. 6.5 Theory & Science Sub Domains

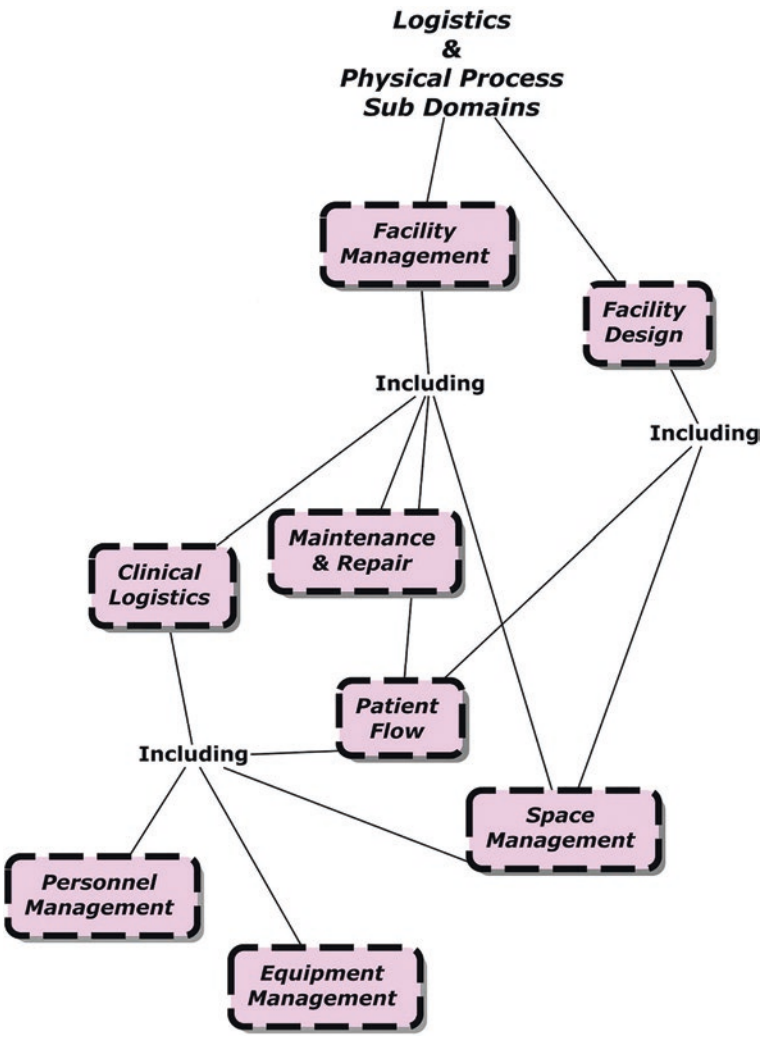

Fig. 6.6 Logistics and Physical Process Sub Domains

ments help to inform value-based incentive payments. Poor patient satisfaction has a traceable financial impact [20]).

A relevant solution to this problem is to create a comprehensive model of a facility, coupled with both staff and patient origin/destination and volume information. Through both mathematical and visual simulation and analysis of this approximate system model, we uncover valuable insights. Some examples: the optimal location of a pharmacy; the mitigation of choke points around hallway junctions; solution to evacuation issues related to lack of high-volume elevators; signage needs; parking lot transit issues; and many other insights that directly and indirectly affect the patient experience.

Summary

A concept map is very likely not definitive, nor is it complete. It can, however, effectively serve as an academic exercise, as a mechanism to extend abstract thought around the application of models, simulations, analysis, and systems thinking into an industry (healthcare) that, eight years ago, the author was a "consumer of" rather than a "member of" today. There are close to a dozen more levels of depth that might be added to each of the child nodes in any concept map – again, another interesting academic exercise informing the creation of a comprehensive model of healthcare modeling and simulation. It is foreseeable that such a comprehensive model might direct industry sub-domains towards certain approaches and practices, resulting in the most valuable information and outcomes.

Hopefully, this chapter helps the reader expand their thinking about the applications of modeling and simulation into areas besides training and education – past the boundaries of a typical academic simulation center and into areas where readers find themselves wondering "why". Why is this such a cumbersome billing process? Why can I not find the oncology office buried in the bowels of this hospital? Why did I receive a prescription for a medicine that negatively reacts with another medicine I have been taking for years?

Why is it so hard to get into and out of the parking garage? Models and simulations can help alleviate "why" questions, and provide value when used to inform solutions.

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Part II

Practical Applications

Simulation to Improve the Capabilities of Individuals

7

Donald L. Boyer, Stanley Caplan,
Shanique Brown Kilgallon, and Samuel A. Rosenblatt

Simulation has the potential to revolutionize health care and address the patient safety issues if appropriately utilized and integrated into the educational and organizational improvement process.

—David Gaba, MD

Introduction

A healthcare system is comprised of many interrelated functions that work together to ensure patient well-being. At the heart of each system are individuals with unique roles and responsibilities that require knowledge, skills, and behaviors, coming together in interprofessional teams to operationalize patient care within the functions of everyday practice. One way of describing the relationships of healthcare teams and the functions they perform is by using a Functional Analysis Systems Technique (FAST) diagram. This method was first described by Charles Bytheway [1] who applied it to show how a light bulb provides luminous energy. It has since been applied in many other contexts including organizational systems [2]. The FAST diagram in Fig. 7.1 depicts the functions involved in the use of simulations to improve individuals' capabilities (shown in red boxes) and how they relate to other functions of a healthcare system. Likewise, Fig. 7.1 also shows how simulations help prevent software use errors (shown in shaded boxes).

Each block in the diagram describes a function of the healthcare system. Each function (F) is defined in a few words including an action verb and a measurable noun. Read the diagram from left to right and ask the question "**How**?" of each function. The answer to the **How** question resides in those functions connected to the right of the function queried. Now, read the diagram from right to left and ask the question "**Why**?" of each function. The answer to the **Why** question resides in those functions connected to the left of the function queried. For example, consider *Prevent Harm* (F2) on the extreme left of the diagram. Going from left to right, ask **How** do you *Prevent Harm*? The diagram provides the answers: *Prevent Medical Errors* (F6), *Prevent Usage Errors Of Software and Procedures* (F5), *Prevent Other Systemic Errors* (F4), and *Ensure Individual's Ability To Execute Medical Procedures Effectively* (F7). Continuing further, **How** do you *Ensure Individual's Ability To Execute Medical Procedures Effectively* (F7)? The diagram responds with *Enhance Knowledge* (F12), *Develop Technical Skills* (F13), and *Create Self Confidence* (F14).

Now reading the diagram from right to left, we ask of functions 12–14, **Why** *Enhance Knowledge, Develop Technical Skills*, and *Create Self Confidence*? The diagram answers to *Ensure Individual's Ability To Effectively Execute Procedures* (F7). Similarly, for the other functions, **Why** *Ensure Individual's Ability To Effectively Execute Procedures* and **Why** *Prevent Medical Errors* (F 6), *Prevent Usage Errors Of Software and Procedures* (F5), *Prevent Other Systemic Errors* (F4)? The answer that satisfies all of these questions is F2, to *Prevent Harm*. By making sure functions are viable answers to the" **How**" and" **'Why**" questions, the logic flow is maintained and the functions ultimately support the primary goal to *Ensure Patient Well-Being* (F1).

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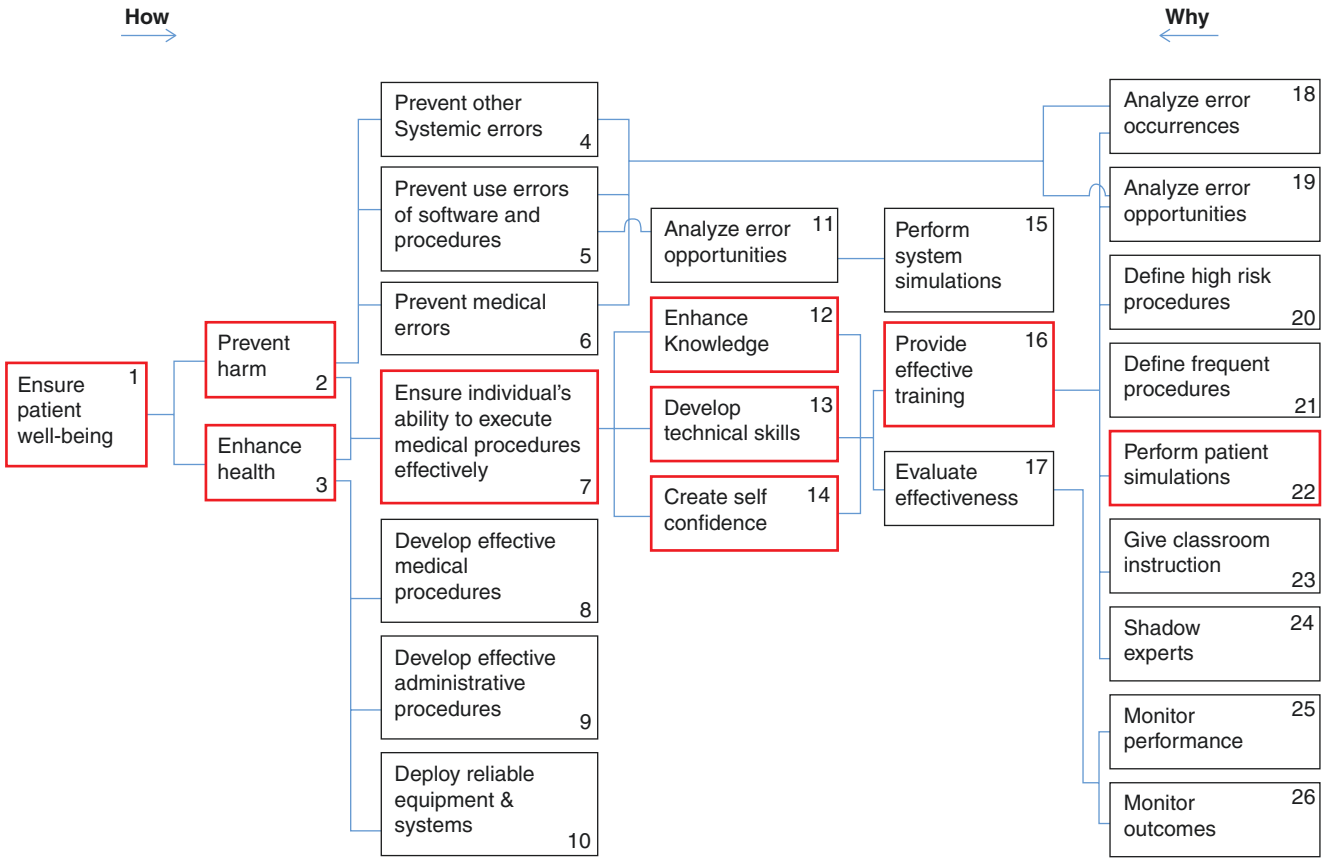

Fig. 7.1 FAST diagram with a simulation focus

Scope of Chapter

The FAST diagram shown here is only a piece of a functional representation of the overall healthcare system. It encompasses the scope of this chapter which discusses the use of simulation to improve the capabilities of individuals (F7) through patient simulations (F22) and system simulations (F15). This chapter and diagram explain why these two related, but different, types of simulations are used to ensure patient well-being through the development and improvement of individual providers. Patient simulations involve direct medical interaction with the simulated patient and are vitally important training tools used to enhance knowledge (F12), develop technical skills (F13), and create self-confidence (attitude) and adjust behavior (F14) of healthcare providers. These three outcomes (knowledge, technical skills, and attitude/behavior) are the main focus of this chapter. Primary examples of *patient simulations* include medical procedures such as surgeries and diagnostic examinations that utilize functional manikins or cadavers. *System simulations* involve the use of software applications and procedures that are indirect, but can affect patient well-being (F1) if errors are made. A few examples include electronic healthcare records (EHR), computerized physician order entry (CPOE) systems, and emergency response procedures. In this chapter, system simulations are compared to patient simulations, but full coverage of system simulations is covered in other chapters. Also not covered in this chapter are other uses of FAST diagramming such as *value analysis of individual functions* to determine if any should be eliminated or enhanced.

Simulation to Improve the Capabilities of Individuals

Simulations can be done well or they can be done poorly. In the healthcare environment, doing them well is critical because they can impact how the team functions and ultimately, patient safety and wellbeing. These two factors, patient safety and wellbeing, depend on having skilled people serving the patient within a system of error-resistant procedures. Effective simulations can help enhance people's capabilities not only as they directly interact with the patient but also as they interact with the varied supporting elements of the healthcare system. Memory, cognitive processing, and physical dexterity are examples of personal attributes that are enhanced, in addition to teamwork skills and interactions

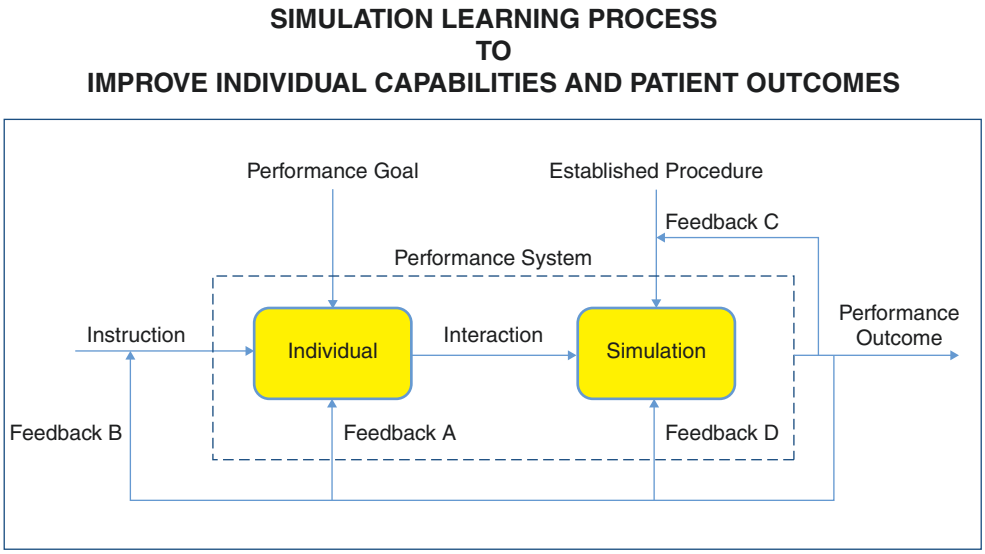

Fig. 7.2 Simulation Learning Process

with the healthcare environment. At the same time, simulations can be used to reduce the load on one's memory, cognitive processing, and physical dexterity by revealing interactive elements that can be made less burdensome. Thus, a simulation done for the right reason, in the right way, at the right time, and under the right circumstances can yield multiple benefits. This is depicted in the closed loop flow diagram in Fig. 7.2.

The performance outcome is observed and/or communicated to the individual (*Feedback A*) so they can adjust interaction behavior to mitigate interaction difficulties on subsequent simulation usage trials. The performance outcome can also be used (*Feedback B)* to modify instruction to the individual, as necessary, to guide them to a more successful outcome on subsequent trials. In some cases, Feedback B is best administered "in the moment" by pausing the procedure and discussing with the individual a particular action that was taken. The feedback can also be administered by a debriefing at the end of the simulation session. In either case, the feedback can positively reinforce actions that were taken or it can bring awareness to improved actions that are needed to better perform the procedure. Observation of performance output can be analyzed to determine cognitive and/or physical root causes of poor performance so that a modified procedure can potentially be developed having less cognitive and physical demands (*Feedback C*). Finally, an individual's performance may impact the simulation itself (*Feedback D*) by showing that the simulation needs to be modified to more accurately mimic the actual procedure.

The scope of possible simulation use is very broad. Direct patient simulations can encompass diagnostic methods, treatment practices, and surgical procedures. These simulations can be used to train students, nurses, and physicians about frequently used activities or they can be just-in-time applications meant to prepare for an imminent operation that is intended for a specific patient having a unique condition. Examples of supporting simulations to improve the capabilities of individuals that go beyond direct patient care include interactions with software applications, equipment, wayfinding (environmental cues for the movement of people), and emergency patient care procedures. In addition, electronic health records [3–5] computerized physician order entry software systems, blood collection software and many other digital software applications should be the focus of simulation training. Effective simulations can help individual users understand how to enter information needed by other users within the system and how to avoid entering erroneous information. Likewise, simulating the use of complex equipment can aid in avoiding errors and having to redo procedures. Required actions during emergency drills can be incorporated into simulation scenarios that can train people to have a rapid and reliable response.

The range of simulation methods is extensive enough to accommodate the various purposes for doing simulation exercises and to cover the multitude of individuals who interact with the healthcare system – e.g., physicians, nurses, technicians, aides, and even volunteers. Depending on purpose, simulation can be used to represent general elements of a procedure or key in on specific procedural elements at a more granular level. Again, depending on purpose, simulators can be as simple as using paper and pencil or as complex as using augmented reality to provide an interactive representation of the situation.

The Halstedian approach to medical education, "see one, do one, teach one," [6] is in tension with the emphasis on patient safety that influences today's medical practice [7]. As a result, re-thinking the way in which we train healthcare professionals is essential, and teaching practices are increasingly employing simulation as a technique by which education and training can be accomplished prior to certain patient

interactions. Simulation can be a powerful educational tool for developing an individual's knowledge, skills, and behaviors with directed practice and behavioral modeling. Simulation provides a learning opportunity while simultaneously addressing patient safety, allowing providers to learn in a low-risk environment [8–10].

In a healthcare context, it is important that simulation training is used as a "discovering and remedying" tool performed in a formative process of education and training. Performing a simulated procedure allows a trainer or administrator to: (1) discern deficiencies in cognitive understanding of the procedure; (2) observe lack of needed physical skill; and (3) observe performance errors that derive from the procedure itself. Armed with that information, the simulation can be changed, or repeated as is, with a subsequent training focus on improving the learner's cognitive and technical abilities.

While early studies of simulation's use focused upon feasibility and acceptability of implementation, research into simulation's impact has evolved from impact on learner self-reported confidence to higher levels of learning [11] such as acquisition of knowledge and demonstration of skills.

There is a fine balance between providing a psychologically safe learning environment and the use of assessment in simulation. Overt assessment through the use of high-stakes examinations using simulation have been deemed by multiple studies not to accurately reflect actual patient care [11, 12] and assessment of simulation's effectiveness through observations of direct patient care is inherently challenging because of factors such as variable case mix and environmental circumstances [13].

As adult learners, healthcare providers and other professionals engaged in medical care come to simulation experiences primed for learning. This "priming" is described by the key tenets of Malcolm Knowles's adult learning theory [14], namely:

- Experience is a basis for learning
- Learning is self-directed and based upon perceived need
- Learning is guided by the need to perform in professional and societal roles
- Motivation for learning is internally-derived
- Application of learning is timely

Since an ineffective simulation is a waste of resources and, even worse, can lead to incorrect learning and unwanted patient outcomes, it is important to determine the effectiveness of simulations, remembering how individuals can best learn from each simulation. This chapter continues to discuss simulation's use to enhance individual capabilities, specifically by addressing the use of simulation to enhance medical knowledge, technical skill, and individual behaviors and attitudes.

Simulation to Grow Knowledge

Knowledge forms the foundation for all advanced professional skills. Exposing primed adult learners to a simulated event forms the basis for learning, with the transformation of experience into knowledge as defined by David Kolb's 4-stage *experiential learning theory* [15] (Fig. 7.3).

In Kolb's theory, concrete experience and abstract conceptualization are two modes of grasping experience, with reflective observation and active experimentation being two modes of transforming that experience into knowledge. Simulation, through its imitation of a real-life situation, is perfectly aligned with experiential learning theory to provide concrete experiences (simulated or real-life encounters) and opportunities for abstract conceptualization in order to facilitate reflective observation (debriefing), with an opportunity for active experimentation (repeat simulation or patient encounters).

These theoretical underpinnings for adult learning through experience inform the current state of simulation's use and have been borne out in numerous studies reflecting the ability of simulation to enhance knowledge. In 2012, the Association of American Medical Colleges (AAMC) in collaboration with the Society for Simulation in Healthcare (SSH) and other national bodies conducted a survey to understand the landscape of simulation's use in member medical schools and teaching hospitals [12]. At that time, a vast majority (96% of medical schools and 78% of teaching hospitals) were using simulation within an educational con-

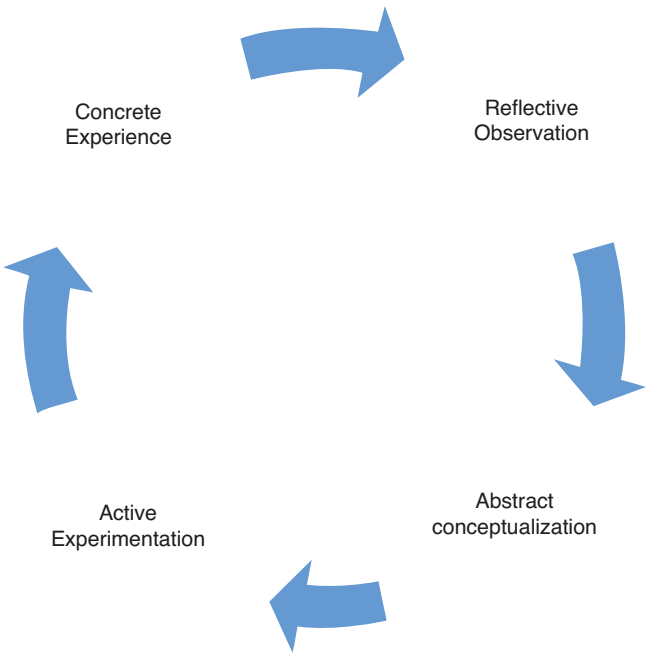

Fig. 7.3 David Kolb's Experiential Learning Cycle. In this model of learning, concrete experiences through real-life encounters or simulated experiences create opportunities for reflection, yielding concepts that can then be applied in future experiences

text to *teach* medical knowledge and a majority (89% of medical schools and 53% of teaching hospitals) were using simulation to *assess* medical knowledge.

Simulation has been demonstrated to enhance knowledge of various learner types (e.g., medical students, graduate medical trainees [residents & fellows], nurses, respiratory therapists) as evidenced by combinations of pre-post assessment and demonstrated performance improvement, within simulated and clinical contexts [16, 17]. Harnessing the ability of simulation to enhance knowledge, multiple specialties and subspecialties are now incorporating simulation training into intensive learning experiences (i.e., boot camps) that seek to provide essential knowledge and skills to groups of learners before engaging in high-stakes patient care or to refine skills of providers already engaged in patient care [18–20].

Simulation to Improve Skills of Individuals

Simulation can address both cognitive and technical aspects of skills through deliberate practice, which is purposeful and systematic practice that requires focused attention with a specific goal of improving performance [21]. Simulation allows health care practitioners to work on specified portions of technical and cognitive skills, receive immediate feedback on their performance, and repeat those skills as necessary when they are performed on manikins that can be reset or replaced easily. Furthermore, skill simulations are often brief, allowing learners maintain focus throughout the simulation and facilitating scheduling [22].

Cricothyrotomy is a potentially life-saving emergency airway procedure which requires incising a patient's neck. Petrosoniak et al. [23] found that a didactic session including deliberate practice with task trainers improved the performance of cricothyroidotomy by emergency medicine residents tested with unannounced *in situ* simulation. Endoscopic sinus surgery is performed in proximity to critical anatomic structures such as the brain and eyes and requires fine motor skills. Harbison et al. [24] demonstrated that didactic material combined with an inexpensive anatomically representative silicone task-trainer could be used to accelerate medical student and resident development of technical proficiency in endoscopic sinus surgery techniques. Assessment was accomplished by video review of procedures performed on cadavers, using global and task-specific ratings. Fried et al. [25] demonstrated that residents who practiced sinus surgery using a virtual reality simulator performed better in vivo. More generally, McGaghie et al. [26] conducted a meta-analysis and found that simulation-based medical education with directed practice is superior to traditional clinical medical education in achieving specific clinical skill acquisition goals.

Beyond improving provider skills in simulation and patient care, Draycott et al. [27] demonstrated that simulation skill training could improve patient outcomes. Their seminal study demonstrated that the introduction of simulation-based shoulder dystocia training for all maternity staff at Southmead Hospital (Bristol, United Kingdom) was associated with improved management and neonatal outcomes of births complicated by shoulder dystocia.

Simulation to Enhance Individual Behavior

Simulation can be used to improve the behaviors, attitudes, and confidence of healthcare personnel who interact with others in combinations ranging from provider – patient dyads to immense coordinated collaborations. Healthcare is delivered by teams, and interprofessional simulations can improve participants' attitudes regarding team leadership, structure, mutual support [28]. For example, simulation has been used to increase reporting behaviors of medical errors by medical students [29]. Simulation improved safety behaviors of trainee anesthesiologists, increasing their likelihood to speak up in unsafe scenarios [30]. Finally, coaching or debriefing are integral to simulations, and modeling desirable behaviors, such as respectful curiosity, during the delivery of this feedback can provide powerful affective lessons.

Simulation can help individuals develop confidence, although the implications of confidence are complex. Many studies have shown that confidence and competence do not have a strong correlation [31, 32], however, appropriate confidence is beneficial. Tanner's Clinical Judgement Model [33], proposes that skilled practitioners adapt to a given clinical situation by calling upon their self-confidence in addition to critical thinking and clinical competency. Confidence has been conceptualized as a caring attribute that fosters trust and respect in a provider-patient relationship [34]. Studies show that simulation can be used to improve confidence of healthcare providers during critical thinking, patient assessment, management and counseling, medication administration, patient communication, clinical knowledge, and procedural skills [35, 36].

Conclusion

Individuals are the core components of healthcare delivery systems; in many ways they are the heart of healthcare delivery. The Functional Analysis Systems Technique (FAST) described in this chapter can be used to elucidate healthcare delivery processes, by probing the **"how"** and **"why"** relationships between simulation and these processes. Simulation can be used to explore and optimize the knowledge, skills, and behaviors of individuals working to improve healthcare delivery processes.

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Simulation to Improve the Capabilities of Teams

8

Agathe Streiff, Katherine E. Law, Renaldo C. Blocker, and Kimberly Blasius

Introduction

Medical errors contributed to an estimated 215,000 deaths in 2013, making it by some calculations the third leading cause of death in the United States [1]. Failures in teamwork and insufficient attention to human factor principles - including problems in communication, information flow, and team performance – are major contributors to this issue [2, 3]. Many healthcare settings can benefit from improved team capabilities, from routine events to high and low frequency emergencies. Especially in the event of rare emergencies and unfamiliar locations, outcomes are affected by the ability of a team to function effectively. A couple of examples of this would be rare events such as malignant hyperthermia (MH) during an anesthetic in the radiology department or an amniotic fluid embolism leading to a maternal arrest in the emergency department (ED). Simulation has a specific role in improving team knowledge. Team knowledge includes interpersonal skills such as role assignment and leadership roles, and additionally involves the implementation of new practices, guidelines, and technical skills, and adherence to proper use of institutional resources. Simulation also facilitates the acquisition of nontechnical team capabilities such as decision-making, resource allocation, and debriefing skills that contribute to ongoing improvement. The quotidian tasks and goals of health care professionals are fraught with challenges in teamwork that are typically only mastered through experiential or opportunity-based learning. Simulation provides an applicable framework that fosters this type of learning in order to improve *in vivo* teamwork and patient outcomes, without the risks to patient care inherent in *in vivo* learning.

Common Types of Teams Found in Healthcare

Teamwork is a product of team members coming together to achieve the same goal. There are multiple types of teams that can vary in their capabilities and how they interact with the characteristics and capabilities of a system. This section will focus on two popular types of teams found in healthcare, ad-hoc teams and consistent teams. Strengths and limitations of each will be addressed.

Ad-Hoc Teams

An inconsistent team, or ad-hoc team, is one where team members assemble and work towards a common goal, but generally have little or no prior experience working with one another. Team members may be familiar with the role and tasks they need to perform but may not be familiar with the other team members or have an understanding of the roles and skill sets of the other team members. A common example of ad-hoc teams in healthcare occurs during what is known as ‘a code’, when a patient experiences sudden cardio-pulmonary arrest and staff urgently assembles to begin resuscitation efforts until the dedicated code or rapid response team arrives. Trauma teams in the ED and disaster relief teams are also examples of ad-hoc teams in healthcare [4]. Ad-hoc teams can also transform into familiar teams over time. For example, rapid response teams often assemble only as needed; however, as only a discreet chosen set of

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providers can fill in those roles, the team members get to know each other well over time. Teams can be *ad-hoc* by intention, such as the examples described above, but teams that routinely work together may also unintentionally randomize into an emergency team as a result of work system pressures. Surgical teams often are subjected to organizational factors such as misaligned clinical staff schedules, staff absences and required break times, causing an initially consistent and cohesive team to become unintentionally *ad-hoc as the work of the day progresses* [5]. Teams may also need to be modified or split to take on a new case or patient [6], causing the modification of a familiar team (Fig. 8.1).

Intentional ad-hoc teams are valuable to deal with specific, generally emergent, issues. Situations requiring these types of teams cannot rely on personal familiarity to achieve the common goal of providing patient care. Rather, they must rely on standardized procedures and protocols, training uniformity across roles, and structured communication to provide optimal patient care [7]. They also often have clinicians on-call for action to form these teams. As a result, an obvious benefit to ad-hoc teams is the ability to provide 24-hour coverage, 365 days a year. Unfortunately, due to the lack of familiarity with individual team members' skills present in ad-hoc teams, team members may not feel as comfortable to speak up or request additional help when needed (Fig. 8.2) [8].

Another challenge can occur when team members are pulled away from their routine tasks into an emergent situation such as a resuscitation. They often feel pressure to return to their original tasks once the situation has been resolved [7, 9] which can result in poor quality debriefs or a complete lack of debriefing. A delayed debriefing can be better than not having one entirely, yet quality debriefings shortly after an event have been shown to improve team performance [10]. In unintentional ad-hoc teams, the challenges faced by the intentional ad-hoc teams may be magnified. For example, agency nurses and locum tenens that are used to temporarily fill positions must overcome their unfamiliarity with other team members, as well as assimilate into the existing culture of the team and organization.

Fig. 8.1 Cardiac arrest during simulation scenario with manikin and multiple team members, emphasizing the importance of situational leaders on familiar teams during a non-routine event. An obstetrical nursing team manages the arrest, until the anesthesia resident and attending arrive

Consistent Teams

The opposite of an ad-hoc team is a consistent team. These teams still assemble to work towards a common goal, but routinely work together and have an established professional relationship. For example, regularly scheduled practices such as primary care teams, rural healthcare clinicians, and transplant teams generally exemplify consistent teams. Consistent teams are more likely to employ or exhibit cognitive and psychosocial characteristics such as shared mental models, implicit coordination, and transactive memory [7]. A study in cardiac surgery showed team members that were familiar with the operating surgeon had significantly fewer

Fig. 8.2 Ad-hoc team assembling during a simulated cardiac arrest on the floor. During these high-stake events, teams must overcome unfamiliar environments, which may impact their ability to locate resources, perform tasks such as placing the patient on a board, and call for help. Teams must also overcome unfamiliar team members with different expertise in resuscitation, technical skills, and communication styles

total event failures and teamwork failures compared to members unfamiliar with the surgeon [11].

Teams that have worked together and are familiar with each other generally perform better, are unafraid to speak up, and have better job satisfaction [12]. Team familiarity in open abdominal surgery has also been shown to improve team performance and reduce patient morbidity [13]. Human factors research related to team performance has demonstrated that members of familiar teams understand one another's strengths and weaknesses, and cross-monitor one another to maintain high performance levels [14]. It is important to recognize though that it may not be realistic to have the same team members together at all times during a task. Surgical teams and clinical teams on ward floors often change throughout a case or patient care due to shift change or breaks, leading such teams to become unintentionally ad-hoc at some point during patient care [15, 16]. Additionally, to establish a familiar team or integrate a new member into a familiar team, there can be a steep learning curve to achieving familiarity depending on previous professional experience and degree of existing familiarity with the team. Research has shown the benefit of having consistent teams; for example, dedicated rapid response teams can help reduce the incidence of emergency resuscitations outside of the intensive care unit [17, 18].

Clinical team functions and performance can depend on the type of team employed and level of familiarity among team members. Simulation has been used to support traditionally ad-hoc teams, such as working through coordination efforts in disaster relief teams [19] and allowing practice of individual tasks during trauma cases [18]. Consistent teams also benefit from participating in simulated cases by refining teamwork skills and improving cognitive factors between team members [20], demonstrating the value simulation can provide to both team types [21].

Settings that Benefit from Improved Team Capabilities

High-reliability organizations such as health care institutions rely on the capabilities of skilled team members for virtually all aspects of patient care. Settings that benefit from improved team capabilities range from inpatient to outpatient areas, from large tertiary centers to small clinics, and from on-site to off-site areas; teams are formed spontaneously or by routine, and the effective delivery of patient care depends on their collective abilities. For example, in one study of ED teamwork, formal training via simulation improved team behavior, clinical performance, attitudes, and opinions. Simulation-based teamwork training not only reduced clinical errors but also improved staff attitudes and approach regarding teamwork [22]. Teams in the ED are often randomly formed based on shift schedules, with team members arriving and leaving at different times, highlighting the importance of fluid, flexible teamwork and communication as well as continuous role re-assignment. The ED is unique for its inherent unpredictability of patient volumes and severity of patient illness. Teams that assemble in the ED must adapt very quickly in response to a dynamic environment with unpredictable workflow and the constant possibility of life-threatening patient emergencies.

Similar to the ED, the intensive care unit (ICU) can have unpredictable clinical demands involving critically ill patients with rapidly evolving and fluctuating health status. Highly skilled teams are required with a common goal of completing patient care tasks every day, and these teams consist of heterogeneous members on different shift schedules. Teamwork skills and in particular, attending physician management and leadership skills are critical. The Physician Management Index lists attributes addressing physician management and leadership performance which correlate with improved patient care, as measured by the achievement of daily patient goals [23]. Some examples of desirable attributes include "acknowledges own mistakes" and "encouraged safe learning environment" [5]. This tool may be utilized in simulation as a metric of skill acquisition.

Another setting that benefits from improved team capabilities is the operating room (OR). The OR provides unique, highly specialized teams that are generally scheduled work in one specific location and often retain the same members for several patient cases for that room and day. The effectiveness of simulation for promoting team situational awareness and addressing technical errors in the operating room has been well documented [24, 25]. The Oxford Non-Technical Skills (NOTECHS) behavioral marker system, used to measure teamwork behavior in the OR, is validated and specific to the OR. NOTECHS assesses teamwork skills such as leadership, team management, teamwork cooperation, problem solving, decision-making, and situation awareness [26, 27]. In one study of a pilot module for 20 intraoperative teams, simulation was effectively used to assess teamwork skills of individuals in intraoperative emergencies such as difficult intubation, hemorrhage, fire in the OR and cardiac arrest [28]. Among these infrequent emergencies, extremely rare events requiring significant institutional infrastructure and periodic training such as MH crisis management have been shown to benefit from interdisciplinary simulation sessions [29].

The cost of learning technical and non-technical teamwork skills on patients necessitates consideration. In emergencies such as neonatal resuscitation on the maternity wards, simulation is one method for first exposure and teaching of trainees from diverse disciplines [30]. The importance

Fig. 8.3 An example of simulation training for highly specialized teams to improve speed to first defibrillation, quality of cardiopulmonary resuscitation, team dynamics and task management. A well-functioning team has a single focus and clear individual roles

of multidisciplinary teams and simulation tools in these settings cannot be overstated since highly technical skills are often acquired via training in silos of specialization, and identification of their indication as well as facilitation of performance is often heavily reliant on teamwork [31]. For instance, the obstetrician must call a neonatologist after making an assessment of poor fetal status, and the neonatologist requires nursing assistance to place monitors and resuscitate the neonate. All these clinical workers must physically negotiate the same clinical space, the delivery room, during and after the birth. High-fidelity training of these teams, especially teams which contain interns, has successfully improved teamwork behavior, workload management, and speed of resuscitation (Fig. 8.3) [32].

Similarly, studies of simulation in adult cardiac arrest teamwork demonstrated that improved leadership skills were associated with higher quality cardiopulmonary resuscitation, including reduced time to defibrillation and improved technical performance, both key factors in improving adequacy of resuscitation [33].

Simulation to Improve Team Function

Supporting clinical teams through simulation provides teams an opportunity to practice and train without direct risk to patients, allowing it to be used to develop and enhance clinical team function. This section will discuss the value of team skills—coordination, communication, and leadership—and team cognition. Simulation fidelity levels and types will also be examined with suggestions on how they can be used for teams.

Team Skills

Simulation presents an ideal environment for developing effective healthcare teams. Team coordination and communication are critical during high risk, high stress situations such as managing trauma cases [34] and resuscitations [35] Team coordination typically involves individuals in different roles performing subtasks sequentially or in parallel [36]. In simulation, teams can establish and practice role delineation so that roles can be clearly identified and the team can provide optimal care when team members must come together for a critical patient [37]. Practicing team coordination efforts in simulation can increase the rate of completion for critical tasks [38–40], as shown by DeVita and colleagues and their study on medical emergency teams [23]. Teams have also employed simulation to improve various aspects of communication. Berkenstadt and colleagues tested a handoff training protocol during simulation-based teamwork training following an adverse event at the hospital [41]. They significantly increased team communication of patient name, age, diseases, and reasons for admission during nurse handoffs. Forsythe found simulated scenarios not only improved communication within surgical teams, but also found reduced power dynamics among participants and increased assertion levels among nurses [42].

Simulation also provides value in strengthening clinical team leadership. Proper leadership and good team management has been linked to efficient patient care [17, 43], shorter lengths of stay [7], as well as reduced mortality and morbidity [44]. Positive leadership behaviors can include determining clinical plan, communicating expectations and assessments (e.g., “this patient has condition XXX” or “my working diagnosis is condition XXX”), allocating tasks to individuals, and soliciting input from the rest of the team (e.g., “speak up if you have any concerns” or “am I missing any important information?”). Such skills have also been linked to improved teams’ task performance as well as situational awareness, decision-making, communication, and teamwork [20]. Team training programs such as anesthesia crew resource management and TeamSTEPPS, a federally sponsored training program available online at no cost, are often employed in simulated settings to improve leadership skills [45–48]. Team and leadership programs can help leaders increase their self-confidence, interprofessional communication, and organizational understanding in a simulated space while supporting team performance [10, 49].

Cognitive Aspects of Teams

Effective teams often rely upon cognitive factors, such as shared mental models and transactive memory, to support performance. Shared mental models ensure team members

are on the same page for tasks and situations and are defined as "shared and organized understandings of relevant knowledge" [50]. Establishing a shared mental model for the team can often lay the foundation for smooth coordination among team members. A familiar shared mental model in healthcare is the structured communication Situation, Background, Assessment, and Recommendation (SBAR) [51, 52], which has been effectively used during briefings and updates, as well as handoffs [53, 54]. Transactive memory is a phenomenon of team cognition that occurs when a team collectively translates, stores, and accesses knowledge because of a mutual understanding of which team members possess certain knowledge [55, 56]. Team members communicate with one another to develop team knowledge and then retrieve it according to one another's expertise. Michinov and colleagues studied anesthesia teams and demonstrated that those who developed and accessed transactive memory had stronger perceptions of team effectiveness, team identification, and job satisfaction [57].

Simulation Fidelity and Teamwork

Much of the research highlighted in this chapter was conducted *in situ* or at institutions with dedicated simulation centers. Yet, there are multiple levels of simulation fidelity that provide value to teams even when not using a high-technology simulator in a dedicated simulation center. Fidelity addresses the extent to which a simulation or simulator reproduces the realism of an actual real-life environment or situation—essentially there is a spectrum of simulation fidelity. But research has shown there are also different *types* of fidelity, thus fidelity is multi-dimensional [58]. There are three major types of fidelity as suggested by Rehmann and colleagues: equipment, environment, and psychological fidelity [59]. Equipment fidelity addresses the appearance and feel of the actual system while environment fidelity addresses the sensory cues of the task environment. Last and most critical, psychological fidelity addresses the extent of believability of the task [45]. The type of fidelity and level needed for a team simulation can vary with the objectives and target learners.

Low-cost simulators or simulations, such as case studies, tabletop exercises, and role-playing scenarios, are easily accessible options due to their limited resource requirements. Case studies involve reviewing a previous event and discussing the effectiveness or ineffectiveness of the team involved. Role-playing scenarios involve acting out an event and can be beneficial for interprofessional teams such as code teams [60] as well as larger, multi-unit teams such as disaster management teams [21]. As a result, both case studies and role-plays are effective at demonstrating the value of teamwork and training key teamwork concepts [45].

Higher fidelity options, such as a simulation center or an in-situ simulation with a high-tech simulator are designed to provide aspects of clinical complexity to a task or event. In dedicated simulation centers, teams often run through simulations multiple times at the direction of an instructor who controls the way simulators interact and present their disease process. Simulators may be computerized to indicate vital signs, or bleeding, or other critical events in real time. As a result of the instructor, specialized equipment, and computer technology required, higher technology simulations are generally more expensive. Nevertheless, technology-enhanced simulators and simulation centers are effective tools to practice teamwork skills under realistic, stressful, and pressure-filled conditions. Following simulated events, debriefing what transpired is integral. Instructors and participating team members can review video, discuss team dynamics, leadership, and task delegation that occurred, and reflect on how the team and team members performed and how to improve [61].

Conclusion

This chapter describes the benefits of strong team identity and collaboration to manage patient care in the continuously expanding settings in which health care is provided. Consistent teams, such as daytime operating room teams, may develop transactive memories, which consists of shared knowledge of each other's capabilities. Ad-hoc teams, members who assemble and work towards a common goal based on pre-established roles, offer flexibility but generally have little prior experience working with one another. Teams may also be formed in advance of specific unusual patient care needs, such as planned complex neonatal deliveries. Teams benefit from morale- and team-building activities, interpersonal familiarity, confidence for the next crisis, identification of issues, and setting of expectations – all which play an integral role in improving patient outcomes. Simulation can be used to improve team functions including enhancing communication, coordination, and task completion, developing shared mental models, and optimizing team leadership. As simulation becomes integrated in increasingly diverse team settings, from pediatric resuscitation in the ICU to the OR, ongoing efforts to simulate teamwork and measure effectiveness will be needed [62].

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Simulation Approaches to Enhance Team and System Resilience

9

Carl Horsley and Siri Wiig

Introduction

Healthcare is now recognised as being a complex adaptive socio-technical system made up of multiple components which interact in unpredictable ways that create ever-changing latent problems [1]. As such, healthcare is dynamic and intrinsically hazardous [2], yet has the ability to succeed under varying conditions [3]. Considered from this perspective, retrospective approaches to safety characterized by corrections of 'error' and the establishment of new rules and protocols, may be inadequate, potentially explaining why progress on patient safety has been limited to date [4].

There has been growing interest in the potential that *resilience* has in enabling complex systems like healthcare to perform in a manner that is both safe and effective. The purpose of this chapter is to discuss the role that simulation might have in enhancing this "resilient performance" and the implications this has for the way we utilize simulation.

Resilient Healthcare (RHC) Principles

Resilient Healthcare (RHC) acknowledges the impacts of complexity and dynamic conditions on healthcare delivery, and is built on the understanding that maintaining high quality care requires the capacity to adapt to challenges and changes at all levels of the system [5].

A system can be said to perform resiliently if it can "adjust its functioning prior to, during, or following events (changes, disturbances, and opportunities), and thereby sustain required operations *under both expected and unexpected conditions*" [6]. This marks the concept of resilience as different from concepts of system robustness or rebound, in which temporary stressors on the system (i.e. patient admissions, acute events, disasters) must be tolerated or 'absorbed' with the expectation of no overt failure or patient harm [7]. Resilience is therefore about a work system's ability to achieve its goals in dynamic and often unpredictable conditions over multiple timescales.

Hollnagel [8] states that the key determinants of resilient performance are the potentials of the system to *anticipate, monitor, respond* and *learn*. These potentials are relevant at the level of individual patient care but also apply to how clinical units or whole healthcare systems deal with changing conditions. This means expanding the ability of work systems to predict the types of changes that could impact the work (anticipate), detect shifts from expectations of how work should unfold (monitor), react adaptively to these changes (respond) and gain understanding of not only the changes but how they were dealt with in real time (learn).

The RHC perspective brings a different view of the role of people within complex systems such as healthcare. Rather than being perceived as the weak part of the system, people provide the adaptability required to respond to changing conditions. They are able to make judgments about what socio-technical resources (e.g. personnel, equipment, location) and mechanisms (e.g. leadership, teamwork, communication) are required to keep the dynamic work system of healthcare both safe and efficient [9]. Clinical work requires more than technical skill, it also requires navigation of competing system demands and constraints in order to attempt to meet a myriad of goals—foremost the delivery of safe, high quality care to every patient. This is the messy reality of everyday clinical work, often referred to as "Work-as-Done" (WAD). This may be quite different from "Work-as-Imagined" (WAI) which is the assumption of how work "should be occurring" as may be represented by clinical policies and procedures

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developed by individuals removed from the clinical frontline.

The final implication of an RHC viewpoint is a focus upon safety improvement efforts that will create conditions that make it more likely that at any given time care is delivered where "as much as possible goes right." To date, safety interventions within healthcare often focus primarily on constraining the system to ensure "as little as possible goes wrong" by adding in new barriers to failure (new protocols, checklists, double checks, regulation). Despite the best intentions, this approach often makes every day clinical work harder and potentially introduces new complexity and risk. An RHC approach to safety instead asks us to think about how to design our systems and foster cultural environments that support healthcare workers' efforts to navigate the complexity and uncertainty inherent in the work of healthcare. This is best achieved by acknowledging that all work systems, including healthcare, are under constant unrelenting pressures and all workers must navigate conflicting goals on a moment to moment basis. Simulation provides an excellent opportunity for shedding light on how humans in the healthcare work system adapt, modify, and cope to keep the work on track, while at the same time highlighting obstacles that undermine resilient performance or the ability for "as much as possible to go right."

Key concepts of an RHC approach can be summarized as:

1. Complex adaptive systems are intrinsically hazardous
2. The resilience of a system is related to its capacity to anticipate, monitor, respond and learn from events and opportunities
3. People contribute to system resilience everyday through local adaptation within a dynamic work system
4. The focus of safety is to create conditions where "as much as possible goes right."

Implications of RHC for Simulation

Simulation has great potential to improve the way people work together in teams to create safety [10]. However, the incorporation of an RHC lens can provide a different approach for simulation that more closely matches everyday work and enhances the adaptive behaviors and interactions necessary for team and system resilience.

Understanding People in their Context

Simulation has traditionally focused on improving the performance of individuals and teams using an educational and procedural proficiency perspective. This often involves clinical staff undergoing an educational event outside of the clinical workspace (e.g. at a dedicated simulation centre). This approach focuses on improving individuals and teams in isolation, away from the work environments they are accustomed to and which they have contextual knowledge about.

Safety, however, is a characteristic of systems and their internal interdependencies, not of their individual components. The traditional approach to simulation make it difficult for 'system level' learning as it loses understanding of the "local rationality" of what people (patients, workers, administration) do in real time, that is, how their actions are determined by the interactions with their work environment, and the social and organizational culture in which they work [11].

This need to understand people in their usual context provides a compelling reason for in-situ simulation, carried out by 'real-life' teams of workers in their 'usual' clinical workspace. In-situ simulation increases understanding of not only how the team works together but also how the design of the built environment, the equipment used, and the work culture impact the ability to deliver care [12]. It further allows an opportunity for critical examination of whether the WAI represented by policies, procedures and guidelines is a good fit with the messy realities of actual care, or if these representations of WAI need to be adjusted or negotiated to better match how work is done. In-situ simulation therefore makes it easier to address any gaps between WAI and WAD based on a fuller understanding of how care is actually delivered in the areas where clinical work occurs.

This change in approach means that those involved in the design of simulations must have a deep understanding of the local context and the realities of everyday clinical work, ideally as healthcare practitioners currently working in those clinical environments. Without this, simulation risks being based on idealised or out of date views on how care 'should be' delivered and risks having limited impact on everyday clinical practice.

Building the Adaptive Capacity of Teams

The ability of teams to adapt to changing conditions is vital. However, current approaches to simulation are often more focused on drills for rare events or training to improve performance based on a normative ideal. While this may be appropriate, particularly with more junior staff, it is an inadequate approach to enhance the ability of local and distributed teams across a wider system to be both "prepared and prepared to be unprepared" [13]. It is therefore timely to review what is required for teams to function effectively in the setting of interdependence, uncertainty and surprise, and to understand the implications for simulation design.

In all types of dynamic systems, communication is not just about the transmission of information. It is also about how the team constructs and continuously updates a shared understanding of the situation, both for the individual patient and for the wider system [14]. This is especially true for more complex problems which exceed the capabilities of any individual and require multiple viewpoints for successful management [15]. These complex situations also require an awareness of how the actions of the team impact the goals and actions of others, both within the team and in the wider system [16].

In order to be able to contribute effectively, the team must hold a shared belief that the team is safe for interpersonal risk-taking [17]. It is this "psychological safety" that allows teams to participate in sensemaking by sharing their various viewpoints, to understand the problem more comprehensively and to actively engage in finding innovative solutions. It also encourages help-seeking behavior, both within the team and across usual work-team boundaries [18], and lowers the threshold required to voice concerns and highlight errors [19]. As such, psychological safety is a key requirement to developing resilient performance for teams in the setting of uncertainty and interdependence.

This has significant implications for the role of leadership in teams, requiring a stronger emphasis on defining team goals, maintaining a shared understanding of the situation, and creating psychological safety for the team [20]. This style of "distributed leadership" means that other members of the team must become "active followers" with a shared responsibility to help the team function effectively. This type of leadership enables more adaptive and timely behaviors by the team as it supports the ability of team to anticipate, monitor, respond, and learn.

Simulations should therefore be designed to focus on how to rapidly build effective ad-hoc teams and should incorporate elements that require teams to identify and share changes in conditions, and to reorient the team and system to new goals as they emerge. The aim is to demonstrate how effective team function enables all the resources available to the team to be brought to bear and increases the ability to recognize and adapt effectively to change. Simulation therefore provides an opportunity to make visible and develop the latent resilient performance and adaptive work already occurring in healthcare.

Shifting to "Interwoven" Simulation

Currently, simulation may be an infrequent event for clinical staff, often related to procedural competency or training for a simulated rare incident. By contrast, RHC requires consideration of how good performance is created and sustained in everyday work, the potential barriers to this and the ways in which safety is created proactively. This requires a move from seeing simulation as primarily an educational event, separated from clinical practice, to instead embedding the approaches used in simulation into everyday clinical work. This involves taking the non-judgmental curiosity, sense of exploration and psychological safety of simulation and transferring these into the active clinical workspace. This integration of simulation approaches into daily practice ("interwoven simulation") represents as profound a shift from in-centre to in-situ simulation. It likewise requires modification of simulation tools to meet the new context [21].

The debriefing of non-simulation real-life events is a key way in which staff can identify and enhance the sources of resilient performance in clinical work. Often, debriefing of clinical events only occurs for cases where there has been a poor outcome. By contrast, reflecting on how things "went well" in usual clinical situations makes visible the active work being done as people work around surprises and deal with changes. By only debriefing those events that go poorly, these hidden sources of resilience remain unseen and undervalued, as do the problems being overcome to produce successful work. Dieckmann et al. [22] describe an approach based on RHC ideas ("learning from success") where mundane clinical events were debriefed to examine the interplay of the people, their environment and the social context. The change in focus enabled an understanding of what makes good performance and how to reproduce and re-apply it.

The use of simulation to enhance system resilience also extends to the use of *ad hoc* simulations to test new processes, to explore particular clinical problems within the workplace and to understand the consequences of potential changes. It engages frontline staff in reflection about work and allows them be involved in the "adaptive reorganization" of the way they work [23].

Finally, having simulation faculty who work in the clinical environment creates a *reinforcing loop*, where what is taught in simulations is modelled in everyday clinical practice, helping learners integrate the lessons and providing social reinforcement of the desired behaviors [24].

This may explain the success of programmes such as PROMPT [25] which are designed to use local clinical faculty and to focus on how to integrate learning into daily practice through systemic changes.

In summary, the key to enhancing resilient performance over the longer term is through engaging key staff as simulation faculty, changing clinical processes to support team functioning, and debriefing regular events.

Case Study – "Team Resilience"

The Middlemore Critical Care Complex (CCC) is an intensive care unit (ICU) situated in Auckland, New Zealand. It is an 18 bed ICU with >1300 admissions each year including children and patients with major burns or spinal cord injuries. It operates in an area of socioeconomic deprivation and experiences high patient acuity with emergency admissions accounting for >85% of the work.

As part of ensuring staff were trained to deal with such diverse patient demands, the CCC established a simulation program in 2011. This evolved from providing single-discipline scenarios in a simulation centre to an established in-situ program with the capability within the CCC faculty to design, run and debrief scenarios for expert learners.

In 2014, the Team Resilience Framework was developed and introduced based on ideas from RHC (Fig. 9.1). The focus was on making the elements of good teamwork clear in a way that was scalable, from resuscitation events through to the ICU ward round through to disaster events. It incorporated many standard simulation concepts and added concepts related to resilient performance.

The framework was introduced during monthly interdisciplinary in-situ simulations which covered common scenarios linked to the CCC curriculum. On each day, the first scenario focused on "teaming," the ability to form an effective ad hoc team quickly, and the second scenario on how team function affects the ability to adapt to the unexpected. These aspects were highlighted in the debriefing sessions with the links being made back to the overarching framework. Junior medical staff had six simulations during their six-month rotations and all nursing staff were involved during their rotating education days.

The group involved in implementing the framework included senior medical and nursing staff who were able to demonstrate how it applied to everyday clinical work. This included introducing concepts from the framework into the ward round, modelling the expected behaviors in resuscitation events and performing focused debriefs of actual clinical events. The ongoing implementation of the framework developed as an iterative process over several years.

In 2016, the CCC Quality Coordinator conducted qualitative interviews with 24 nursing and 4 senior medical staff to explore perceptions of team function in the CCC over the preceding 2 years. Thematic analysis of the staff interviews identified three main themes [26]:

Improved team functioning: Staff felt there was more clarity about how to build an effective team and that there was more of an expectation about "how things should go." Of note, the team was asking senior medical staff (who had not yet been involved in the simulations) to give recaps and share their plans. The expectation of how teams were meant to organize and a focus on active followership meant junior staff were asking for the leadership behaviors they needed for the team to function effectively.

Anticipatory safety behaviors: There was a perception that there was more discussion about the expected trajectory of a patient in addition to any predicted risks. This enabled staff to more rapidly identify and respond to both predicted and unanticipated changes.

Improved psychological safety: Nursing staff reported feeling much safer to "speak up". There was little use of the escalation tool from the framework, suggesting that their sense of feeling able to "speak up" did not come

Fig. 9.1 Team Resilience Framework. This work is licensed to Team Resilience, Middlemore Hospital under the Creative Commons Attribution 4.0 International License. To view a copy of this license, visit http://creativecommons.org/licenses/by/4.0/

from having a tool to escalate concerns. Instead, staff described feeling part of the team and being expected to contribute to discussions about the patient.

There was also a change seen in the degree of reflection and innovation by the staff, demonstrated by significant changes to the approaches to hand hygiene, patient care handovers and the way incidents were investigated. The changes were all based around an understanding of "Work-as-Done" and designing processes which "make as much as possible go right."

Conclusion

Simulation has clear potential to improve team and system resilience. Incorporation of RHC principles fundamentally change the way simulation is designed and delivered. Successful application requires an understanding of people in their work context and a focus on enhancing the adaptability of teams and the wider system. Finally, simulation should no longer sit remote from everyday clinical work. Simulation approaches should also be interwoven into the way every day work is done in order to build a culture of reflection, learning and improvement.

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Improving Handoffs Using a Systems Framework and Simulation

10

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Introduction to Handoffs

Handoffs are an integral part of patient care in which responsibility and accountability for patients is transferred between clinicians [1]. These transfers may also be referred to as handovers, sign-outs, or shift changes. Handoffs occur when clinicians need to be relieved at the end of a shift or when patients are transferred between units.

Handoffs have received little attention until research emerged in the 1990s and 2000s that linked the number of patinet handoffs to members of a different medical team to poor patient outcomes [2]. The hundreds of published studies [3–5] about provider training in handoffs, communication tools, mnemonics, checklists, and other process-based mechanisms to improve handoffs underpin regulatory mandates to standardize handoff communication in clinical practice [6]. Although standardized handoffs are far from universal, healthcare providers and educators must now demonstrate that they have policies and procedures in place to ensure safe handoffs.

Handoffs involve more than the exchange of information between individual care providers or care teams. Indeed, Patterson and Wears (2010) highlighted other functions that are fostered during handoffs, which include information processing, using and forming stereotypical narratives, fostering resilience, transferring accountability, interacting socially, sharing cognitive load, and developing and maintaining cultural norms. Although most published work on handoffs focuses on information processing, all functions should be considered in handoff improvement efforts to prevent failures. Some of the failures can be attributed to the limited consideration of conceptual and theoretical underpinnings that can be used to inform the development of handoff improvement strategies including tools and education. One opportunity to decreases failures associated with handoffs is to incorporate a socio-technical systems approach. Socio-technical systems emphasizes a joint optimization between the social and technical elements to achieve effective and efficient functioning of an overall healthcare organizational system [7]. The purpose of this chapter is to apply a conceptual framework that can highlight the complexity and failures inherent in the handoff socio-technical system and, explore how the use of simulation can be used to improve handoff training and performance.

Systems Frameworks to Study Patient Handoffs

Several theoretical frameworks and models underlying sociotechnical systems have been influential in guiding health IT research. The fields of systems and human factors engineering offer several frameworks to understand healthcare systems and their outcomes including the Systems Engineering Initiative for Patient Safety Sociotechnical Systems Theory (SEIPS) [8] and the Interactive Socio-technical Analysis model [9]. Here, we briefly describe Donabedian's Model of Healthcare Quality, given that it has been widely used and applied to understand handoffs.

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Donabedian's Model

Donabedian's model focuses on understanding structures and/or processes in order to improve outcomes [10]. The model is comprised of three major components- structure, process and outcomes. *Structure* refers to the setting, professional personnel, and administrative system through which care is delivered; *processes* refer to the ways care is delivered; and the *outcomes* refer to the desired products for the organization [11]. The model is characterized by interdependencies between components and their effect on each other [10]. In other words, effective structures increase the potential for effective processes, thereby leading to effective outcomes [11]. The model has been used to guide studies on patient safety, process standardization, and quality of care [12, 13]. Donabedian's overall model applied to handoffs is illustrated in Fig. 10.1 and additional examples of structures, processes and outcomes related to handoffs that can be incorporated into research or quality improvement efforts in practice are shown in Table 10.1.

Donabedian's model has been applied in several studies of handoff processes, such as standardizing handoffs from the operating room (OR) to the intensive care unit (ICU) [15]. In these circumstances, the structure is the physical transport between departments; the process is the standardized handoff content; and the outcome is the impact on patient safety [15]. A multi-center prospective study using this model identified failures in communication and patient flow, and differences in the experiences for physicians and nurses [16]. This prompted recommendations to improve communication that included standardized face to face handoffs for physicians (structure) and avoiding patient transfers between units at shift change for nurses (process). The standardization of handoff communication to improve patient care was also suggested by Watkins who used Donabedian's model to study the effectiveness of provider handoffs and discharge planning from the emergency department to primary care [17]. Although there are many ongoing efforts to improve handoff practice, there is relatively less attention on conceptually-based or evidence-based handoff training methods.

Simulation Methods Used in Handoff Training

Formalized lectures, workshops, role play exercises, virtual worlds and computer simulations are strategies that have been used in nursing and medicine for handoff training [18–29]. Objective Structured Handoff Experiences (OSHEs), in which junior residents complete a verbal and written hand off to a senior resident, using a simulated case, provide a valid and reliable way to assess handoff skills through direct observation. The junior residents receive feedback on the verbal handoff from senior residents and scores on the written templates from faculty. Markova and colleagues (2015) found that medical residents had greater confidence and ability in handoff following handoff training using this type of simulation [30]. Similarly, Gaffney et al. (2016) utilized multi-patient OSHEs and found that handoff training experience in medical school was associated with higher handoff scores (23% no training vs 33% either third OR fourth year training vs 58% third AND fourth year training, $p = 0.02$) as well as improved prioritization of patients based on acuity (12% no training vs 38% prior training, $p = 0.014$) [31].

Examples of Handoff Simulations and System Improvement

Examples of simulation methods to improve communication within systems are not widespread. Low-fidelity simulation, such as role play, has more commonly been used to teach handoff as compared to high-fidelity simulation methods [18, 32, 33]. Although not developed around the Donabedian model, the landmark I-PASS (Illness severity, Patient summary, Action list, Situation awareness and Contingency planning, and Synthesis by receiver) handoff study can be understood using this model. The I-PASS bundle includes a comprehensive handoff curriculum (structure) and simulation education and training (processes). Outcome data from a multi-site I-PASS handoff curriculum study demonstrated a 23% reduction in overall medical-error rate across multiple sites (24.5 vs 18.8 errors per 100

Fig. 10.1 Handoff process. (Adapted from Chelluri, 2008 [14])

Table 10.1 Examples of Donabedian's components related to handoffs

Components	Examples
Structure	Clinical setting and environment, organizational standardization policies on handoff processes, handoff training and didactic curricula, handoff mnemonics, handoff specific technologies, other health information technology-based tools (e.g., Electronic Health Record), healthcare providers (sending and receiving clinicians), communication technologies (e.g. telephone, Skype [Microsoft Corporation, Redmond, WA], Vocera [Vocera Communications®, San Jose, CA]).
Process	Sequence of steps in the handoff workflow process, transferring responsibility, identifying sender and receiver, interruptions, inclusion of patient in handoff communication, handoff sender's organization and information sequence, and handoff receiver's attention to care planning during handoff.
Outcome	Situation awareness and information recall by the receiving clinician, receiver's confidence in decision making, handoff errors (missing and/or incorrect information), preventable adverse events, handoff efficiency, handoff quality satisfaction, costs, and patient satisfaction).

admissions, $p < 0.001$) and a 30% reduction in the rate of preventable adverse events (4.7 vs 3.3 events per 100 admissions ($p < 0.001$) [27, 34, 35].

Informed by the Donabedian model and modeled after the medical I-PASS, the N-PAS (Nursing-Patient Summary, Action Plan and Synthesis by Receiver) mnemonic was developed using a Delphi panel of nurse experts and focuses on the structure and process of handoff [36]. Using real world nurse-to-nurse handoffs, O'Rourke and colleagues found that the vast majority (72%) of patient care information handed off at shift change is patient summary data, which could be pulled directly from the medical record. Up to 7% of information communicated during handoffs is not pertinent to the patient plan of care [36]. Plans are underway for developing an N-PAS curriculum that includes didactic and simulation components. Both the I-PASS and N-PAS are well-designed handoff mnemonics that follow a structured and standardized approach to handoffs.

Other examples provide evidence for system improvement during unstructured events.

Preparations for the 2014–15 Ebola epidemic provide an example of how simulation can be used to establish system improvements in communication. One medical school identified the need to prepare using more than just a review of guidelines. Simulation drills were used to practice and provide feedback on clinician and administrator performance that addressed gaps and improved aspects of their preparedness efforts to communicate and respond successfully to real patients [37]. Similarly, a children's hospital, used the Plan-Do-Study-Act (PDSA) process [38] to rapidly develop simulations that prepared clinicians for potential Ebola patients. The simulations focused on the entry points of patients, communication, and detailed care of any patients across the hospital. Using the PDSA process and simulation observation, they were able to identify potential threats and breaches in the system [38]. This chapter has provided examples which address the use of simulation to improve handoff processes, but similar principles can be applied to many healthcare processes.

In summary, a well-designed, systems approach to simulation-based handoff training is possible. The choice of simulation training methods should be well-planned, grounded in relevant models and current evidence and match the organization's experience and resources. Finally training objectives that are observable and have measurable outcomes should be chosen at the outset of the program.

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Exploring Workarounds: The Role of Simulation to Build Resilience

11

Kimberly P. Stone

As part of a simulation in the Emergency Department (ED), the ED team is caring for a sick patient with a life-threatening infection. After successful resuscitation, the patient is started on several intravenous (IV) infusions, including medications for blood pressure support and broad-spectrum antibiotics. The team is struggling to get all the infusions on pumps and hooked up to an IV pole to transport the patient to the Intensive Care Unit. The tech who went to retrieve the pole and pumps from the supply closet reports that there were no poles or pumps and asks the Team Leader if she should call Central Supply to obtain some. The Team Leader responds, "There isn't time. Central Supply always takes too long to get us supplies and we need to move this patient now." A nurse runs out of the room and returns a couple moments later with an IV pole and 3 pumps. The Team Leader smiles and remarks, "Thank goodness. Where did you find those?" The nurse responded, "This always happens. I stashed some supplies away for situations just like this."

In this scenario, the nurse's "stashing away" of needed supplies constitutes a "workaround." A workaround is a behavior that circumvents or "fixes" perceived or actual workflow barriers to achieve a desired result [1]. Medical providers often implement workarounds to overcome what they experience as inadequate or faulty systems which make it difficult to deliver efficient and effective healthcare [1–4]. Examples of workarounds include stashing of materials, as in the scenario above, taping a patient's barcode wristband to the stretcher for ease of medication administration [5, 6], placing duplicate medication orders to bypass computer order entry constraints [7], using paper orders in lieu of computerized order entry for efficiency [8], and the use of text boxes in the electronic health record (EHR) as a means of conveying important information [9].

Workarounds are described as both a sign of flexibility and a patient safety danger in the literature [1, 3, 4]. While healthcare providers are expected to be nimble and adjust with varying work conditions, and nurses are often touted as problem-solving ninjas, the existence of workarounds is polarizing. Workarounds that circumvent intentional safety barriers in the name of efficiency have been associated with medical errors [1, 6]. However, workarounds that offer solutions to systems problems are championed [5]. Workarounds are often symptomatic of underlying systems deficiencies but are infrequently reported [4] resulting in lost opportunities to uncover the underlying problem for why the workaround was needed in the first place. This "second-order problem-solving" [4] is missing in healthcare yet desperately needed to build resilience. As compared to first-order problem solving which fixes the immediate problem, second-order problem solving involves understanding and eliminating root causes so the problem isn't repeated [4, 10].

Workarounds provide a glimpse into a slice of the health care system that is not working for the front-line provider. Simulation offers a unique opportunity to explore the underlying causes for workarounds and learn from the adaptive responses of team members to support organizational resilience. Resilience is the ability to recover and respond quickly to a set-back and is a characteristic of high reliability organizations (HROs) [11]. HROs are organizations that operate in complex, hazardous systems without experiencing the expected level of adverse events [11, 12]. HROs seek to cultivate resilience through a continuous focus on safety over performance [13]. As health care continues its journey to improve patient safety, more attention is being paid to how health care can embrace the principles of HROs to build organizational resilience and reliability.

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The Role of Simulation in Identifying Workarounds

The first step to learning from workarounds is to identify them [3, 14]. But how? The complexity of healthcare delivery can make it challenging to observe even routine processes, and observation becomes even harder with infrequent processes. Team members can be asked to self-report but given that many may not identify their actions as workarounds [1, 6] or are unlikely to report them [4] as this will take additional effort and potentially result in penalty, the yield will be low. Audits and other observational activities provide an opportunity to capture workarounds, however, these can be time-consuming and may be limited to certain routine processes or situations (such as daytime hours) unless particular care is taken to target non-routine situations.

In situ simulation offers the ability to approach reality by using actual care team members in their native environment to explore both routine and infrequent processes [15]. By coming close to reality when observing reality cannot be done, *in situ* simulation can get us closer to understanding how work is done versus how work has been imagined [16]. Team member actions during simulation can be observed against planned processes, and potential workarounds can be identified and explored. This is especially important for high-risk yet low-frequency events (e.g., medical emergencies, fire drills) where the likelihood of observing a real event is extremely low. In the opening scenario, a high-risk resuscitation identified the stashing workaround a team member created to manage a lack of critical supplies.

Another benefit of using *in situ* simulation is the opportunity to see parts of a process that may not typically be visible. Healthcare is complicated, often with a multitude of healthcare team members, complex processes, and care that spans hospital departments, with multiple components. All this complexity means that few people may understand the entirety of a healthcare delivery process, which can lead to misinformation. When was the last time a healthcare provider was able to observe the next team taking care of their patient after handoff to fully understand the flow of information and potential impact of any workarounds? How often does the pharmacist responsible for preparing the critical medications have an opportunity to observe the medical teams using the medications? With *in situ* simulation, observing all parts of a process becomes possible, and even preferable, to understand the layers of complexity. Returning to our opening scenario, what might be learned by continuing this simulated patient's care in the intensive care unit (ICU) and having both ICU and ED team members observing the entirety of the resuscitation? Perhaps each team would discover that the way they perform the central line safety bundle may be different than another team's process. What might be learned by having observers from Central Supply attend the simulation? Could the underlying problem of limited supplies be mitigated?

In addition to allowing visualization of the entire process, *in situ* simulation offers the opportunity to manipulate conditions to identify potential workarounds efficiently. One could simulate different staffing models, different locations in the hospital, or at different times of the day to understand staff behaviors under these varying conditions. For example, the opening scenario could be simulated for transitions of care to any number of settings to see if the challenges for staff are the same, for instance, ICU ➔ operating room ➔ ICU; Medical floor ➔ ICU, etc. Are similar or new workarounds created because of processes or priorities in other areas of the system? Have the staff in one area found a creative way to overcome their challenges and do the learnings need to be shared?

Simulation provides the opportunity to explore the "What Ifs?" What if part of the anticipated process or work system failed, was missing a component or otherwise did not function as designed? What would be the natural actions of the team members? What workarounds would be created by health care team members to achieve their goal? Exploring and identifying some of these potential workarounds could guide anticipatory planning for teams. Rather than expecting the system to work as imagined, using simulation to explore possible failures builds on the systems' adaptive response. The workarounds created by team members can be expanded and shared for organizational learning. Observers can be utilized when it is not possible to simulate multiple permutations and can add to the learning from any given scenario [17]. Encouraging a broad range of stakeholder observers allows for more diverse sets of eyes with which to experience the simulation. Each observer can then go through the mental exercise of how the same or similar simulation might play out in their part of the work system. For the opening scenario, having observers from the ED, ICU, OR and medical floor observe the simulation and querying them on their team's experience can also lead to workaround identification, as well as identification of commonalities and differences.

Using Simulation to Explore Workarounds

Once a workaround is identified, it is crucial that the reasons for the workaround be thoroughly explored. Several studies identify operational failures (such as resource issues, incomplete documentation, missing information) as precursors to workarounds [1, 5]. These studies often involve detailed observations followed by lengthy interviews [6, 8, 18, 19]. It can be difficult and resource-intensive during actual patient care to pause and inquire about the reasons for a team member's actions. Depending on the situation, time con-

straints and patient care needs may not allow for a detailed discussion of a team member's actions. Fortunately, in simulation, the debrief is intended for just this purpose.

Simulation debriefs are the opportunity to explore team members' behaviors and mental frames to get at the root of their thinking and actions [20, 21]. During the debrief, the debriefer can identify workarounds and investigate the perceived need(s) that led to it. In the opening scenario, the debriefer may start by pointing out her observation, "I noticed that you had saved some IV poles and medication pumps apart from the typical supply to have for an emergency." In case the nurse did not already identify this as a workaround, the debriefer could then name it and delve deeper into the nurse's experience and reasoning. "I'm curious that you felt the need to create this workaround to get critical supplies. Tell me more about your experience with supply shortages and why you felt saving some supplies was important to do."

Simulation debriefers can also be trained to continue to probe to understand root causes [22]. A straightforward response in the above scenario such as, "I've had this happen before," could elicit a further request for details from the debriefer. "Tell me about another time when this happened during an emergency." Additionally, the debriefer can question other attendees about possible similar experiences. Learning of additional experiences strengthens the thesis that the reason for the workaround is a systems issue.

Artefact identification is another technique that can be used by debriefers to identify and query workarounds. Artefacts, such as documenting vital signs on a paper towel to be later entered into the electronic health record (EHR), can be a physical representation of an adaptation and may not typically be identified as a workaround. Debriefers can explore the need for an observed artefact during the simulation, "I notice that you wrote the patient's vital signs on a paper towel that you then later entered into the EHR. I'm curious as to why you needed to do this." This line of inquiry can allow team members to explore how the designed process conflicts with typical workflow (e.g., computer inaccessible at bedside where vital signs are obtained). In their study on nurses' paper artefacts when using EHRs, Saleem and colleagues found widespread paper persistence for a variety of reasons including, but not limited to, perceived efficiency and ability to manage task complexity and organize data [8]. The existence of such *ad hoc* tools is a signal for further exploration of the role such artefacts plays within clinical cognitive work.

Debriefers can also seize the opportunity with front-line staff to understand why they think the problem(s) or barrier(s) exists, and potentially, what is needed to fix the underlying problem. This *deference to expertise* is a key element of high-reliability organizations [11] and has the benefit of getting first-hand experience in identifying the system flaw. In the opening example, asking our nurse and other participants why they think the ED has supply shortages may provide some interesting insights. Perhaps we will learn that although the new ED has expanded its capacity and now has a higher acuity, the number of critical care supplies that are stocked are the same. Or we may learn that the shortage of IV poles and medication pumps is known by central supply, but they have not been authorized to order more. In situations like the latter, the learnings from simulation may be useful to build a case that additional supplies are needed, and inform efforts to address the underlying problem(s) or hazards rather than the symptoms. How to leverage learnings from simulation for systems resilience is discussed below.

When to Use Simulation

Although every simulation encounter could identify a workaround, certain situations may provide the highest yield. Systems-based simulations are simulations in which the goal is to evaluate the system itself [22], thus making these simulations particularly useful to identify and explore workarounds. Systems-based simulations are probes into how the system is or is not functioning and offers a proactive approach to safety, mirroring the preoccupation with failure tenet of HROs [11]. Numerous chapters in this book address additional principles and specific examples of simulation used to improve patient care at a system level.

In the ideal world, new work systems or processes would be developed and tested with simulation. The traditional way in which a new process is created and implemented begins with a stakeholder meeting(s) to hammer out the details and sequence of the process [plan], followed potentially by a pilot study with a limited population or provider group [do], then maybe some tweaking of the process, with feedback [study], followed by implementation [act]. This plan-do-study-act cycle can be repeated several times but often involves the "doing" and "studying" with real patients and real teams, risking patient safety, at most, and staff frustration, at least [23]. *We propose that instead, the first PDSA cycles be done with simulation to iteratively trial the process under near-real conditions, allowing stakeholders to observe the process entirely and allowing frontline staff to give feedback.* Observed workarounds or identified challenges that may prompt workarounds and artefacts generated, can be further explored and options trialed.

Particular attention should be paid to the introduction of new technologies into existing workflows. In his book, Wachter calls out the unintentional consequences and potential safety hazards of the very technology which is intended to improve patient safety [24]. Similarly, studies on workarounds identify a mismatch between technology and existing workflows as a common situation necessitating a

workaround [1]. In their study of a computerized order entry systems for pediatric patients, Walsh and colleagues identified workarounds prompted by unintentional consequences of new technology, a computerized system that could not accommodate medication orders for complex pediatric patients that could previously be managed through paper ordering systems [7]. Koppel and colleagues described 15 different types of workarounds associated with barcode medication administration (BCMA) systems and concluded that successful implementation of BCMA needed systems which included safety features to support their use [6].

Simulation can be used to understand the interface between the work system and the proposed new technology and to evaluate trust in this new system. Trust, mistrust and distrust, especially as it relates to new technology, has been shown to affect how users accept, overly rely on or reject the new system [25–27]. In his study, Weber found that trust in the system and data was a major predictor of the likelihood that advance practice nurses would use a clinical decision tool system [27]. Simulations and their debriefs can offer insights into what features of the proposed system or technology elicit trust or distrust, which will affect their acceptance and the potential need to generate workarounds.

While it would be most efficient to incorporate simulation at the start of a work system or process development, simulation could still be done prior to implementation as a final test drive, providing there is time to allow for necessary post-simulation modifications. Combining simulation with the risk assessment tool, FMEA (Failure Mode Effect Analysis), provides a structured way of performing a proactive risk analysis and is effective at identifying latent safety threats that can lead to system failures and the need for workarounds [28]. Similarly, simulation can be used to aid in evaluating work system designs for safety and workflow. In a study by Horsky and colleagues, participants used simulation to compare the accuracy of two different EHR medication reconciliation designs, clearly identifying that one EHR design stimulated fewer participant errors and workarounds. Visualizing the participants' interactions with the EHR designs and obtaining feedback allowed the researchers to proactively understand inherent challenges and limitations of each design [29].

Similar to *in situ* simulation use with new work systems and processes, we propose that simulation be employed to assist with the design and evaluation of new and remodeled clinical care areas. The work environment has implications for patient safety [30] and several studies demonstrate the use of simulation during the design of new spaces [12] or following construction of new spaces [31, 32] to identify latent safety threats and systems issues that lead to workarounds (see Chaps. 14 and 15).

Following a patient safety event, simulation can be used to help understand the role of workarounds in an error. Traditional quality improvement tools such as RCA (Root Cause Analysis) have been combined with simulation to identify systems issues underlying medical errors [33]. By re-creating the clinical situation preceding a medical error, systems inefficiencies and barriers that may have contributed to a workaround can be identified. Simulation also offers the benefit of potentially re-creating the situation that lead to the error with more than one team to further explore themes and contributing systems elements.

Routine simulation educational activities also have a role in identifying workarounds as exemplified in our opening scenario. *In situ* simulation education often incorporates routine processes thereby creating an auditing opportunity for these processes. Educational simulation debriefs can be structured to incorporate workaround identification and exploration as part of a systems analysis, in additional to traditional debrief discussions of knowledge, skills, teamwork and communication [20]. For example, an *in situ* simulation focused on anaphylaxis management that includes routine elements of assessment, orders and medication administration may reveal a physician participant using verbal orders instead of the computerized emergency anaphylaxis order set. For this simulation, in addition to the discussion on recognizing and treating anaphylaxis, the debrief should include a discussion of the verbal order workaround and seek to understand the reasoning behind the physician's use of verbal orders over the computerized order set. This discussion could lead to learnings of misunderstandings of how to use the orderset or alternatively, challenges with using computerized order sets in time-sensitive emergent situations. By systematically including an opportunity to identify workarounds and systems issues that may lead to workarounds, educational simulations also become intentional systems probes.

While we have focused on *in situ* simulation, it's important to highlight that workaround identification and learning can and does also happen in a simulation center. In their study, Geis and colleagues evaluated team roles and responsibility related to the opening of a new ED first in a simulation center, identifying role disparities and inefficiencies that are precursors to workarounds [34]. Additionally, Landman and colleagues evaluated usability testing for a new EHR in a simulation center and demonstrated the feasibility for conducting these tests while garnering important translatable information [35].

Simulation to Improve Resilience

Returning to our opening scenario, we see that our *in situ* educational simulation identified a workaround of stashing critical supplies created because of systems inefficiencies in obtaining necessary supplies. The nurse in this situation had

completed first-order problem solving [4] and managed to secure needed materials for her patient – a win for this patient at this time. But what effect does her workaround have for the next patient? For the system as a whole? Perhaps, her supply stashing has resulted in decreased supplies in the ICU which results in a delay for another ICU patient, or decreased supplies elsewhere in the hospital. Ultimately, the problem is transferred to someone else [5] and may create a vicious cycle of perceived shortages stimulating more stashing which exacerbates shortages. If the workaround exploration stops with the simulation debrief what has been learned by the next team? By the ED leaders? By the leaders of Central Supply who determine what supplies are stored in what location? To effect change beyond this patient at this time, there needs to be an escalation, calling attention to the problem to allow for a systems-level change, which has been called "second-order problem solving" [4].

Fortunately, some simulation programs already have in place a system to escalate identified issues [10]. In most cases, these programs utilize existing safety reporting mechanisms to include findings from simulations. This process allows for both proactive and reactive probing of the system to identify failures and barriers. Witnessed workarounds and their learnings can be reported in these systems and serve as a starting point for second-order problem-solving.

Simulations that result in organizational change can go a long way to improving the overall trust of health care team members in the larger health care system. Trust is an important element in a patient safety framework and for supporting a safety culture [36]. Health care team members need to trust that their experience and input is valued by health care leaders. Learnings from simulations and the resultant system changes need to be widely shared and communicated as a means of reinforcing the value of the input and building trust.

In the case of our opening scenario, the concern for timely access to critical supplies was escalated to leadership for both the ED and Central Supply. While the request for additional supplies to be stored in the ED had previously occurred, the staff action identified in the simulation indicated a level of staff concern not previously appreciated. ED leadership also had concerns about where to store the extra supplies and, by partnering with the nurse who had creatively solved this problem, discovered another option. Additional materials were then secured for the ED and all staff were informed of the location of the additional supplies. By escalating concerns, valuing the input of frontline staff and engaging in collaborative problem-solving, the observed supply stashing workaround identified in simulation led to a systems-level change to potentially benefit all patients.

Conclusion

Ultimately, the existence of a workaround indicates a process or work system that is not working for those for whom it was designed. Using simulation to explore workarounds provides a tool by which systems failures, inefficiencies, barriers, and human adaptations can be identified and true operational resilience can begin (Box 11.1, 11.2, 11.3).

Box 11.1 Learning the secret code

An *in situ* simulation was conducted to assist with redesigning an ED resuscitation room for better efficiency. Several stakeholders were invited to observe the simulation including the Director of Supply Chain who controlled the inventory in the resuscitation room. During the simulation, the nurses were observed several times interacting with a new locked supply dispensing cabinet, having to re-enter a code and, then moving through a number of steps to choose a default entry in order to retrieve the items needed. This practice resulted in several wasted minutes. During the debrief, the debriefer noted the observation and asked for further information. The nurses, clearly frustrated, explained that if the supply cabinet doors were left open for the entirety of the resuscitation, a loud alarm would sound and since they were required to answer questions to allow for appropriate patient charging from the supply cabinet, they created a workaround by quickly scrolling through the questions and choosing a default answer. This needed to be repeated with each cabinet interaction so as not to have the alarm blaring during the resuscitation. The Director of Supply Chain, never having observed a medical resuscitation before, quickly identified that an emergency override option for the supply cabinet had not been activated and would be useful in just these circumstances. He walked to the cabinet, punched in a series of numbers and then showed the nurses how the emergency override worked. By activating the emergency code, the nurse could punch in a set of numbers one time and leave the supply cabinet open to be easily accessed throughout the resuscitation. In a matter of minutes, because he could visualize the problem the nurses were having, the Director of Supply Chain fixed a systems problem that had been plaguing the staff – and potentially jeopardizing patient care – for months.

Box 11.2 A more efficient way to get blood quickly

In order to evaluate a new emergency protocol for bleeding patients, several *in situ* simulations were conducted in clinical areas. The draft protocol was created by stakeholders and specialists including team members from critical care units, the operating room, the blood bank and several others. During the first *in situ* simulation, it was observed that several team members were independently calling the in-house Blood Bank to check on the status of the requested new blood transfusion pack, which was expected to arrive within a 30 min window. The team caring for the simulated patient needed to know when the blood transfusion pack would be arriving at the nearby tube system so someone could retrieve it. Observers of the simulation stationed in the Blood Bank witnessed that the Blood Bank team members were continually interrupted to answer the phone while they were diligently trying to prepare the blood products. During the debrief, both observations were raised and discussed. Team members caring for the patient identified that they had no way of knowing when they could retrieve the blood and wanted to be able to get it to the patient as soon as it arrived. Their workaround for not having a process was to just call the Blood Bank and ask them when to expect the blood products. Blood Bank staff identified that there were only 2 staff members working most hours of the day (non-peak hours) and so, in addition to preparing the blood products, they were responsible for answering the phone. The limited number of Blood Bank staff during non-peak hours was new information to everyone else. Based on these observations and feedback, the next iteration of the protocol included a point person from the team caring for the patient who the Blood Bank staff would call once the blood transfusion pack was being sent. The point person's name and contact phone number was listed on the lab slips and orders related to the activation of the emergency bleeding protocol. In subsequent simulations, the number of calls and interruptions to the Blood Bank staff decreased significantly [37].

Box 11.3 Seeing is understanding

As part of a systems-based simulation assessing a newly built cancer care unit, a scenario was designed to evaluate a new in-room chemotherapy protocol. The new protocol incorporated the required safety elements, along with medication preparation and administration processes. During the simulation, it became clear to both participants and content-expert observers that the new protocol, although designed with the new unit in mind, did not work as imagined in the new space. The nurse participant had challenges with several elements of safety (e.g., not easily being able to access a 2nd nurse for required double-checks) and preparation (e.g., the layout did not allow for ease of the nurse's physical flow) that made the nurse leaders concerned for patient safety. Rather than risk implementation of this new in-room protocol and the creation of workarounds, the nursing leadership opted to temporarily proceed with the existing protocols and to use simulation to create a new protocol in the new space after they moved in and were more familiar with their new surroundings.

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Whiteboards that Work

12

Priyadarshini R. Pennathur, Ann M. Bisantz, and Laura E. Schleelein

Information Displays in the Healthcare Environment: An Overview of the Design Challenges

Healthcare workers use information displays all the time for their patient care tasks. Through the medium of displays, they read and create patient documentation, track and interpret patient information, communicate and coordinate with other providers about patients, plan and schedule patient care tasks, and make critical, life-changing clinical decisions about their patients.

Given the critical nature of healthcare work and given the interactions healthcare workers have daily with information displays to succeed in their work, the designers of these displays face a unique set of design challenges. To overcome the design challenges and to make information displays effective, design teams have a valuable tool in their arsenal - simulation. Before design teams build the software and hardware that give form and function to a health information display, and before they implement the displays en masse in a healthcare setting, they can simulate many alternative display designs, test their effectiveness, and avoid expensive design changes and workarounds after implementation. They can experiment with a variety of display formats and functionality for the different patient care tasks healthcare workers perform in various medical contexts. They can get feedback from workers about the simulated alternatives and tweak their designs before implementing a final design on a large scale. During the simulation, design teams can also configure various end goals for their design alternatives, such as improving team situation awareness, or improving the rate of correct clinical decisions. They can then use the end goals to measure how well their simulations capture and represent real-world scenarios.

While simulation has other uses in healthcare settings as elaborated in other chapters in this book, our goals in this chapter are to highlight simulation's utility as a tool for designing and testing information displays for healthcare settings. We first elaborate the factors design teams must consider when simulating information displays. Next, we present a case study that shows the practical implications of using simulation as an approach to design and test information displays.

Factors a Design Team Must Consider for Simulation: User, Task and Situation Characteristics

Design teams need information about users' background and constraints (see Table 12.1). Each team member fulfills a different role on the team, and therefore, may require information to be presented differently on the display or require a separate display altogether to meet their needs. For example, in the operating room, a malignant hyperthermia crisis during a surgical procedure requires an immediate coordinated effort from the entire operating room team because it is a rapid, life threatening event. Once identified, the sole focus is on treatment. Each team member has very specific, defined responsibilities to accomplish rapid administration of the life-saving medication, dantrolene, to the patient. In contrast, a cardiac arrhythmia in the ICU is just as life threatening, however the cognitive needs for decision-making are different. Optimal diagnosis and treatment require determining the

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Table 12.1 User characteristics

Category	Characteristics to consider for simulation
User background	Target user population – nurses, physicians, trainees, professional staff, patients and family Demographics of target users
User roles and responsibilities	Primary roles and responsibilities of the user; Output expected from the user; Input expected by the user;
Use constraints	Voluntary or mandatory use; User login and user profile setup Type of interaction (read versus enter information)

cause of the arrythmia, which is rarely obvious, and as such requires the development of a differential diagnosis list. Designers of tools and technology can use simulations to complement or augment surveys, observations, focus groups and interviews to gather important data about the nature of the target users' work.

Task data for design includes task definitions, requirements, constraints, outcomes and evaluation criteria (see Table 12.2). Techniques such as observations and task analysis can help the designers compile and analyze task data. For example, a nurse completing a pre-operative checklist has very different requirements for a display compared with an emergency department physician who is running a resuscitation of a patient in cardiac arrest. The first needs to be a 'yes/no' type of display with no time constraints, versus the second, that would potentially require an interactive interface that supports timed tasks for tracking clinical interventions and response.

Last, but not least, design teams will need to extract and model an information display's use contexts based on what they find in the physical, social, and organizational environments in which workers will use the displays (see Table 12.3). When design teams accurately represent the different working conditions and constraints in their simulation, they maximize user acceptance and adoption of the displays. For example, a simulation may test an information display configured and tailored towards specific interaction needs such as data entry for different users and tasks subject to different time constraints. Simulation results may reveal that users in fast-paced environments prefer keyless login for quick data entry situations. Designers can gather context data through contextual inquiry methods [1], and through field observations and interviews.

Importance of Form in Information Displays

The physical form an information display takes plays a crucial role in accommodating user needs with the flexibility to represent contextual information in a format sensible and

Table 12.2 Task characteristics

Category	Description
Task Attributes	Input, output and decision points for the task Task content Granularity of task steps Sequence of tasks Relationships and interdependence between tasks Importance of the task for completing the other task/process
Task Requirements	Collaboration and communication needs User control and flexibility User customization and personalization of task Training and Learning Types of interactions Task completion and disposal of task Maintenance of the task routine
Task Constraints	Temporal constraints of task Role constraints Information constraints
Evaluation criteria	Accuracy Time to perform task Quality of output Compliance to policies

Table 12.3 Contextual characteristics

Category	Description
Healthcare unit	Specific units under consideration for information display implementation
Pace of the work environment	Slow-paced or fast paced
Physical environment	Layout of workstations in relation to information displays
Social environment	Communication and collaboration needs; interruptions and distractions
Policies and guidelines	Policies and guidelines in the organization
Location of information displays	Public vs private/individual displays; depends on need to obtain an overview, monitor, plan, and make decisions collaboratively or individually

familiar to the healthcare worker. For example, historically large centrally located manual whiteboards have been utilized in surgical settings to display operating room cases and associated information (e.g., order of cases, needed resources) each day. Use of this approach makes it easy to write out as much information as needed, move cases to different operating rooms as needed, and change personnel assignments with ease. The transition to electronic displays has not always been smooth. Case information is limited by display restrictions; special circumstances around a case are difficult or impossible to add based on electronic display limitations; and if the electronic display fails the 'brain' of the daily operation is gone. Research shows mixed results when comparing electronic and manual information displays for reducing errors, and for supporting healthcare work [2–7].

Measures of Evaluation

To test and assess whether a simulated display design is effective, designers can use several measures including a display's usability, a worker's situation awareness when using the display, and the quality of decisions workers make when using information in the display.

The main usability considerations for designing information displays include: the ease of access, flexibility and memorability, salience and visibility of information, refresh rates for real-time dynamic information, and integration of status information [8–12]. Some usability tools include System Usability Scale (SUS), Software Usability Measurement Inventory (SUMI) and custom-designed user experience surveys [13–15]. Tests for situation awareness will demonstrate whether the simulated design allows users to (1) perceive information critical to their performance; (2) understand what information on a display means; and (3) project future states based on information they see in the display. Design teams can use the SAGAT [16, 17] method to integrate situation awareness in the experimental simulation. Task performance measures can include accuracy, task duration, errors made, and workload. Design teams can program the simulated session to capture these measures automatically during testing and use these simulated sessions as training tools later.

Case Study 1: Human-in-the-Loop Simulation of Emergency Department Information Displays

Immersive evaluation of simulated interfaces by healthcare workers can yield design insights to improve information displays. Research has used human-in-the-loop simulation (i.e., requiring human interaction) techniques in laboratory and clinical simulation center testing of electronic whiteboard displays which provide patient information in emergency medicine (Emergency Department Information Systems, or EDISs). A series of research studies investigated how data sets derived in part from mathematical discrete event simulation could be used to populate simulated EDIS displays for research purposes [18, 19]; how extended-time, multi-person simulation scenarios could be created and used to test the effectiveness of novel EDIS visualizations within a clinical simulation setting [7, 20]; and finally, how those same simulated scenarios could be used within laboratory usability testing [21]. These studies were conducted within a larger effort to combine simulation techniques with cognitive systems engineering design methods to create and test novel EDIS visualizations which support the complex, cognitive work of ED health care providers [5, 22].

Here, we briefly review this approach, emphasizing the development of data sets which were used to drive the simulated information displays and in creating scenarios for human factors-oriented evaluation.

A fundamental aspect of human-in-the-loop evaluation of complex, interactive systems is the creation of immersive, representative experiences for participants such that they can make realistic assessments of the systems as they would be used in a real-life setting. This requires at minimum, and among other methodological concerns, that the systems provide participants with the ability to view and interact with realistic, representatively complex information about the work environment of interest, and that they engage with that information through tasks which support challenging tasks representative of actual work, and which "stress" the boundaries of interaction.

To effectively evaluate EDIS visualizations, therefore, it was necessary to create data sets which were representative of actual emergency department patients, so that data about those patients either individually, or in aggregate, could be displayed. Pennathur et al. (2010) [18] describes a process by which such data sets could be created. In particular, the process took as input, outputs from a discrete-event simulation of an emergency medicine department [23]. Discrete-event simulations are computer-based models of complex systems that mimic the behavior of probabilistic processes that occur in real systems (see Chap. 25). For instance, in a hospital emergency department, the time between patient arrivals, the severity of patient complaints, and the time to treat patients through a variety of possible stages can all be modeled using probability density functions drawn from observation or system data from hospital records. Model entities representing individual simulated patients can then be assigned values from these distributions, which are then used through a Monte-Carlo approach to generate higher level performance measures of the ED (e.g., throughput, wait time, utilization) as the simulated patients move through various probabilistically modelled treatment phases [18].

Pennathur et al. (2010) [18] used these results to create a set of events (e.g., arrival, triage, assessment, laboratory tests), with associated times, for a number of individual patients. While the original discrete-event simulation model included patient entities with associated severity scores and events, they were not contextualized with demographic details, specific chief complaints, tests, orders, and plans. Therefore names and chief complaints were added. Emergency medicine physicians on the research team worked to develop clinical details related to laboratory and medicine orders, treatment plans, and disposition orders. These details were used along with the event times create a time indexed "script" of events, with clinical details and associated information that would be shown on the EDIS at that time, for each patient. Then, scripts for the complete set

of patients were combined and ordered by time to create a comprehensive event timeline which included the time, the event, and the EDIS display content. The EDIS simulator, a computer program that included a basic display similar to the traditional manual whiteboard, then read in the events in sequence, updating the computer display at the appropriate location, with the new information for each patient, at each time-step, and was used to support a laboratory evaluation of some aspects of work with electronic patient tracking displays [19].

Later work expanded that data set in order to meet the needs of a novel set of displays developed through an iterative cognitive engineering/user-centered design methodology [22]. Working with clinical members of the research team, patient cases from the initial data set were supplemented with additional cases and clinical details, and events and timings were reviewed to ensure they were realistic for the planned study and presented a reasonable and realistic load across patient cases. This data set, representing 54 patients over a 500 min period, is available for download and use through the University at Buffalo Institutional Repository [20]. Similar to the initial EDIS simulator, the novel visualizations were dynamically populated by reading events into the simulator, which displayed patient information such as test results, and aggregated ED information, such as the number of patients in the waiting room, across the appropriate displays. These simulated displays (Fig. 12.1) were used to support a human-in-the-loop study conducted in a clinical simulation center. Two patient bays containing mannequin patients, a nurse and a physician computer workstation, and a large screen display were included in the set-up. The experimental session was completed by two-person teams (pairs of emergency medicine nurse and physician participants) who were first oriented to the displays and their "assigned" patients through video tutorials and audio-taped patient sign-overs (handoffs). Then, throughout a 45-min experimental scenario, the teams monitored patients and interacted with the dynamically updating displays, "treated" two mannequin patients, and completed various tasks which caused them to interact with the system (e.g., responding to simulated phone queries). Additionally, at one point, participants were asked to perform an assessment and make decisions regarding current patients in the face of an expected influx of patients from a mass casualty incident. The immersive scenario and interactions were designed to allow participants to more realistically experience the displays to order to provide assessments of their effectiveness and impact on cognitive workload. At several points throughout the scenario, the simulation was "frozen" and participants were asked questions designed to assess their level of situation awareness [16].

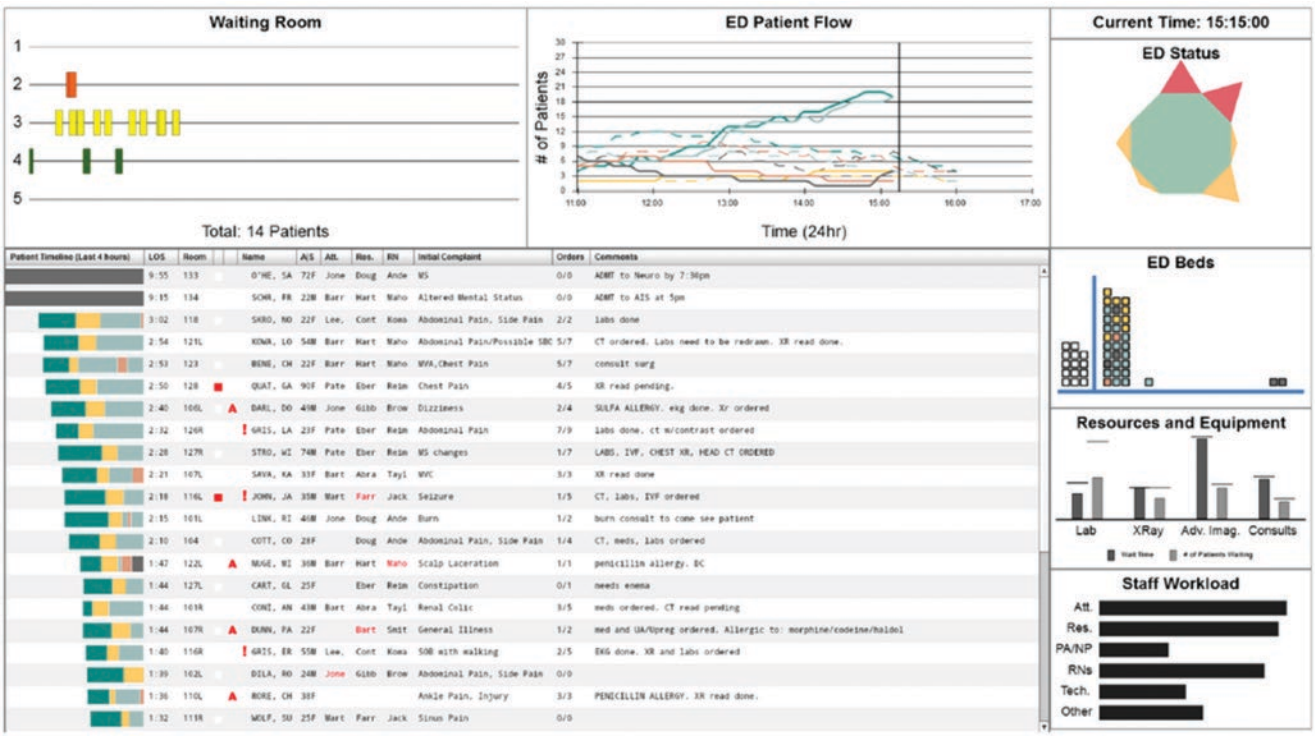

Fig. 12.1 The prototype overview display used to present a condensed/miniaturized version of the seven display areas and to navigate into those displays. (Copyright Ann Bisantz, University at Buffalo, The State University of New York. Originally published in McGeorge et al. [7])

Finally, we performed laboratory usability studies which relied on the same simulated-data driven visualizations [21]. In these studies, participants (ED nurses, physicians, or mid-level providers) were first exposed to the dynamic, interactive EDIS visualizations by watching a 12-min voice-over video which demonstrated components of the visualizations and functionality. They then used the EDIS prototype to answer a series of multiple-choice questions, which ensured they had interacted with the various components of the system. Participants next listened to an audiotaped shift change sign-over which introduced them to the patients and situations being shown on the prototype EDIS (Fig. 12.1). The EDIS simulation was then advanced to a point in time 20 min into the simulated scenario (i.e., showing the patient data as it had evolved over 20 min time), and participants engaged in an immersive orientation task that required them to reorient to the displays after a resuscitation. The simulation was advanced another 20 min and participants performed a second immersive task, in this case a planning task in which they assessed and made decisions regarding patients in preparation for an influx of patients from a mass casualty incident. Usability evaluation data was collected regarding (a) the degree to which the visualizations supported the cognitive work of the care providers (b) the degree to which the visualizations were usable and provided information that was useful and (c) an assessment of how frequently display components would be used. Results indicated that the visualizations were generally usable, useful, and supported cognitive work; however, some aspects, such as the display of current vs. historic wait times and the degree to which the displays supported task prioritization, were less valuable, usable, or supportive. Thus, participants were exposed to the simulated visualizations showing patient state data at multiple points in times, as it would have realistically evolved, and through that exposure were able to provide feedback on specific components of the visualization designs.

Conclusions

Healthcare providers manage large amounts of fluid information, and effective design of information display is essential to optimize the care providers are able to accomplish. While the form and format for health information displays may evolve with newer forms of technology (e.g., wireless mobile devices), the principles and processes governing the design of interactions between people and technologies are well-established. Simulation of clinical environments and interfaces associated with those contexts enables us to carefully evaluate the design and usefulness of displays in a low-cost, feasible, and safe manner.

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Tele-Simulation for Healthcare Team and System Improvement

13

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Introduction

Tele-simulation, a simulation that involves physical separation necessitating the use of technologic solutions to maintain communication, for education or healthcare system quality and safety assessment, has become an attractive solution for healthcare education in a variety of environments [1–8]. With a lack of trained facilitators as a major limiting factor for simulation-based education, and a shortage of faculty development opportunities such as 'debriefing the debriefer', tele-simulation technology to connect a qualified educator and facilitator is hugely attractive. Further, with recent advances in the use of simulation for system improvement such as detecting safety hazards, proactively constructing better workflow and clinical environments, and selecting particular healthcare equipment [9–13], the role of tele-simulation continues to expand. In this chapter, we will discuss the definition of tele-simulation (as we will use in this chapter), technical specifications, use for team educational intervention, and future applications for system improvement.

Definition of Tele-Simulation

A consensus summit of the simulation community in 2016 defined "tele-simulation" as "*a process by which telecommunication and simulation resources are utilized to provide education, training, and/or assessment to learners at an off-site location.* Off-site location refers to a distant site that would preclude education, training, and/or assessment without the use of telecommunication resources" [14]. Further refinement of the terminology used for simulations where there is separation by time and/or physical site is on-going. This chapter will use the term tele-simulation as outlined above and will not refer to simulations where there might be temporal differences in the components of the simulation experience.

This chapter will mainly focus on tele-simulation being used with the "learning team" on-site in a healthcare facility or simulation center, to improve teams and systems and the simulation facilitating and/or debriefing team off-site. The underlying principles of tele-simulation in this form can be adapted to other experiences that involve physical distanced simulation experiences where the learners might actually be off-site but the simulation itself is in another physical location. During the recent pandemic, a variety of the combinations among simulation equipment, leaners, and facilitators are becoming more practiced across the institutions [15]. There are also 'hybrid' models where some facilitators and learners are on-site together while other facilitators or learners are physically distant.

At minimum, tele-simulation, for the purposes of this chapter, involves real-time interactions between participants in a simulation and an educator/facilitator at geographically remote sites, bi-directionally connected with a video conferencing system for audiovisual communication. Often a facilitator remotely controls simulators (if electronic simulators are used) and screen displays. A local educator can be involved to optimize the simulation environment and participate in co-debriefing with a remote facilitator/debriefer.

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Technical Specifications of Tele-Simulation

Tele-Simulation Platform

The technology that is needed for tele-simulation will depend on the type of off-site services that are provided. Off-site services can include control of the simulator, facilitation and/or support of the simulation experience, and debriefing. Figure 13.1 shows an example of the system used between Children's Hospital of Philadelphia in the United States as an off-site facilitating site and Kanazawa University School of Medicine in Japan as an on-site training location [3]. At least two computers are used at the remote facilitating site: one to remotely control an on-site simulator through the training-site computer, using a free remote-control software, and the other dedicated to bi-directional audiovisual communication. At the simulation training site, there are also two computers: one to directly control an on-site simulator, and the other to facilitate the bidirectional audiovisual communication. Important technological considerations for successful tele-simulation include establishing audio capability and informative camera views.

Common technical problems include interruption of internet connections, low-quality sound resolution, and reverberation noises. Video image issues, including delays or pauses of the image stream or degradation of the image quality, may also happen. Therefore, an immediately available, independent backup system (e.g., a different video conferencing software) is recommended to minimize any interruptions during the simulation session. This backup system can also be used as a communication tool to troubleshoot with the on-site simulation educator. Some video conference software packages also provide a toll-free international call-in phone number, which can be used as a back-up communication method.

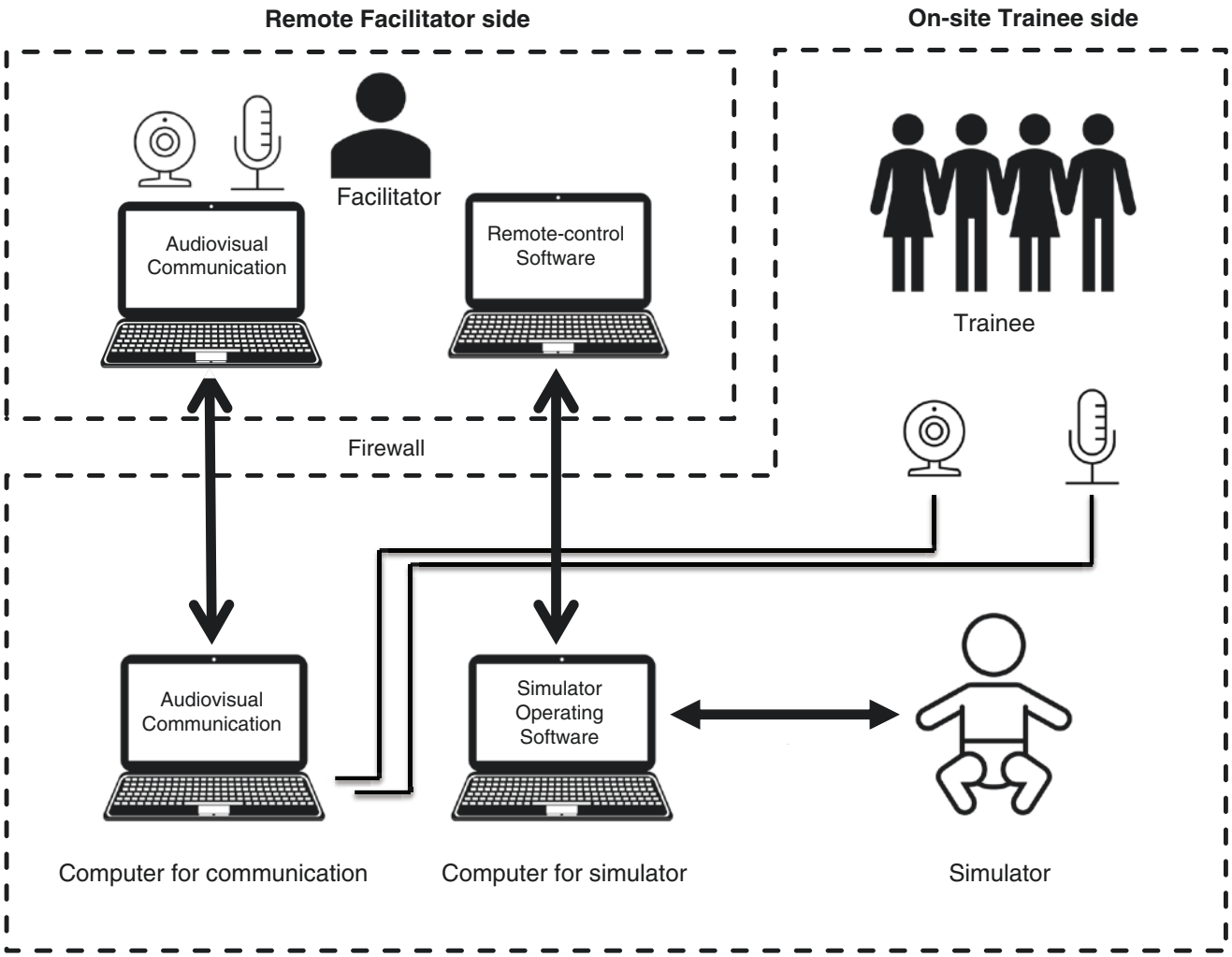

Fig. 13.1 Example of a tele-simulation system between two healthcare facilities in different countries. A free remote-control software (e.g., Teamviewer, GmRH, Germany) is used to control the simulator from remote facilitator site. A separate system is in place for bi-directional audiovisual communication

On-Site Simulation Environment

The on-site simulation room location, the materials of the room wall (e.g., sound-absorbing), and the location of the microphone and the video cameras in the room directly impact the audio and visual quality for both remote faculty and on-site learners. The speaker and microphone should be located so as to minimize reverberation or echo. To decrease the 'blind spot' of remote facilitators, two video cameras with different views are typically used.

Personnel and Training Needs for Tele-Simulation

Although theoretically possible, it is usually not realistic to expect 'simulation personnel free' conditions at the on-site tele-simulation training location. Preparing a simulator and necessary medical equipment as well as setting up local video cameras and microphones for bi-directional communication typically requires a dedicated person who has familiarity in both simulation and telecommunication systems. This process can be streamlined with standardized operating manuals once the system is developed. The personnel needed to operate a simulator during the session can be omitted if the simulator is remotely controlled by a remote facilitator and/or a scenario is pre-programmed. In a resource-limited setting, on-site learners can set up a simulator and a tele-simulation video camera and microphone, which eliminates the needs for a local facilitator.

Dry-Run

Dry-runs are essential to ensure the systems to run the simulations at both the remote and on-site locations work seamlessly. Many potential technologic and logistical challenges can be detected and mitigated during the dry-run, including issues related to internet connections as well as to the simulation environment. Audio and video quality are affected by the specificity of the computers, microphones, video cameras, and the internet connection quality. Institutional firewalls often block the remote control of the simulator and bidirectional video conferencing. This becomes complicated when a firewall exists in both facilitating and training institutions. Consultation with the information technology team of the respective institution may be warranted. The internet traffic may also affect the audio and visual quality, depending on the time of the day at both locations.

Simulation Structure

The overall simulation structure, including a pre-briefing, simulation, and debriefing, is not different from an in-person simulation. However, pre-briefings are even more critical before conducting a tele-simulation. During the pre-briefing, off-site facilitators can prepare on-site learners with the key points listed in Table 13.1 to prepare participants and optimize the learning environment, in addition to a standard orientation to simulators and the surrounding environment [16]. Alerting leaners to the limitations inherent in the audiovisual communication technology is essential to establish and maintain the learners' trust. Off-site facilitators may also choose to make on-site learners aware that non-verbal communication can be more challenging to visualize and recognize. In order to overcome this limitation, ensuring the facilitator's visual presence to learners and more explicit communication (i.e., address participants by name, paraphrase,

Table 13.1 Key pre-briefing points to optimize tele-simulation sessions

Pre-briefing item	Specific aspects of tele-simulation addressed
Make participants aware of limitation in audiovisual communication	Limitations in verbal and non-verbal communication and the off-site facilitator's limited visual fields need to be addressed by ensuring facilitator's visual presence to learners and more explicit communication
Help participants engage in tele-simulation environment	By exploring learners' experience in distant learning or telemedicine, participants may feel more receptive with tele-simulation approach. This step may help learners to enhance their sense of belonging to the tele-simulation exercise.
Ensure learner-centric approach is maintained	Due to limitations resulting from tele-simulation technology, facilitator-centric debriefing may occur. The facilitator can make both him/herself and learners accountable for maintaining participant-centric approach.
Help reduce learners' conscious effort	Limitations in audio and visual communication can be mitigated by optimizing audio and visual settings of teleconferencing system before simulation sessions. Communication technology platform can be challenging to learners. Orient leaners with the technology platform before the simulation. Ask learners to speak up when they don't clearly hear facilitator's questions or comments during debriefing. Inform leaners if the chatbox function in the teleconferencing platform will be used to supplement communication between facilitator and learners.

recap key comments) may be necessary throughout the simulation and the debrief [16]. To reduce on-site learners' cognitive load due to the "facilitator not being in the circle", an off-site facilitator may want to ask learners to speak up when they don't hear the off-site facilitator's questions or comments.

Uses of Tele-Simulation

Tele-Simulation as an Educational Intervention

Tele-simulation for education has been shown to be well-accepted by learners. Several studies have shown a learning benefit at least equal to that of simulations where the full simulation team- learners, facilitators, and debriefers are physically collocated. Otha et al. reported the effectiveness of tele-simulation in pediatric resuscitation training for medical students who were 1–2 years away from graduation [3]. Students were allocated to either tele-simulation or traditional on-site simulation and demonstrated a similar performance improvement in both groups. McCoy et al. conducted a feasibility study to evaluate whether an emergency medical services training course on mass casualty incidents for healthcare providers can be done by tele-simulation overseas [17]. After the course, all participants provided a favorable response to the survey regarding their thoughts, feelings, and attitudes toward learning via tele-simulation. Ahmed et al. evaluated the perception by emergency medicine trainees after remote or locally facilitated simulation. The perceived learning effectiveness was small but significantly lower in the tele-debriefing group using a validated debriefing assessment tool [5]. Authors attributed this finding to the difficulty in perceiving or using non-verbal cues through the tele-simulation system, inability to demonstrate hands-on skills, and inability to identify subtle actions performed during the simulation.

Christensen et al. performed a non-randomized study for newly graduated interdisciplinary healthcare professionals in Australia [18]. While the knowledge acquisition was similar in both tele-simulation and on-site simulation, learners reported the effectiveness was significantly lower with off-site facilitation. Table 13.2 summarizes the key themes identified that are relevant to tele-simulation. While the sense of realism may increase in tele-simulation, the participants' engagement with an off-site facilitator may be challenging. The off-site facilitator may have limited peripheral views and can miss a side conversation that may be distracting to participants or should be discussed as an important topic highly relevant to participants. Non-verbal communication becomes more difficult, and both facilitators and learners may have a higher cognitive load from their explicit verbal communication. In addition, off-site facilitators need to be aware of the difference in cultural expectations if they don't share the same background.

Table 13.2 Key themes identified through interviewing tele-simulation learners

Theme	Definition (by Christensen et al.)	Comments
Belonging	A feeling of being personally involved with the group and interacting with the instructor at a personal level	Leaners may have challenges to be personally engaged with instructor during debriefing.
Surveillance (Learner's sense of being monitored)	Low awareness of being observed	Learners may have challenges by sensing they are being observed through video cameras, while others report absence of instructors' physical presence make learners engage simulation more realistic way.
Realism	The similarity of the activity with real world environment	Learners may have challenges in suspending disbelief in tele-simulation. This perception may persist during debriefing.
Control of attention	Low awareness of non-relevant objects and events	Instructor may miss non-relevant learner's actions apart from the simulator or side conversations by learners.
Conscious mental effort	Low awareness of effort required to interpret a situation	Learners likely need to pay more attention to communication. Information exchange through non-verbal communication is likely to decrease.

Contents are adopted and revised from Christiansen et al. [18]

Tele-simulation can deliver highly standardized training to multiple learners across different institutions. In a multicenter study that implements a complex study protocol, unified high-quality staff training is required. A large National Institute of Health-funded Pediatric INsulin Titration (HALF-PINT) study utilized tele-simulation to train study coordinators on-site at participating intensive care units (ICUs) to increase patient and guardian consent rates for study participation [19]. In our recent study to implement a video laryngoscopy-assisted coaching for tracheal intubations in 9 neonatal ICUs, all neonatologist trainers at each neonatal ICU were trained (i.e., train-the-trainer) on-site using tele-simulation. The central core educator acted as a remote standardized trainee, and the trainer participant at each site practiced coaching through tele-simulation. The standardized trainee's profile view and video laryngoscope view were shared with the trainer during the session.

Tele-Simulation for System Improvement

Systems improvement in health care applies to systems engineering and risk management principles to improve patient care. The health care system is a complex adaptive system with many components with multifaceted interrelationships [13]. These components include work environment and workflow, processes and protocols, institutional context and financial pressures, organizational management, task factors, and technology infrastructure and interfaces [20]. Simulation can provide a medium through which patient care experiences can be created or recreated from actual cases, to systematically observe, modify, and evaluate the safety and quality of care delivery [21, 22]. A system-focused debriefing using a common system engineering conceptual framework (e.g., System Engineering Initiative for Patient Safety: SEIPS 2.0) is recommended for participants to elucidate predetermined stakeholder objectives as well as participant-identified issues [23].

Tele-simulation use for system improvement has not been well reported to date. However, many of the same benefits that tele-simulation provides for educational purposes can be leveraged for system improvement. Tele-simulation can bring the knowledge of a remote facilitator who excels in system-focused debriefing to the simulations. In addition, tele-simulation can bring the expertise of remote patient safety and human factors experts to local sites that might not have that expertise readily available. Healthcare facility construction now involves simulation-based space testing at various stages of construction from pre-construction (designing phase) to post-construction (readiness testing phase) [24, 25]. Consulting simulation experts to design and run the simulations can improve safe workflow and substantially cut costs by reducing the needs of reconstruction of the workspace. This simulation consultation process can involve both onsite simulation and tele-simulation to utilize expert opinions in the future.

Future Direction

Tele-simulation has become easier with recent technological advances and cost reduction in high-speed internet access and web-cameras. Tele-simulation will be more widely used with the appropriate approach taken to address its shortcoming. A hybrid approach using both an on-site and remote facilitator is one way to utilize strengths from both. Once a standardized system evaluation tool is developed, tele-simulation for system improvement will become readily available for new healthcare facility opening or relocation. Tele-simulation has distinct strengths in delivering a consistent simulation setting, scenario, and debriefing. Future work will involve rigorous multi-center evaluation of healthcare quality and safety, such as the hospital's ability to rescue acutely deteriorating patients.

Summary

Tele-simulation is an attractive solution for simulations when there are challenges to the co-localization of simulation equipment, personnel, and learners. Tele-simulation can remove geographic constraints to allow access to simulation expertise in areas where that is not readily available. Tele-simulation likely also will be shown to have other benefits compared to fully on-site simulations such as the ability to reach a broader and larger audience of learners while perhaps decreasing the high-demand resource of time from simulation experts. Dry-runs, pre-briefing with participants, and specific facilitator training for tele-simulation can optimize tele-simulation's effectiveness. Future tele-simulation applications will continue to expand and the technology will continue to improve as the potential of tele-simulation is realized.

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Planning Patient Care Areas Using Simulation

14

Anjali Joseph, Jennifer Reid, and James J. Kearney

Introduction

The built environment is a critical component of the healthcare system. It can promote or inhibit patient safety, quality and efficiency [1–3]. Latent risk factors in the built environment may directly impact clinical events such as falls, accidental removal of embedded medical devices (i.e. entotracheal tubes or intravenous lines), communication failures, medical errors, and infections [1]. It may also create conditions that lead to adverse events and delays in care [1, 4–6]. For example, the design of the emergency department may impact clinicians' visual and physical access to patients, inhibiting or promoting their ability to respond to emergencies in a timely manner [7]. The width of a hallway or doorway may prevent optimal patient and equipment movement, resulting in unintended extubations or decannulations during patient transfers [4]. Patient care spaces should enable the provision of safe, high quality and efficient care for patients, families and care teams. The healthcare facility design process provides a singular opportunity for designing spaces that promote safe and high-quality care.

Clinicians have deep knowledge of their work processes and challenges to delivering safer patient care. However, few are experienced in the facility design process. Most are challenged with translating architectural plans into a three-dimensional personal experience or understanding design options and limitations [8]. Architects and designers are able to creatively design solutions to meet the needs of multiple stakeholders while balancing structural requirements, as well as building codes and regulations. However, design teams may be less familiar with end user needs, processes and specific high-risk scenarios. Therefore, it is critical to involve clinical end-users in the design process, simulating real world patient care, and testing design solutions early in the life cycle of a project, when associated costs for modification are low and long-term impact on safety, quality and efficiency is high [9, 10].

Virtual and physical full-scale models of spaces, called mock-ups, are increasingly being employed by healthcare architecture firms and health systems while planning for new or remodeled patient care areas [11]. However, the approach to testing these mock-ups to obtain feedback varies. Walk-throughs and tours of mock-ups, while providing an overall feel of the space, may be ineffective or incomplete in helping users understand how the space actually supports their work. Simulations of clinical scenarios, including reenactment of common and critical tasks, in three dimensional models, allows end-users to provide detailed feedback about the functionality of a space, leading to design improvement [10–12].

Using Simulation for Planning Patient Care Areas

Simulation techniques, where users re-enact tasks and scenarios from clinical practice individually or in a team, have been used for a long time in the medical field for education and skills training [3]. These techniques are now increasingly being used during the healthcare facility design process to enable stakeholders to visualize how typical and high-risk clinical and operational scenarios would play out in a new space that is being planned, but does not yet physically exist [11]. A physical representation or model of the new space or

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unit called a mock-up is built and participants enact a range of scenarios to understand how that space would support their work [13]. The intent of these simulations, conducted during the facility design process, is usually to provide feedback to the design team about the layout and design of the unit so that design improvements can be made before the facility is built.

Peavey, Zoss and Watkins [11] make a distinction between experience-based simulation models and computer-based simulation models to indicate the level of immersion and interactivity possible as well as the type of model. Experience-based models are usually full-scale physical or virtual replicas of the space or spaces being evaluated and allow individuals to be in the space and to interact with the people and objects in the space, though the degree of interactivity and immersion might vary based on the model characteristics. Peavey, Zoss and Watkins define computer-based simulations as computational simulations where future outcomes and behaviors can be modeled or predicted based on past data input into the model [11] (examples are provided in Chap. 25).

Physical mock-ups are often made of cardboard, foam or plywood and may include simulated objects (e.g. cardboard box to represent a chair) or real objects (e.g. surgical booms). Physical mock-ups used during the design process can be of varying levels of fidelity (detail and realism in the mock-up)– ranging from those that use tape on the floor to demarcate spatial boundaries, to detailed mock-ups with realistic walls, real furniture, equipment and high-fidelity patient-manikins [14]. Figure 14.1 shows simulation underway at three different types of physical mock-ups – tape on the floor, cardboard and high fidelity – constructed as part of the design process for an operating room prototype [13]. Mock-up construction is typically overseen by the design team, whose expertise lies in translating plans into three dimensional spaces.

The overall scope of the mock up is determined by critical areas of concern. For example, in a new neonatology unit, stakeholders prioritized safety and efficiency for patients moving through the unit (e.g. hallways, vestibules, elevator shafts). The physical mock up included the patient transport elevator vestibule, hallways and a series of patient rooms. As one would expect, the costs of mock-up construction increase with the scope and fidelity of the mock-up. Given the relatively high costs of construction, high-fidelity mock-ups are usually built only for a small number of critical patient care spaces and often these are constructed later in the design phase once key design decisions have been finalized [14]. At this point in the process, these mock-ups are useful for making small design refinements and also for training and engagement of staff. These mock-ups can also be used to conduct research studies and experiments given the high level of realism in these environments [11].

Low fidelity cardboard mock-ups, on the other hand, are very useful early in the design process when design decisions have not been finalized and multiple alternatives may be up for consideration. These mock-ups are most effective if they are built to have flexible, movable and interactive components that allow simulation participants to move things around as they enact different scenarios and identify issues that need to be resolved [14]. Healthcare teams may choose to build a mock-up of a single space, a small number of spaces or even a whole unit based on the size and scope of the building project. Other than cost, the factor determining the feasibility of large-scale physical mock-ups is the availability of space to construct large unit mock-ups; an empty warehouse can be ideal. The ease of access to the mock-up is critical since simulation-based mock-ups require active participation from clinical teams and locating the mock-up in the same building or campus where the clinical teams practice is most effective [14] (see Fig. 14.2).

Experiential virtual models are usually constructed using a gaming platform and enable the participant to experience the healthcare space by being inside the space virtually [15]. Participants can use gaming controls to move around in the space or set of spaces though currently there are limits to the degree of physical movement possible in virtual environments [9]. There are varying degrees of fidelity in virtual

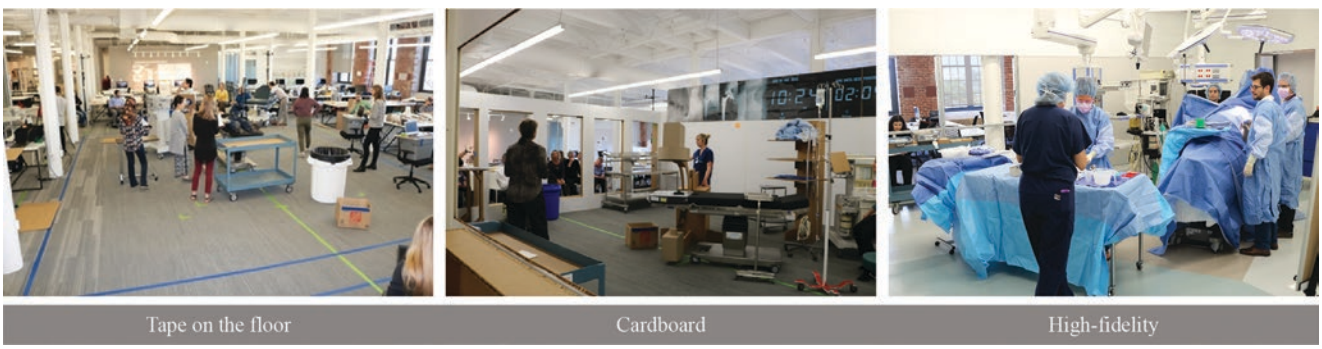

Fig. 14.1 Three different types of operating room physical mock-ups built at different points in the design process – tape on the floor, cardboard and high-fidelity

Fig. 14.2 (**a**) Low fidelity OR mockup in virtual reality; (**b**): Medium fidelity pre-operative room mock-up in virtual reality

mock-ups as well – ranging from simple environments with no interactive objects or people to virtual environments that provide highly immersive and realistic user experiences [15] where experiments can be conducted with increased ecological validity [16]. The costs involved increase with the level of interaction and realism desired in the virtual environment. Augmented or mixed-reality environments that combine aspects of virtual reality with the physical, tangible properties of a physical mock-up, offer interesting possibilities for simulation-based evaluation for planning patient care areas. However, these types of mock-ups are less common at this time due to technology and cost issues though that may change in the future.

Discrete-event simulation (DES) is a form of computer-based simulation that allows numeric modeling of a system as a discrete sequence of events in time [11]. In healthcare it is most commonly used to look at patient or supply flow patterns. DES is highly relevant in architectural design and operational planning. DES can dynamically model the changes to a system over time as a result of changes at different steps and can represent the results in real time numerically and/or visually as animations with figures moving and interacting in the model [11]. These types of simulations are particularly effective for modeling flow and outcomes related to efficiency, resource utilization, wait times and more. These models are data intensive and require a significant amount of time and resources to construct but can be highly effective for testing different operational and design scenarios. However, DES is not suitable for understanding the functioning of spaces from the perspective of individual users since the computational models are typically not immersive or interactive at the spatial level.

The type of model that is used (experience-based or computer-based) and the fidelity of the model determine the fidelity (level of realism) that is possible in the simulation as well as the types of design and planning issues that can be resolved using a simulation-based evaluation. For example, if the team wants to understand the impact of room size on adequacy of space for performing patient care tasks in an intensive care patient room, they would likely need to mock-up rooms of different sizes. They could then have participants enact typical and high-risk clinical scenarios in these alternative layouts to understand how the room would function when varying number of people and equipment are brought into the room. Constructing multiple high-fidelity physical mock-ups may not be feasible or necessary to answer this question of room size. Marking out the different room options using tape on the floor or with cardboard walls and then bringing in teams to play out how they would use the room in different scenarios provides important feedback. However, if the team wanted to find out how the placement of surgical booms affects the visibility of team members and displays in the operating room, they would need a high-fidelity space which included surgical booms, displays and other equipment.

The fidelity of the simulations impacts the types of design recommendations and feedback that may be generated by participants. Higher fidelity mockups and simulations results in more tangible design recommendations. Figure 14.3 shows the relationships between types of mock-ups, fidelity of mock-upsMock-ups, associated costs, and level of simulation fidelity possible, and provides examples of the types of information that can be obtained through evaluation.

Conducting Simulation-Based Evaluations of Patient Care Spaces to Support Innovation and Quality Improvement

The Health Quality Council of Alberta (HQCA) provides a framework for conducting simulation-based evaluations during the facility design process [14]. Some of the key strategies and steps for conducting simulation-based evaluations put forth in the HQCA framework and adapted in other studies [4, 13] are summarized in Fig. 14.4:

Identify design objectives to be evaluated One of the most important steps in using simulation to evaluate

Fig. 14.3 Types of mock-ups, associated costs, level of simulation fidelity and interactivity possible and types of questions that can be addressed

Fig. 14.4 Steps involved in conducting simulation-based evaluations of patient care spaces

mock-ups of patient care spaces is clearly identifying design objectives. For example, in a new neonatal intensive care unit, stakeholders identified key safety objectives: safety and flow of patients through the unit. Similarly, several design objectives were identified for the design an operating room prototype including reduce disruptions, improve movement and flow and reduce surface contamination [13]. These objectives then determined which spaces need to mocked-up and to what level of fidelity, specific scenarios that need to be tested and the participants and equipment that need to be included in the simulations.

Create scenarios Scenarios link objectives and clinical situations together into a cohesive experience for evaluators [17]. In the neonatal unit example, teams identified the objectives of efficient flow of staff and patients through the unit and good visibility of patients from nursing stations. In addition, stakeholders identified common situations: an admission, routine medication administration and daily respiratory care. High risk situations included: respiratory decompensation, intubation and CPR. These objectives and situations formed the building blocks of the simulation scenario: transport team admission, moving through the hallway, settling into a patient room, providing routine medications and respiratory care, followed by a respiratory decompensation requiring intubation. Participants evaluated the design's ability to meet their objectives (e.g. safety- risk for decannulation while maneuvering in hallway or transferring patient, line of sight visibility from nursing stations, and flow-number of trips for staff to acquire equipment, total distance patient travelled).

Identify simulation participant roles Conducting a simulation requires many roles. The simulation director oversees the event, much like the director of a play. The simulation director pre-briefs the participants, cues the scenarios and

participants as needed, leads debriefing, promotes design evaluation and keeps the event on track. The director probes participants with follow-up questions (e.g. tell us more about how many trips you took and to which locations). Ideally, the simulation director has a deep understanding of the clinical context that is being evaluated or collaborates with a clinical content expert. Simulation participants should represent the full care team for the clinical scenarios that are planned. In the neonatology example, participants included front-line nurses, physicians, respiratory therapists, transport specialists, unit clerks and unit technicians, each functioning in their normal role. Omission of frontline roles can inhibit effective evaluation of a design.

Clinical stakeholders can also play a supporting role in mock up construction: advising on or creating three dimensional models of equipment or bringing in real equipment for simulation. In the neonatal unit, it was the unit clerks who identified several line of sight limitations. Design experts (e.g. architects) provide expertise for design features, limitations and viable alternatives. Observers, or note takers, are crucial for witnessing and capturing issues. Observers may include stakeholder leaders, additional members of the design team or front-line staff. They should be provided plans, observation checklists and evaluation criteria [13]. During the scenario, observers may mark on design plans tight corners or bumpy floor junctions which could pose safety risks. During the debrief, observers captures the team's observations in the evaluation template. Support staff should be assigned to collect and document a master set of all evaluation findings immediately following the simulation so that the design team can refer to these suggestions while making changes to the design.

Plan the simulation event Prework includes the development of an overall schedule and plan for the day, identification and scheduling of participants, observers, design experts and support staff, including back-filling of clinical roles. Simulation director and observer packets need to be prepared, equipment lists developed and assigned, and consideration and planning for photography or video of the simulation to share learnings with those not present.

Coordinate and run the simulation Simulation starts with an orientation. Most participants, observers and designers have not participated in a simulation focused on design evaluation. Orientation introduces the goals, roles, enactment process and process for design evaluation. Participants and observers are reminded to share their input out loud during debriefs and to record all evaluations. Design experts orient participants to the mock up, answering questions that will promote a more robust evaluation and provide safety information. The simulation director, potentially assisted by simulation facilitators, identifies starting locations for participants and observers, and commences scenario enactment. Participants and observers frequently need prompts to maintain scenario progression. At breakpoints during scenarios (e.g. after the transport patient arrives in the hospital room) and at the end of each scenario, the simulation director, and or simulation facilitators, request feedback and explore issues, particularly in alignment with evaluation metrics. The overall schedule for the simulation-based evaluation should account for time required for the interviews and debriefing session as well as time required to switch out the physical or virtual model between design options.

Build design alternatives for evaluation The opportunity to do back-to-back evaluations of different design options in a mock up, whether physical or virtual, is unique. Prior to the simulation, the simulation director and design experts should agree upon the logistics of altering the mock up to support evaluation of multiple design options. In the neonatal unit evaluation, there were two potential layouts being considered. Prior to lunch, all scenarios were simulated in design A. During lunch, the design team swapped the mock up to design B. After lunch, all scenarios were simulated in design B. On a smaller scale, two different patient room layouts were being considered. The design team mocked up both. The participants ran the same scenario in room A then room B. More fluid design modifications can also be supported in real time. In the neonatal unit, one narrow hallway corner posed a risk for decannulation. Design team members examined the plans, determined that the corner could be widened and rounded, then modified the cardboard wall, allowing the participants to validate the safety of the new design within the hour. Similarly, to evaluate multiple options within the same mock-up, a team working on an operating room prototype constructed the mock-up out of prefabricated carboard modules that were assembled on site. The mock-up contained components such as walls, storage, scrub sinks and doors that were fixed using Velcro and could be relocated easily to facilitate testing of multiple design options [13]. Figure 14.5 shows how a door in an OR mock-up was converted into a wall with a window and scrub sink using modular cardboard elements. This facilitated easier transition between different design options and resulted in time savings during simulation.

Evaluate design alternatives Evaluation of a design's safety, quality and efficiency includes participant and observer assessment using objective evaluation criteria as well as subjective evaluation via interviews and focus groups. Evaluation metrics included in the neonatal intensive care unit evaluation that were related to the objectives of safety included: risks for accidental decannulation/extubation, line-of-sight visibility

Fig. 14.5 Using a modular wall to test design alternatives in a cardboard OR mock-up

of patients at all times and distance traveled, for the patient and staff. Similar objective metrics should be developed based on specific design objectives for the simulation. In addition to these objective metrics, the simulation director and facilitators promote deeper understanding of issues and potential solutions during debriefs. Participants may have varying levels of comfort sharing their observations out loud and some discussions can be dominated by individual perspectives. Individual surveys- written or electronic, or individual interviews- may provide a more robust evaluation of the design. Focus groups, composed of the design team and participants may need to meet to discuss, problem solve, redesign and validate proposed changes. As part of the planning process, structured tools should be developed for conducting interviews and focus groups as well as checklists for collecting observational data focused on the specific design objectives for the session. Bayramzadeh and colleagues [13] describe a range of tools developed during a simulation-based evaluation of an operating room including a simulation director's guide, observation checklist and interview protocol. These tools could be easily adapted for other simulation-based mock-up evaluations based on the specific design objectives, scenario and setting under consideration.

Develop design recommendations Team members should be specifically assigned to collating and organizing all input from the design event and presenting the findings in the form of design recommendations, so that stakeholders and the design team can validate which portions of the design are moving forward and which areas need revision and retesting. Stakeholders, simulation directors and the design team should anticipate and plan for additional validation of significant design changes or focused design challenges. Most simulation-based mock-up evaluations identify design challenges that need more work.

Benefits of Conducting Simulation-Based Evaluations during the Facility Design Process

Simulation-based evaluations of proposed patient care spaces allows teams to revise and refine a unit or room design before it is built or remodeled. This helps ensure that when the space is actually built or remodeled- things are right, avoiding significant expenses related to 'fixing' problems and the associated disruptions to patient care. Further, the engagement of front-line clincians in the process facilitates staff buy-in for design changes and makes the transition to the new environment easier. For example, at the University of Pennsylvania Health System, a 30,000 square foot mockup was built and evaluated with 100 staff members participating in simulations. This was initiated as part of the design process for a $1.5 billion new hospital pavilion scheduled to open in 2021. The simulations resulted in a completely different floor plan and building exterior. This knowledge was gained at a cost of about 0.5% of the total cost of the building [18].

Average new hospital construction costs in the United States in 2016, excluding equipment, was about $400 per square foot. In New York City, average costs of hospital construction were about $1200 per square foot [19]. Regulatory hurdles in healthcare meant to ensure safety can also create long timelines for approval and revisions prolonging the design process. High construction costs and the complex regulatory approval process in the US magnify the importance of getting it right the first time. The economics of simulation during the design process can be further justified in light of the consequences of design mistakes that would otherwise be appreciated only after occupancy. This is especially true for high-risk clinical spaces such as patient rooms and operating rooms that are not only expensive to build but are constructed multiple times in a healthcare facility. The

impact of poor design decisions would also be multiplied as many times. For example, a badly designed patient bathroom may make it hard for staff to help a patient during toileting, contributing to staff and patient injuries. Any renovations to the bathroom post occupancy would be extremely expensive and cause disruptions in care.

Since 2012, Medicare payments [20] are based in part on patient satisfaction scores on the Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) survey. Medicare and commercial insurance companies now also use "pay for performance" incentives and penalties. Well executed facility design can drive hospitals to financial stability in this new payment model if the space provides a positive patient experience and reduces adverse events such as falls and infections. Simulating patient and staff flows in mock-ups can help the organization create a positive patient experience and correct safety deficiencies at an early stage.

Simulation also allows for a democratic process in the design of new facilities. Staff from multiple different departments, and the full range of the healthcare team, can participate and have their voice heard to suggest changes in their future workplace. The ability to allow all levels of future users to participate in the design process promotes engagement and a culture of respect. Going through a simulation experience uncouples the attendees from their job pressures (patient needs, having to stay on schedule) and allows them protected time to be thoughtful about their job duties, reflecting on how they can improve their workplace. For new designs to be successful, changes to processes and culture may be required. Participation in simulation-based evaluations helps staff to not only contribute toward design changes but also understand how their own tasks might change in innovative new spaces. The experience facilitates staff transition to the new facility and creates leaders who may help to train and transition other staff members.

Conclusion

Simulation has the potential of significantly contributing to the design of safer and higher quality patient care spaces when conducted during different points in the healthcare facility design process. The process is most effective when design objectives are clearly outlined and detailed scenarios developed to test how the space performs. Simulation-based evaluation requires coordination of schedules of multiple stakeholders including busy clinicians. When these simulations are planned thoughtfully and run efficiently, they can help in engaging clinicians and creating excitement about the project throughout the organization. It is also important that the team systematically evaluates the design options that are under consideration and documents findings such that they lead to iterative design improvements and new innovations. Simulation with active participation from multidisciplinary stakeholders can be incredibly helpful to identify design challenges and develop design innovations.

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Exploring New Hospital Patient Care Spaces Using Simulation

15

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Exploring New Hospital Patient Care Spaces

Simulation is a widely utilized methodology for the education and training of healthcare providers. Now more than ever, its application has expanded beyond that of purely educational activities; simulation has become a method for improving patient safety, quality, and patient care. The utilization of simulation as a tool to improve clinical systems of care, *systems improvement* is under-utilized within the simulation field [1]. With a systems improvement approach, simulation becomes a powerful patient safety tool to help prepare new hospital environments for patient care. The rationale for using simulation in the post-construction phase, but prior to opening, is that it can assist with identification of needed personnel, potential clinician educational needs and gaps, ideal systems of care and workflows, and the optimal types and number of equipment and supplies for safe operation of the new patient care area before bringing patients into the environment.

Healthcare organizations can use *post-construction simulation-based activities* to help prepare for opening a new hospital environment in five main ways that can be done sequentially and sometimes simultaneously:

1. *Plan for transition to a new space:* Simulation may be used to orient staff and prepare for activation of the new clinical environment, preparing them for new workflows and care processes, equipment, and spatial layout.
2. *Improve operations:* Simulation provides a test bed to trial and refine new workflows prior to implementation, ensuring that processes, equipment, and systems work best in the new clinical environment:
3. *Identify latent safety threats:* Simulation provides a safe method to uncover hazards before they harm an actual patient.
4. *Enhance patient experience*: Simulation with actual patients and caregivers, or trained actors, can provide valuable insight into how a new clinical environment affects patient satisfaction and safety to enhance the patient and family experience.
5. *Prepare for special circumstances*: Simulation offers a unique ability to help improve preparation for rare, but high-risk, situations (e.g., mass casualty or natural disaster) with regard to management of clinical space and novel workflows.

The goals of this chapter are to discuss ways simulation can support a safer opening or ongoing operations of a new clinical environment and to review some of the specific methodologies and technology to consider in post-construction simulation.

Applications

The process of developing and implementing post-construction simulation will vary depending on the primary goals of the project. For all post-construction simulation projects, success requires thorough planning. Similar to other simulation endeavors, performing a needs assessment, creating a project plan with deliverables, implementing the plan, and monitoring outcomes are key. The content of the simulations, debriefing strategies, and overall project planning must be geared towards the goals identified during the needs assessment process. This section reviews several types of projects where post-construction simulation may be of value.

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Plan for Transition to a New Space

The act of moving into a new space is no small task and requires transition planning to ensure that move day goes smoothly. Transition planning may be thought of as having two distinct components: (1) preparing staff for new workflows and other changes they can expect in the new physical space, and (2) preparing for and executing the actual move day and activation [2].

Prepare for New Workflows and Environments

Simulation is an educational tool and thus can be a great way to orient and train staff for care in a new clinical environment. While there is no standard approach for preparing and training interprofessional healthcare staff on how to work in a new clinical environment, simulation provides a potential tool to enhance this process [3]. The move from one facility into a new one can be stressful for all involved, with staff benefitting from the ability to orient and train in the physical space in which they will be using new equipment, technologies, workflows, and processes of care prior to opening [4–6]. Input for these simulations will require input from the workers on what constitutes "routine" and "non-routine" clinical work, which will also inform the timeline and structure of the simulations needed.

Prepare for Move Day

Opening a new healthcare space is both exciting and challenging. Staff may look forward to it if they perceive benefit in design or improvements in the new space. However, people may resist change for numerous reasons. Berry and Parish [7] demonstrated that the act of moving to a new facility is sometimes associated with lower staff satisfaction and retention. Staff members must not only become familiar with the new work environment and unfamiliar processes, but within the inpatient setting, staff members are also responsible for moving patients safely and efficiently from the old space to the new environment, which is no small task. This move requires extensive planning. Medwid and colleagues [8] demonstrated that the majority of over 100 staff members who participated in simulations viewed post-construction conditions favorably. Those staff members viewed simulation as an effective way to prepare to move into their new emergency department. However, participants did not experience lower stress during the first week of occupancy than staff who did not participate, as anticipated. When healthcare staff members understand their shared needs, moving to a new facility becomes less daunting [9]. Move planning provides an opportunity for staff to rally around their shared vision. See the steps for planning a large move using simulation in Table 15.1.

Table 15.1 Preparing for move day[a]

Target	Activity
1 year prior to mock move day	**Complete a move day plan.** Due to the complexity of transitioning to a new facility/space, some healthcare organizations hire consultants who specialize in developing these plans.
9 months prior to mock move day	**Develop** simulation **scenarios** and exercises. Multi-disciplinary, informal tabletop sessions led by a facilitator allow staff to review the scenarios, identify "what if" events, and plan how to address possible complications.
6 months prior to mock move day	**Simulate** patient move activities **weekly** for several months leading to the move using a variety of scenarios. Time each simulation. All staff members involved will provide feedback during formal de-briefing sessions after each simulation to inform decision-making and the identification of needed follow-up.
1 month prior to mock move day	**Identify** additional staff members to serve as **mock patients** during the simulations.
1 month prior to mock move day	**Secure equipment** (e.g., stretchers, wheelchairs, IV poles) needed for simulated moves.
1 month prior to mock move day	**Prepare** for at least one **emergency station** with necessary staff, equipment, and supplies in case patients experience complications during the move from the old to the new space/facility. Consider locating a station at the half-way point.
1–2 months prior to *actual* move day	**Hold** an institution-wide **mock move day** (using volunteers and/or mannequins as mock patients).
Within 1 week of completing mock move day	**Revise** the **move day plan** based on patient and staff feedback from the mock move day. Communicate changes to the plan effectively to staff.

[a]Compiled from concepts in Comeau et al. [2]

Improve Operations

Prior to occupancy of a new facility, hospital administrators need to ensure that their buildings are designed and operate as envisioned. Simulation tools enable them to test how processes will work and where risks to quality of care may lie. By practicing major flows and processes, such as patient registration, transfers, discharge, and admission, in both normal and emergency situations, healthcare organizations can identify potential failure points. They can then develop strategies to address the failure points either through staff training, process change, or facility alteration. Healthcare organizations may identify operational risks, such as neglected steps in the workflow, staff's unfamiliarity with new, complex technologies, insufficient wayfinding signage, or potential risks for electronic data loss. In response, operational improvement plans, such as adding patient flow measures, training programs, or technical assistance, may be planned to better prepare the staff.

When implementing simulation for operational improvements, taking a Plan-Do-Study-Act (PDSA) cycle approach can provide a framework for more rapid solution finding. PDSA methodology is a classic quality improvement approach that involves planning for a change/improvement, doing or implementing the change, studying and evaluating the impact of the change, and acting to implement the change or perform further cycles of change for continuous improvement [10]. By utilizing simulation as a tool for performing PDSA cycles related to new work environments and new or modified operational processes can be vetted in a safe way that doesn't involve tests of change during actual patient care.

Identify Latent Safety Threats

The Agency for Healthcare and Research Quality has recognized a link between hospital or clinical environment design and actual patient care outcomes and safety [11]. Latent safety threats are hazards in design, organization, process, training, or maintenance that remain hidden until negatively affecting an actual patient. Latent safety threats may contribute to medical errors and have other adverse effects on patient and provider safety and satisfaction. When a new hospital environment is built, new workflows, equipment, healthcare teams, facility layout and design, and systems of care are developed with the best of intentions. Sometimes healthcare designers and other decision-makers can miss unintended latent safety threats during the development of these new hospital environments. Simulation, when implemented as a clinical system test post-construction, but before opening, provides a safe and realistic mechanism for uncovering these latent safety threats by recreating high risk, rare, high volume, and/or routine patient care scenarios in the new environment.

Simulation-based clinical system testing is a newly developed robust process improvement tool that can proactively test complex systems (people + physical environment + processes) involved in new patient care settings. The goal of performing clinical system testing with simulation is to identify potential latent safety threats in our hospital systems and environments with simulation before they could reach actual patients or hinder patient safety. Involving front-line personnel in clinical simulations aimed at stressing systems applies at least three principles of high reliability organizations (HRO): preoccupation with failure, reluctance to simplify observations and interpretations, and deference to front line expertise [12].

Studies demonstrate that hospital and other clinical environments interact with healthcare providers, processes of care and workflows, patients, equipment, and technology in ways that can positively or negatively impact patient safety [13]. Despite this fact, it is not commonplace to evaluate hospital layout and design for potential flaws during and after design and construction. New healthcare facilities are a high-risk endeavor because of the potential for latent safety threats such as missing equipment or not having enough space to perform certain procedures. Published literature has demonstrated that using simulation before opening a new healthcare space is effective for identifying latent safety threats. In 2012, the Agency for Hospital Research and Quality (AHRQ) recommended that hospitals engage in simulation early in the design phase to identify and prevent design related threats to safety such as hindered patient visibility, lack of room standardization, lack of noise reduction measures, provider fatigue, and more [14]. In their report, the agency recommended that healthcare organizations implement simulation throughout the construction and post-construction phases.

Simulation is being used as a tool for identification of latent safety threats in preparation of opening new hospital environments in almost all clinical areas, from new emergency rooms to ambulatory clinics, from inpatient units to entire hospitals [6, 15, 16]. Geis and colleagues [6] conducted both laboratory and in-situ simulation before opening a new pediatric emergency department, and participants identified 37 latent safety threats, mostly related to equipment or the allocation of resources. Simulations were video recorded, and team behaviors were scored using the Mayo High Performance Team Scale. Each staff member's perceived workload was evaluated after every simulation; then, participants engaged in debriefing sessions led by trained facilitators utilizing the video recordings to identify and attempt to mitigate latent safety threats. In another study, Medwid and colleagues [8] found that staff identified 35 latent safety threats during 15 simulations conducted over a one-day period. Some of these threats were facility-specific, such as monitors mounted too low, which could be corrected before the new emergency department welcomed actual patients. More recently, Colman and colleagues [17] utilized simulation to evaluate for latent safety threats post-construction for a new outpatient facility, identifying over 300 latent safety threats in 15 different ambulatory clinics prior to opening.

Thus far, a growing number of case reports have demonstrated the feasibility and successful proactive use of post-construction simulation-based clinical system tests to identify potential latent safety threats in new hospitals, labor and delivery units, emergency centers, ICUs, ORs, and outpatient care facilities [15, 18–21]. The rationale for using simulation in the post-construction phase, but prior to opening, is that it can assist with identification of needed personnel, potential clinician educational needs and gaps, ideal systems of care and workflows, and the optimal types and amount of equipment and supplies for safe operations of the new patient care area before bringing patients into the

environment. Additional benefits include an opportunity for providers to learn how to function in their new environment, enhance their ability to get to know their co-workers, and develop teamwork in newly formed teams.

Enhance Patient Experience

Post-construction simulation can be used to understand how patients, including those with special needs or conditions, would experience a newly constructed space. Here simulations are targeted at enhancing the patient experience, patient engagement, and ultimately patient care outcomes in the new clinical environment. Standardized patients (i.e., patient actors) with specific conditions may be brought in to participate in simulation exercises to assess how well the facility provides for their needs. For example, standardized patients who use walkers and wheelchairs may be involved in exercises simulating a visit to the emergency department to identify problems such as inadequate circulation space in the waiting area. Or, standardized patients experiencing visual decline may notice small fonts or insufficient contrast on directional signage. Actual patients or patients' family members can add invaluable perspective. Table 15.2 lists some design-related questions that may be addressed during post-construction simulation exercises to improve the healthcare experience of all types of patients.

Table 15.2 Design considerations for persons with special needs or limitations

Conditions	Examples of design considerations
Mobility impairment (e.g., persons using assistive devices such as canes, walkers, and wheelchairs; persons with Parkinson's disease)	Are doors wide enough for a person in a wheelchair and their needed equipment to pass through? Are handrails available? Is there seating in long corridors for patients who may need to rest along their path? Does seating have arms to support persons who may have trouble getting in and out of seats?
Visual impairment or disorder (i.e., persons with low vision or blindness)	Is the font size on signage large enough? Does contrast on the floor clearly indicate level changes? (high contrast between 2 flooring types may appear as though there is a level change where there is none; contrast on steps or stairs may heighten awareness of level changes) Is there sufficient contrast between the toilet and the floor? Is there sufficient contrast between the floor and the walls?
Cognitive impairment or disorder (e.g., Alzheimer's disease, autism spectrum disorder, Down's syndrome)	Are the patterns in flooring materials subtle enough so as not to confuse patients? Are there icons on signage to assist persons who cannot read?
Behavioral/mental health conditions (e.g., depression, anxiety, schizophrenia, substance abuse disorder)	Are items that could be used for self-harm properly managed? Does the environment afford patients the ability to choose whether or not to informally interact with other patients and visitors? Are there positive distractions (e.g., artwork, interactive displays, access to nature) to help reduce anxiety?

Prepare for Special Circumstances

Post-construction simulation conducted after a facility has been occupied may be helpful in assessing how well an existing environment will perform during an unexpected natural disaster, infectious disease outbreak, terrorist attack, or other type of mass casualty incident. Coordination with representatives from the local municipality in the development of simulation scenarios and participation in simulation exercises, including assessment of the team's response, can lead to the identification and implementation of strategies to enhance performance should a real incident occur. This type of simulation is common across the United States. For example, Tampa General Hospital (TGH), in Tampa, Florida, participates in a large-scale, county-wide mass casualty drill each year. The scenarios selected are intended to evaluate the hospital's emergency operations plans. These simulations also provide an opportunity to assess how well the designed environment could perform under catastrophic circumstances. TGH's emergency department opened in 2007 as part of a health pavilion designed by Gresham Smith. Designers implemented several innovative strategies in the emergency department to improve its ability to withstand and respond to a major event. For example, the glazing is hurricane resistant, and the emergency department is located on the second level, rather than the first, in case of flooding. Should the need arise, approximately 200 locked medical gas cabinets located in patient rooms, corridors, administrative areas, and public spaces can be unlocked, only with permission from the State of Florida, quickly tripling the capacity of the emergency department. In the garage, located below the emergency department, there is a large decontamination shower and marked areas that can be used to triage a large number of patients at once. With a different scenario simulated each year, there have been many opportunities to identify changes that healthcare organizations may need to make in terms of resource allocation, workflows, and the physical environment to better support emergency care on a large-scale.

Methods for Developing and Implementing Post-construction Simulation

To create post-construction simulation projects requires a significant amount of planning and project management. Healthcare organizations must start as early as possible to achieve the identified goals. This section addresses key elements to planning and implementing a successful post-construction simulation project.

Simulation Project Planning

The key steps for planning a simulation project are presented in Table 15.3.

Performing a Needs Assessment

For a large-scale project such as a post-construction simulation endeavor, performing a needs assessment is a critical early step. Results of the needs assessment help determine the primary goals for a post-construction simulation project and guide project planning A systematic approach to prioritizing goals for post-construction simulation projects provides a strategic way to plan within the confines of resources available. A formal needs assessment will be necessary prior to implementation to assist in prioritizing patient care scenarios and areas in which to implement the simulations. Additionally, the formal needs assessment will provide valuable insight for important issues to address and discuss during debriefings. Results of the needs assessment should drive the development of simulation scenarios and the overall framework for the project.

There are many ways to perform a needs assessment. Needs assessment sessions are best performed with a variety of providers and staff: front line clinicians, clinical and administrative leaders, quality/patient safety experts, biomedical engineers, technology/communications experts, facilities, and patient and family representatives, among others. Methods for performing a needs assessment can include, but are not limited to:

- Surveys: Sending surveys to stakeholders, clinicians, and leadership can be an easy way to identify simulation priorities. Limitations can include vaguely worded questions resulting in inaccurate responses, poor response rates and difficulty understanding the scope of responses without an in-person dialogue.
- Brainstorming Exercises: In person brainstorming sessions can allow more robust discussion from all stakeholders on the goals for post-construction simulation activities. The intent is to identify what processes, clinical scenarios, patient care areas, and concerns would benefit most from simulation. Methods such as performing a SWOT analysis (Strength, Weaknesses, Opportunities, and Threats), KJ Merlin Exercise, or use of Audience Response Systems during large group meetings can be used [22, 23].
- Change Management Exercises: In person meetings with focused exercises can be used to identify high risk or high impact scenarios suitable for simulation [24].

Table 15.3 Steps for planning a simulation project

Steps	Comments
Perform a needs assessment	The needs assessment will drive the goals for simulation and help determine the scope of the project.
Identify key stakeholders	It is critical to engage stakeholders early on for success of the project.
Develop a simulation project plan	Create a project plan and timeline based on available resources and the goals of the simulation project.
Develop simulation scenarios	Create scenarios based on the goals of the simulation project and the type of new hospital environment being evaluated.
Determine simulation methods	Identify the appropriate simulation technology and type of simulators based on functionality needed to achieve the determined goals.
Develop a debriefing plan	Develop a plan for debriefing to ensure gaining the most information out of the project.

Identifying and Engaging Stakeholders

The success of post-construction simulation rests heavily on the composition and active participation of healthcare staff and other key stakeholders. The first opportunity to engage staff and other stakeholders happens during the planning and design of a new facility/space. Staff participation in the design phase has been associated with improved staff preparedness for a move and higher overall satisfaction with the new facility [25]. Staff members involved in the design process will have some understanding of the rationale behind certain decisions and the trade-offs that were made to accommodate budgetary or other resource constraints and, therefore, often provide more valuable insight during post-construction simulation if involved earlier in the process. The current reality, however, is that there are many challenges associated with engaging a wide variety of healthcare staff in the design process. For example, it may be costly to compensate front-line staff for additional time needed to participate in user group meetings, and healthcare organizations may be hard-pressed to find qualified clinicians to provide patient care in their absence.

The composition of a simulation team might include representatives from each of the participant groups listed in Table 15.4. The extent to which team members actively participate or simply observe will vary depending on the pur-

Table 15.4 Recommended participants and their roles in post-construction Simulation

Participants	Examples of potential contributions to post-construction simulation exercise(s)
Executives/ administrators	Provide vision and leadership Ensure that new space supports the organization's mission Provide resources (e.g., financial, personnel) required for needed modifications before or shortly after the move Address and resolve latent safety threats identified during simulation
Managers	Serve as the central point of communication with simulation team members Recruit participants for simulations Identify simulation objectives and outcomes of interest Lead simulation exercise(s) Ensure participants are compensated for participating, as appropriate
Clinicians and clinical staff (e.g., physicians, nurses, physician extenders)	Develop realistic scenarios for simulation Participate in simulations and recommend improvements to processes and/or the facility to minimize latent safety threats
Allied health professionals (e.g., pharmacists, social workers)	Participate in simulations and identify barriers to effectively performing their duties (e.g., malfunctioning pneumatic tube system; insufficient space for private conversations between patients and social workers)
Staff (e.g., unit clerk, receptionist)	Participate in simulations and identify barriers to efficient patient flow and effective staff communication
Operational effectiveness experts (e.g., system or human factors engineers)	Develop simulation models Test what-if scenarios Recommend modifications to patient care processes
Facilities personnel	Determine whether environmental systems are operating as intended Complete or contract for space modifications, as needed
Environmental services personnel	Suggest procedural or facility changes that might reduce room turnover time Identify barriers to effective infection control procedures
Patient and family representatives	Describe the patient experience during simulation exercises and recommend process or facility improvements
Quality and patient safety leaders	Participate in the development of the simulation priorities Provide content expertise
Representatives of the local municipality (e.g., elected officials, first responders)	Assist in the development of disaster-related or other types of surge scenarios Evaluate a healthcare organization's response to a simulated event

pose of the simulation exercise(s). Developing a steering team early on will help create the vision, remove barriers, and provide oversight for post-construction simulation projects.

The first step in developing a simulation team is to involve the right people. It is also vitally important to demonstrate that each team member's specific expertise or perspective is valued and recognize that their contributions are critical to the success of the simulation activities. Each team member's time is valuable, so leaders must run meetings and other activities associated with simulation as efficiently as possible. When team members are pulled from their regular work duties to participate in simulation exercises, it may be necessary to ensure that other qualified persons can provide appropriate coverage until team members return. Finally, ensure that follow-up communication about the results of the simulation activities and any decisions that were made based on those activities occur as swiftly as possible.

Tips for Successfully Engaging Simulation Team Members

- Involve a wide variety of participants in planning and design of new space and simulation exercise(s);
- Communicate importance of simulation exercise(s) from the highest level possible;
- Recruit respected stakeholders and avoid appointing people;
- Document simulation exercise(s) using audio and/or video recording;
- Document and value participants' observations and recommendations, though not all suggestions can be implemented;
- Thank contributors for participating;
- Follow-up with participants about changes resulting from simulation(s).

Developing a Simulation Project Plan

With any large-scale project, it is important to remain punctual and on task when developing a project charter or plan. A developed plan can help ensure the goals and scope of the work to be done and can create a plan for the steps needing to be accomplished. There are many project management tools available that developers can utilize to create a project plan. Whether taking an agile, traditional, or six sigma approach, creating a project plan is critical as most post-construction simulation projects involve many steps with significant complexity and resources. The type of project plan used will typically depend on the organizational and post-construction simulation goals, stakeholders, and resources available. While it is not within the scope of this chapter to discuss project planning, we recommend working with an expert with project management skills for post-construction simulation activities.

Creating and Designing Simulation Scenarios

The needs assessment will drive the content for simulation scenarios. In general, each scenario will need to be created based on the goals of the project. Creation of the simulation scenarios involves identification of the flow or expected "story-board" for each simulation. It is helpful to adopt and follow a standardized template that includes all the vital information needed to implement a scenario. These include patient information and history, equipment and supply needs, expected list of participants, and expected actions of the participants with corresponding changes in the simulators' vital signs. Most importantly, each scenario should include the "objectives" of the simulation. For educational simulations, these would be the learning objectives typically broken down into three domains: cognitive, technical, and behavioral. For evaluation of latent safety threats or systems integration simulations, these would include "testing" objectives broken down into categories such as process of care objectives, facility/design objectives, and roles and personnel objectives. Each simulation session should include expected actions of the participants that provide an opportunity to meet the previously identified patient care goals from the needs assessment. A well-designed simulation scenario meets the objectives.

Consider different scenario flows depending on the intended purpose of the patient care space. For example, in a new ICU, one might run multiple simulation scenarios simultaneously to create the complexity of a virtual unit containing many patients. In contrast, to prepare and evaluate an entire new hospital, one might create a series of sequential scenarios following the trajectory of a single simulated patient as a "day in the life" format, with stop and restart debriefings as the patient moves from one patient care area to the next. The decision of how to structure the simulation scenario flow should be based on the objectives of the project, with the intent to recreate patient care similar in nature to actual patient care in that new environment.

There are three main categories for simulation structure that can be considered:

1. Discrete Scenarios: Single, independent simulations are shorter and are appropriate when training staff to a new room or smaller location. For example, if opening a new intraoperative MRI suite, one may only need individual simulation scenarios to help orient staff to the new space, equipment, and workflows.
2. Virtual Unit: A partial or full unit can be set up with simulated patients (mannequin or actor type) and with a fully operational staff including physicians, nurses, and other ancillary staff. Scenarios typically include both routine patient care and emergency situations. For example, if opening a new neonatal intensive care unit with multiple pods, one might simulate one pod, fully staffed as planned, with each room in the pod having a simulated patient and a scenario for the staff to care for.
3. A Typical or Worst Day in the Life: Following a single simulated patient (mannequin or actor) through a series of locations provides a method for evaluating multiple patient care spaces in one session, typically lasting a half to full day with intermittent pauses for debriefing. For example, in opening a new community hospital, one might follow a simulated patient arriving in the emergency room, being transferred to the operating room, then recovering in the recovery room, and ultimately being transferred and cared for in an inpatient floor or ICU.

Identifying Simulation Methods

An important part of planning and executing post-construction simulation in a new healthcare space involves choosing the most appropriate simulation methods or tools to achieve your specific objectives. Four commonly used approaches to post-construction simulation include virtual and augmented reality, systems modeling, and utilizing virtual patients (e.g., mannequins) or trained actors (i.e., standardized patients) in simulated scenarios.

Virtual Reality/Augmented Reality

As a major part of the recent digital health revolution, interactive computer-based simulation tools have been used by hospitals for medical training, casualty management, pain management, patient experience improvement, and transition planning. Interactive computer-based simulation is a technology that allows a user to interact with simulated environments that include auditory and visual elements and sometimes other types of sensory feedback such as haptic and olfactory. Augmented reality (AR) and virtual reality (VR) are the most rapidly advancing interactive simulation techniques. While AR allows for adding digital elements into the actual environment by layering virtual information over a live camera, VR creates a multimedia immersive experience. These two technologies can co-exist in one system called mixed or hybrid reality.

Although design companies use VR or AR mostly in the design development phase to facilitate communication of ideas with clients, these technologies can also be used during orientation to the new hospital environment. Hospital personnel donning the virtual reality headset can walk into an immersive three-dimensional environment and find their way to different locations. For this purpose, the level of fidelity can be determined by the spatial attributes of the environment and available resources. What is important is that the scenario makes sense to participants and they can adequately perceive the realism of the expected situation. As a result, once the facility starts operating at full capacity, they can locate,

access, and use spaces, equipment, and systems without delays or adverse events and with minimal risk of error [26]. To facilitate operational readiness before opening the new facility and to minimize the interruption in delivery of care, the Ann & Robert H Lurie Children's Hospital used Moment One Readiness Orientation (MORO) [27] developed by Children's Memorial Hermann Hospital. The MORO team developed a virtual replica of the new 23-story building as part of a blended learning solution. Using this VR tool, staff were able to orient themselves in a realistic simulation of the facility by creating mental maps of the routes, clues, and landmarks which helped them navigate through the facility once it was occupied.

Systems Modeling

A growing number of hospitals and healthcare systems use computer-based simulation modeling tools to inform clinical and operational decisions and to study healthcare management problems. They employ mathematics to create a modeled reality of a system of multiple interrelated variables and conduct experiments with the model, predict the outcome of a change in strategy, or evaluate the implications of adopting an alternative policy. The advantages of systems modeling are flexibility and the ability to handle the variability, uncertainty, and complexity of dynamic systems. The following modeling approaches are being used in studying healthcare problems: Monte Carlo (MC), discrete-event simulation (DES), system dynamics (SD), and agent-based simulation (ABS).

DES is the most used method in healthcare management due to its capability to model complex patient flows through a facility and to test "what-if" scenarios by changing patient flow rules and assumptions. Based on queuing theory, this approach models the operation of a system as a discrete sequence of events and tracks the system dynamics over time. DES in healthcare commonly focuses on (1) improving patient flow, (2) managing bed capacity, (3) scheduling staff, (4) managing patient admission and scheduling procedures, and (5) using ancillary resources (e.g., labs, pharmacies) [28].

Virtual Patients

Mannequins, serving as simulated patients, have been used for many years to train medical specialists and professionals without any risk of harming real patients during general practice, treatment, or surgery. These life-sized human simulators with human anatomical features are often interfaced with a computer program that can produce human physiologic functions in response to clinical actions and medical treatment activities.

Mannequins can be used in simulation scenarios designed to orient clinicians before opening a new facility. For example, before a new emergency department starts providing care, clinical teams need to ensure disaster preparedness. With touch-sensitive mannequins that simulate major trauma and injury, give birth, talk, and even respond to medications and anesthesia gases, clinical teams can practice disaster responses to ensure patient safety and patient-centric care before opening new emergency departments.

Standardized Patients and Patient/Family Advisors

"Standardized patients are individuals who have been carefully trained to present an illness or scenario in a standardized, unvarying manner" [29] and are commonly utilized in simulation exercises. Additionally, patients and their family members, particularly those without healthcare backgrounds, can provide unique perspectives on post-construction functionality. Their participation may involve facilitating staff training or medical education by portraying a specific patient or an accompanying person role in a simulated scenario. The same volunteer members of the community who engage in the design phase may act in the role of a standardized patient or a family member. They can also provide feedback on the newly constructed hospital to help personnel examine the process of care in a variety of scenarios, such as domestic violence, abusive/aggressive patients, or mass casualty incidents [30].

Preparing the Debriefs

Any simulation session should have a well-thought-out plan for debriefing based on the goals for the project and the identified priorities from the needs assessment. A prepared script can help ensure all the goals for each scenario are discussed. If the goals of a simulation are orientation and training for a new environment, the debriefing may be very similar to an educational simulation focused on individual and team performance. However, if the goals are to improve operational effectiveness or identify latent safety threats in a new clinical environment, then the focus will be on systems of care, processes, layout/design of the new space, and other operational issues. Based on the Promoting Excellence and Reflective Learning in Simulation (PEARLS) educational debriefing framework, Dube and colleagues [31] developed a debriefing framework that helps facilitators lead debriefings focused on improving patient safety and patient care systems. This framework provides a valuable guide for debriefing post-construction simulations and can specifically help identify and explore challenges and gaps in providing optimal patient care in the new clinical environment.

Conclusions/Summary

Simulation is a powerful patient safety tool in many contexts and applications. A growing body of literature demonstrates the value of simulation to support patient safety and outcomes during the post-construction phase of new clinical environments. Simulations conducted prior to occupancy

can address both educational and operational goals. Simulations can be used to help prepare and orient clinicians, refine transition plans, identify latent safety threats, and mitigate risk prior to opening the newly built environment. Performing these complex simulation projects requires identification of the goals for simulation and in-depth planning and preparation. These projects require significant resources including equipment and supplies, but most importantly the participation of healthcare workers. As this application of healthcare simulation expands and the demand for building new clinical environments continues, we believe the use of simulation in the post-construction phase of clinical environments will continue to grow.

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Airway Emergencies: Simulation for System-Wide Process Improvements

16

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Introduction

Emergency airway management is a critical capability required across settings of prehospital, emergency medicine, critical care, inpatient hospital medicine, and operating room patient care in modern healthcare systems. Difficult airway adverse events are the fourth most common adverse event in the American Society of Anesthesiology closed claims database, with devastating impact not only on patients and families, but also on providers and institutions [1]. Rapid and effective response to airway emergencies is vital, as any failure in our response systems may result in preventable morbidity or mortality to at-risk patients.

Simulation is uniquely positioned to be an integral component in the development, implementation, integration, and maintenance of emergency airway response systems. The use of simulation for provider skill acquisition, emergency airway management protocol development, airway response team training, and protocol refinement or system readiness assessments are all critical areas to explore. This chapter will address approaches in the literature and from the authors' experience of using simulation to optimize emergency airway management systems.

Common themes across adverse events previously noted in airway management failures include inconsistent paging/communication, lack of availability of advanced and specialized airway equipment, insufficient training/experience of providers for advanced and specialized procedures, lack of a mechanism for reliably enlisting more experienced physicians, and unclear definition of roles and responsibilities during a multidisciplinary airway event [1].

Airway Management Skills Acquisition

Emergency airway management requires that providers are proficient in the performance of basic and advanced airway techniques. Skills required for emergency airway management are not isolated to the procedural skills alone. Like many other clinical processes, behaviors and knowledge play significant roles. As airway emergencies are uncommon, both developing and subsequently maintaining the necessary procedural skills, behaviors and knowlege can be challenging.

Simulation plays a valuable role in both initial skill acquisition and skill retention through the availability of a wide variety of task trainers for the pediatric and adult population and the provision of deliberate practice opportunities. Airway task trainers allow training in airway opening maneuvers such as the jaw thrust and chin lift; the use of airway adjuncts such as nasal and oral airways; bag-mask ventilation, supraglottic airway device insertion, endotracheal intubation with direct laryngoscopy, video laryngoscopy or flexible laryngobronchoscopy; and surgical airway interventions such as needle cricothyrotomy, surgical cricothyrotomy, and slash tracheotomy. Task trainers and technology enhanced manikins allow for the difficulty of the airway emergency to be increased through reduced neck mobility or mouth opening, tongue enlargement, pharyngeal edema and laryngospasm. These simulators can be used to replicate challenges that may be encountered in high acuity, low frequency clinical emergencies, helping to improve provider procedural competence (Fig. 16.1).

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Fig. 16.1 Simulation to practice removal of an aspirated foreign body from the airway of a pediatric manikin. Participants are looking at the image from the telescope that the endoscopist (not visible) is using, projected onto the monitor suspended over the foot of the bed and the monitor in the upper right corner of the photo

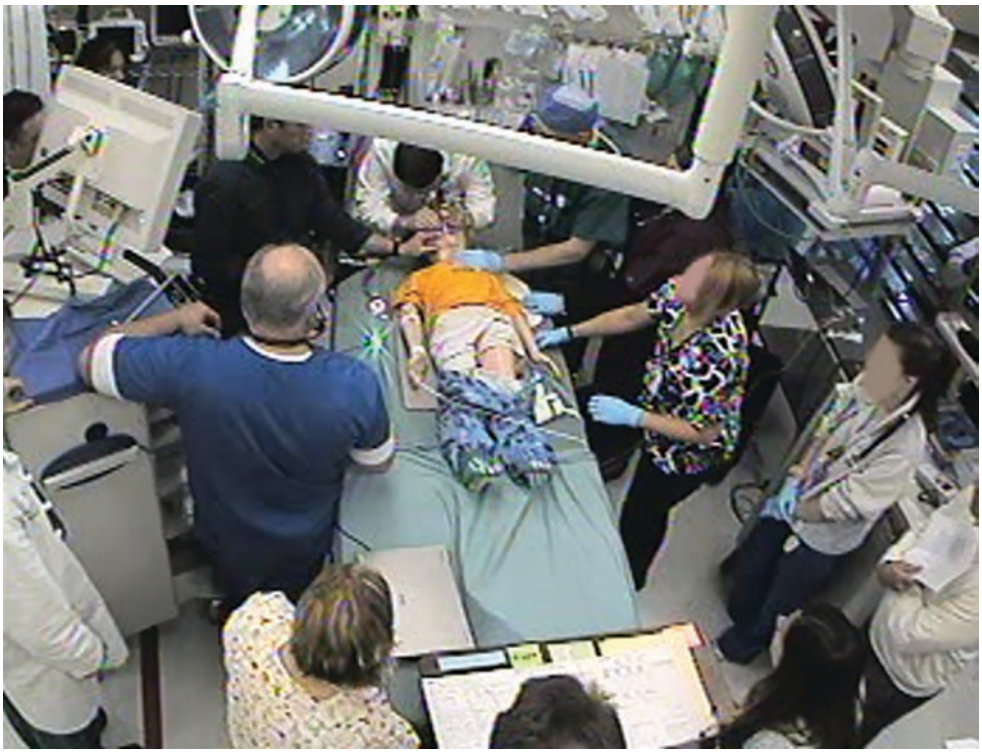

Fig. 16.2 Simulation of interprofessional management of a pediatric manikin in the emergency department, with an aspirated foreign body

In addition to technical procedural skill acquisition and retention, providers can participate in technology enhanced simulation scenarios to teach and evaluate emergency airway management. Skills assessed can include ability to comply with airway management algorithms that encompass the management of the patients' oxygenation and hemodynamics during the intubation procedure [2]. Following emergency airway management skill acquisition, these tasks can be incorporated into mega-code or small group scenarios where the skills are required to appropriately care for the simulated patient (Fig. 16.2). Simulation-based emergency airway management training has been shown to be superior to both no intervention and non-simulation-based interventions for knowledge and skill outcomes [3]. In order to maximize safe and effective airway management, it is critical that learners have the opportunity to also incorporate challenges related to the individual patient's disease. Including complexities in the learning environment through simulation reinforces the importance of optimization of a patient's physiology to reduce morbidity and mortality during intubation, especially in the critically ill patient [4–6].

Airway Emergency Response Team Training

Healthcare is provided by an interdisciplinary team consisting of Physicians, advanced practice providers (Physician Assistants, Certified Registered Nurse Anesthetist, and Advanced Registered Nurse Practitioner), Registered Nurses, Respiratory Therapist, Pharmacists and more. Given this culture in healthcare, team-based interdisciplinary training is vital for the acquisition, retention, and assessment of emergency airway management technical and non-technical skills. These healthcare teams require training in teamwork and communication principles to maximize their effectiveness- simulation has been shown to play an integral role in this interdisciplinary team training. Through participation in simulated scenarios, positive behaviors can be reinforced so as to increase the likelihood of them being used during real clinical events.

Using simulation-based interdisciplinary training is an excellent platform for the assessment of non-technical skills including leadership and communication skills involved in emergency airway response teams. Leadership skills are easily assessed during simulation-based training including leadership assignment, confidence levels, and ability to delegate roles & responsibilities [7]. Communication principles can also be observed, including creation of a shared mental model, non-verbal communication (tactic communication), and open-loop and closed-loop communication. These simulations may be conducted in-situ, in the clinical environment where these events take place.

Outside of observation and assessment of non-technical skills, interdisciplinary simulation-based education is a useful educational tool for building technical and non-technical emergency airway management skills and strengthening interprofessional team collaboration [8]. Interdisciplinary sessions have been shown to help optimize quality of care, patient outcomes, and adherence to protocols, as well as improve patient safety [8–11]. In addition to patient related outcomes, multidisciplinary and interdisciplinary simulation-based trainings have been linked with improvement in teamwork, confidence, and collaboration during crisis scenarios [12, 13]. Simulation-based education has been shown to improve emergency airway response teams regarding patient outcomes and teamwork.

Developing Emergency Airway Management Protocols

Several healthcare institutions have developed specialized airway teams to respond to airway emergencies that occur in the institution outside of the operating room because of the morbidity and mortality that occurs from failed airway management. The composition of these multidisciplinary teams can differ based on the institution but can include specialties such as general surgery, otolaryngology, anesthesia, emergency medicine, nursing, respiratory therapy, and pharmacy.

In-situ simulation can be used in the development and refinement of emergency airway management systems and protocols. In-situ simulations can assist in the identification of deficiencies in current protocols and systems of care, known as latent safety threats or latent errors, such as problems with the paging system or the availability of necessary equipment. With the identification of latent safety threats and protocol deficiencies, changes to an emergency airway management system and protocol can be made. Following changes to the protocol, protocol implementation and knowledge dissemination can occur in a series of in-situ simulations. During in-situ simulations, knowledge and skill deficits can also be identified including knowledge of the emergency airway algorithm or protocol instituted, or lack of proficiency in operation of equipment or performance of a procedure.

The difficult airway response team (DART) developed by Johns Hopkins Hospital illustrates how simulation can be used in provider procedural training, team performance improvement, and protocol development and improvement [14]. In 2008 the DART was implemented in response to several critical adult emergency airway management incidents that occurred in the hospital [15]. The DART was a multidisciplinary team consisting of trauma surgery, otolaryngology, anesthesia and emergency medicine (if the patient was in the emergency department) which responded to adult patients deemed to have a difficult airway requiring emergent intervention [16].

To supplement clinical case reviews, in-situ simulations were developed, and the team's performance reviewed to identify deficiencies in the DART) system including problems with the paging system, team response times, adherence to established algorithms and the equipment cart location and composition. When issues were identified, through review of clinical or simulated events, modifications to the care process were made and their effectiveness evaluated during subsequent in-situ simulations. In the first 5 years of the program, there were no deaths, sentinel events or malpractice claims resulting from emergency airway management events [1].

Similar programs have been developed at Cincinnati Children's Hospital Medical Center (CCHMC), in the neonatal units at The Children's Hospital of Philadelphia, and elsewhere [17, 18]. At CCHMC, 12 in-situ simulations were implemented to compare the existing emergency airway response system to a newly proposed one. The updated system included changes to the paging system, airway equipment and staff, and Emergency Department management algorithms (Fig. 16.3). These simulations and emergency

Fig. 16.3 Difficult airway team cart designed during development of the novel system of care for pediatric critical airway obstruction. (Reprinted from Johnson et al. [17])

airway response system changes resulted in significant reduction in mean time from ED attending physician request to otolaryngologist arrival (by 2.8 min) and in mean time to airway equipment arrival (by more than 6 min) in simulated events [17]. Using the existing emergency airway response system, 2 of 6 simulations resulted in simulated patient deaths; following implementation of the new protocol, there were no simulated deaths in 6 simulations [17]. Combining simulation with the implementation of updated emergency airway response systems and protocols has been shown to improve outcomes in simulations and may improve actual patient safety outcomes.

Protocol Refinement and System Readiness Assessments

Once an emergency airway response system has been established, it is vital that the protocols be consistently and regularly evaluated. Tracking relevant quality improvement metrics could be done using an online registry or simple data forms that are completed after each emergency response. Relevant outcomes to track include how quickly the team responds, and how quickly a secure airway is established. Additional details, such as complications and communication difficulties, as well as factors contributing to success, should be collected. This data should be reviewed frequently by a steering committee to identify areas that require improvement, as well as necessary resources. Simulations should be arranged to address the deficiencies and continue building on previously acquired technical and non-technical skills.

Planning for a series of regular in-situ simulation sessions should be included as an ongoing maintenance plan following implementation of an emergency airway response protocol. The specific content of these scenarios may be informed by the data collected above. For example, if communication is recognized as a common problem during activations, the steering committee could organize a simulation session to address this issue specifically. Since it is unlikely that all clinicians would be able to participate in these sessions, the simulation session could model best practices. A video recording, or written summary, of the session could be distributed electronically to all clinicians in the institution. A long-term effort should be made to have as many clinicians as possible participate in the simulation sessions.

Ongoing maintenance of airway equipment is also a critical factor. There may be significant excitement and collaboration, or one-time allocation of funds or grants, during the initial implementation of an emergency airway response system. Unfortunately, when the equipment begins to wear out or break over time, or funding becomes limited, there may be less ability to maintain or upgrade the equipment and staff needed to maintain the system and respond to emergencies may be diverted to other responsibilities. Planning for these eventual resource needs and costs with a very clear designation for who will cover which needs in the future is a crucial part of the initial development and implementation process of a successful emergency airway management system.

Hospital Wide Integration of your Emergency Airway Management System

As with any process improvement initiative, hospital wide integration of a solution starts initially with recognition of the problem. Institutional awareness regarding rapidly life-threatening complications associated with failed emergency airway management is vital. Closed claims data involving failed emergency airway management has demonstrated significant losses attached to brain injury and death both inside and outside of the operating room [19]. Understanding the overall impact on patient safety related to reduced risk, including through the review of closed claims data, may be useful for justifying investment in emergency airway management systems.

Incorporating all stakeholders in the planning for an emergency airway response program will aid in overall adoption and implementation. In some circumstances, an adverse occurrence or highly visible near miss may be the initiating event that drives a system toward action. Recruiting hospital risk, quality and patient safety departments often provides institutional support both through access to claims data, details of documented high risk near-miss and adverse events as well as financial resources. Obtaining buy-in from multidisciplinary decision makers related to the construct of the teams is critical to ensure the necessary personnel will be empowered to proceed [15].

Training and preparation for the team requires leadership from the physician, nursing, and administrative sides to act as champions for necessary change and additional resources.

The literature demonstrates successful implementation of emergency airway response systems in both pediatric and adult patient populations [1, 14, 20]. To standardize operations throughout the hospital it is recommended that the notification system should be aligned with the team composition [14]. Difficult airway response equipment must be accessible in clinical areas, and locations in which patients are at highest risk should be prioritized. Systems should be established for restocking supplies.

Airway management protocols are often challenged by the varying approach across specialties and individual providers. Standardization of practice is encouraged to better set expectations for team member roles and skill performance [1, 15]. Training requirements for full team implementation can be extensive with one study reporting performing 18 airway courses for a total of more than 200 providers over a 5 year period [14]. Instruction should involve not only enhancement of clinical skills but also reinforcement of skills related to team communication and leadership. These important principles adopted from programs such as Team Strategies & Tools to Enhance Performance and Patient Safety (TeamSTEPPS) have been utilized in emergency airway response teams training to enhance overall teamwork performance [15].

Difficult airway management protocols should be reviewed by a multidisciplinary team as part of a committee on a regular basis. This is necessary to ensure that equipment is updated and maintained as well as the clinical protocols for the team members. Team coverage should include the response of an attending physician with experience and expertise in difficult airway management. It is recommended that all emergency airway response encounters be reviewed real-time or within 24 h. Frequent and timely analysis allows the team to identify and address system issues, provide education where needed and make protocol improvements proactively [1, 14].

Many programs have successfully created Rapid Response Teams and Code Response Teams that have demonstrated improved outcomes. This may be best demonstrated in systems that utilize proactive rounding to identify potential patient deterioration or risk for airway compromise early [21]. While emergency airway response systems have demonstrated improved outcomes related to failed airways, resources allocated in the original studies at Johns Hopkins necessary to establish full programs may not be readily available at many hospitals [16]. Combining opportunities for providing immediate access to advanced airway equipment (e.g., portable video laryngoscopes) and providing the advanced airway and team training to the teams responding in a rapid response and code circumstances are likely viable alternatives. Having the appropriate composition of these teams to ensure that when difficult airways are encountered, that the providers have the equipment, team training and skills necessary to optimize the care of the patient.

Conclusions

Emergency airway adverse events are associated with high rates of neurologic and cardiovascular complications, including death. Healthcare providers and teams who care for critically ill patients with compromised airways need emergency airway management skills, protocols, and equipment. Simulation can be used to develop, refine, implement, reassess, and integrate emergency airway management protocols, and provide deliberate practice opportunities. Most importantly, simulation-based emergency airway management systems have been shown to decrease emergency airway adverse events and improve patient outcomes.

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Simulation to Prepare for the Surge: Workload Management When There Are Too Many Patients

17

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Introduction

The capacities of individual providers and healthcare facilities are often challenged with surges of patients due to circumstances such as influenza season, other viral outbreaks, or larger scale natural or man-made disasters. As a part of everyday life, clinicians commonly stretch their capacity to manage an abundance of patients and may be faced with too many patients at a given time. This surge phenomenon has been demonstrated in COVID-19 hotspots around the world. Healthcare providers and facilities need to anticipate and train for patient surges when the capacity to care for individuals is exceeded.

Healthcare providers are often trained and evaluated in an encounter of a single patient [1, 2]. Yet, all of patient care occurs in the context of the larger environment and each patient encounter is influenced by the external system components including hospital or clinic census. ***The status quo of healthcare education does not adequately address the increasing cognitive complexity and system influences of real-life clinical environments***. As much as healthcare strives toward outcomes-based education and assessment, healthcare education still predominantly relies on antiquated traditional teaching and apprenticeship models.

The Institute of Medicine report, "To Err is Human", in 2000 [3] stated that environments that are more heavily distracted and have higher patient acuity are at greater risk for error, especially Emergency Departments (EDs), Intensive Care Units (ICUs), and operating rooms (ORs) [4]. Prior error reduction work has predominately centered around preventing distractions, minimizing interruptions and reducing work volume. It is however difficult to prepare for every unique clinical situation. Simulation provides an opportunity to enhance providers' adaptability within complex environments with multiple patients – and to inform the preparation for unpredictable surges in patient volume [5]. There is strong evidence to illustrate the negative impact of high workloads on provider wellbeing and engagement [6, 7]. One study of hospitalists in a high acuity setting found that increasing high complexity and overcapacity may not only be a risk to quality of patient care, but also resulted in diminished efficiency and consequential increased length of stay and higher cost [8]. Yet, the simultaneous care of multiple patients within any given specialty is infrequently discussed or trained. Emergency medicine (EM), is one medical specialty that experiences surges in patient load due to the nature of the work. The American Board of Emergency Medicine (ABEM) has long included a multiple patient simulation case as part of the oral board testing for physician specialty certification [9].

Previous questions about the translational impact of outcomes in the simulation lab to outcomes in actual patient care have been largely answered [10–12]. Simulation based education (SBE) is an educational tool uniquely suitable for improving the quality of education for all healthcare providers across the continuum of learning. The more appropriate

Dedication

This chapter is dedicated to the essential Healthcare workers who have risen to the occasion to care for others in the era of COVID-19. There are many who prepared for a surge that did not come and those who lost their lives caring for others. A simple thank you is inadequate.
We strive to shape our clinical environments to earnestly learn from the triumphs and errors of the past to create a healthier future – where we are prepared for patients whenever they seek medical care.

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question is now – ***when, for whom and under what circumstances is simulation the best educational intervention and modality***? The use of SBE and principles of simulation pedagogy to improve the quality of care during clinical surges is a domain ripe for future understanding and exploration.

In this chapter we will: (1) Review current literature on provider performance and patient safety implications during the care of multiple patients in a surge setting and review the assessment tools to measure workload across disciplines; (2) Review the theory of decision making and workload processing during periods of surge; (3) Provide a practical guide for simulation educators and researchers to improve the individual, team, or system skill level during clinical surges; and (4) Summarize and discuss the impact of surges and the sequalae on provider workforce.

This chapter will cover the spectrum of surges ranging from managing more than one patient at a time to the decision to initiate an internal disaster response. Further details about disaster responses are addressed in Chap. 21.

Learning to Drive: Building Incremental Skills

Think back to the anxiety you felt when you learned how to drive a car and merge into traffic for the first time. There are many novel skills that one must acquire to drive safely on the road. When learning such a complex new skill, it is customary to practice and master building block skills to achieve competency with increasing difficulty of such a complex skill. The acquisition of each new skill component requires our concentration, attention, and the appropriate level of stimulus. Fortunately, in the healthcare environment, simulation offers the opportunity to practice skills with increasing levels of complexity and difficulty and encourages "failure" in safe environments. In response to environmental stimuli, cognitive demand, or behavioral experience, the brain has an extraordinary ability to functionally and physically change or reconfigure its structure; this property is known as neuroplasticity [3, 4].

SBE allows educators to provide training experiences that enhance the neuroplasticity of learning to care for multiple patients in safe environments without direct risk to patients. The ability to practice building block skills in a safe learning environment reduces cognitive load in the clinical environment. Cognitive load theories help us understand the factors that impact how individuals' function when performing new or many tasks simultaneously.

The current educational paradigm that trains and evaluates provider performance treating one patient at a time should be expanded to develop healthcare provider skills to manage the cognitive complexity inherent in the real-life work. Every healthcare provider works within a system and the ultimate outcome of quality is how well the system works for the individual patient. Yet the care and treatment of each patient in a hospital, clinic, critical care unit, inpatient hospital unit or emergency department is influenced by a multitude of individual, team and systems factors that impact quality of care provided. The care of patients occurs within the system, not in isolation.

There is a multiplicity of skills sets, expertise, performance shaping factors, environmental variables, team dynamics, organizational policies, cognitive challenges and technical limitations that must be navigated. This already complex and dynamic system is further stressed in a patient surge situation. The terms used in this chapter are defined in Table 17.1.

Table 17.1 Keywords within the chapter are defined here for reference

Attention	A finite "supply of mental resources" at one's disposal for information processing.
Cognitive load	Describes the mental processing requirements that use limited working memory.
Mass casualty incident (MCI)	Current definition describes an event that *overwhelms* the local healthcare system, with the number of casualties that vastly *exceeds* the local *resources* and capabilities in a short period of *time*.
Multitasking	Human factors research suggests that the term multi-tasking is often a misnomer. Debate exists among psychology and human factors research suggesting that **most** tasks cannot be effectively completed at the same time. Instead individuals switch tasks. The term often utilized in human factors research is "task switching" or "task sharing" when the performance of tasks occurs nearly concurrently. An example of true multitasking is walking and chewing gum at the same time.
Neuroplasticity	The brain's ability to functionally and physically change or reconfigure its structure in response to environmental stimulus, cognitive demand, or behavioral experience.
Surge	The care of multiple patients beyond a perceived normal workload. A surge of patients may be defined along a continuum from a normal workload for a well-prepared provider in a well-equipped environment up to the point where the surge of patients reaches the definition of an overwhelmed or disaster environment.
Task shedding	An organizational practice which enables the workers to defer or discard some of their low priority tasks under certain conditions and circumstances.
Task switching	The process of redirecting cognitive, decision making or physical resources between tasks. An example of task switching is talking to families while entering orders in a computer.
Working memory capacity (WMC)	The temporary storage and active retrieval of task-relevant information.

Current Literature Reviewing Provider Performance during the Care of Multiple Patients

There is a paucity of simulation literature that addresses the education, assessment, and outcomes of healthcare providers managing multiple patients in complex clinical environments. A sample of studies across healthcare disciplines were compared [13, 14]. In one study, the cognitive task of patient prioritization consisted of three components: (a) a brief overview of the entire cohort of patients to determine a general strategy, (b) an individual chart review to develop a functional understanding of each patient's status at that moment in time and c)the creation of a relative priority list [15].Other studies have examined specific cognitive strategies and teamwork functions that impact the care of patients when there are frequent interruptions and shortages of time, personnel, equipment, space, and supplies. Kobayashi et al. recommended that distinguishing features of multi-patient exercises should include (1) broadened educational scope (2) enhanced scenario complexity, (3) controlled exposure to high workload environments, (4) expanded communication requirements, and (5) increased potential for reflective learning [16]. Fackler et al. identified five broad categories of cognitive activities: pattern recognition; uncertainty management; strategic vs. tactical thinking; team coordination and maintenance of common ground; and creation and transfer of meaning through stories [17]. One study explored novice physician decision making during high cognitive demand situations in an avatar mediated virtual setting [18]. The opportunities for further study of the care of multiple patients utilizing simulation and experiential learning in healthcare are enormous.

Theory of Decision Making and Workload Processing During Periods of Surge

Perhaps one reason for a paucity of studies evaluating decision making during periods of surge is the sheer complexity of designing and implementing such studies. Another possibility is that we have just begun to incorporate lessons learned from human factors research and decision-making theory into healthcare education and research.

Implications of High Workload for the Individual

Human factors research suggests that the term multi-tasking is often a misnomer. Debate exists among psychology among human factors research suggests that **most** tasks cannot be completed effectively at the same time as another task. Instead individuals switch between tasks. Healthcare providers may use both **multitasking** behavior, defined as the simultaneous performance of two automatic, discrete tasks, and **task switching**, defined as changing between two separate tasks, sometimes rapidly (See Table 17.1). Multitasking can only occur when the two tasks can be performed at the same time, such as walking and chewing gum. *It is likely that task switching is the more common and accurate description of typical clinician behaviors* [2]. Medical professionals often seamlessly task switch in a manner that creates the appearance that multitasking is occurring—for example an anesthesiologist may monitor the patient's vital signs throughout a surgical procedure while simultaneously administering medications. Some tasks are more integrated making task switching easier. The characteristics of the task, including the cognitive resources required, impact the ability to task switch. Individuals have limited mental resources, or **attention**, available to contribute to the tasks being performed. With a greater number of tasks, an individual's attentional resources become exhausted causing performance to decrease on all or some tasks.

Attentional resources can be increased; reconfiguration of brain structure may occur in response to environmental stimulus, cognitive demand, or behavioral experience. This neuroplasticity, the brain's capability to change both physically and functionally, expands attentional resources and allows for more efficient and effective processing of cognitive load [3, 4]. Simulation scenarios in which providers experience the full demands of a patient surge and multi-patient care will provide opportunities for trainees to be prepared for similar conditions in the field. This property has been examined extensively in many domains, including neurodevelopment and adult learning, but infrequently applied to learning in healthcare.

In addition to the amplitude and duration of a surge, as well as the illness severity of the presenting patients, individual expertise and natural variation in capacity can impact cognitive processes and healthcare worker performance. **Working memory capacity** (**WMC**) is the temporary storage and active retrieval of task-relevant information. In the setting of distractions or increased demand, WMC can be reduced, hindering the storage or retrieval of relevant and necessary information [19]. Some individuals have a large WMC which enables them to maintain and retrieve information even in settings of disruption or distraction. An individual's baseline WMC predicts their ability to task switch effectively which is a valuable trait during surges in patient volume.

Individual expertise and natural variation in capacity can greatly impact cognitive processes and health care worker performance. Errors are more likely to occur when cognitive

capacity is reached or exceeded. Under the circumstances of large surges in patients, health care workers are likely to experience more interruptions and attempt to conduct more task switching. Interruptions and task switching both require that information unrelated to the primary task be processed, consequently increasing the overall cognitive load. These conditions place undue demand on the provider and can lead to fatigue and errors.

Despite a variety of interventions, patient care surges can raise attentional and WMC demand above the capacity of the individual. It is in these moments where prioritization and decision making must be utilized broadly to attend to the appropriate tasks, appropriately implement task shedding and manage the overall situation. Dual process theory [20] is the dominant theory of decision making.

The available capacity within the facility, including both personnel and material resources, drives the management of the increased demand. Accurately simulating multi-patient, high workload conditions will help trainees identify opportunities for task shedding and utilization of available resources for management of attention and WMC. Additionally, these simulations can identify opportunities for *institutional improvement to address system infrastructure to support provider workload.*

Implications of High Workload for the Team

While healthcare is constantly changing with new technologies and advances in care, the presence of an interdisciplinary health care team has become a constant. During times of high patient demand, health care workers must not only rely on their individual capabilities and capacity, they are also required to work with a team to ensure optimal patient outcomes. Communication among members of smaller teams or larger distributed "teams" within the hospital or hospital system differs. While both are important, the type of information shared, the frequency or timing of this information transmission, the mode of communication delivery all may vary. Communication both relies on and continues to update a Shared Mental Model (SMM), a common understanding, across the interdisciplinary team. Focusing on communication and a strong SMM during simulation can improve team strategies for handling high workload.

One potential breakdown of a SMM can occur during periods of surge when there is little time for coordination of care with interprofessional members of the care team. Routine processes include SMM opportunities during care rounds. At this time supervising physicians, physician trainees, nurses and other members of the care team are included. Data and care plans are shared and interprofessional members and patients have opportunity for input and to clarify misinformation. Periods of surge limit this formal process. It is imperative to take opportunities to build a strong SMM no matter how brief. Small huddles of time to create SMM greatly benefit overall quality of care.

Implications of High Workload for the System

Workload at the system level is the amount of stress placed on the system pushing it toward a moment of failure. As Rasmussen describes, in a complex sociotechnical system such as hospitals, an overabundance of coupling of processes—or interdependencies--sets the stage for errors [21]. Tightly coupled systems maximize efficiency by reducing duplicity and removing excess resources; however, it results in critical dependencies that may be unpredictable during extreme conditions [22]. During periods of patient surge, the high demands may be managed by a highly reliable system where demand can be shifted to individuals or teams with available capacity to complete the work. When reserve capacity is further strained or the system is not able to respond, often due to tight coupling, and meet the needs of the professionals or the patients a failure or loss may occur. For example, shifting patients out of the emergency department (ED) is dependent on bed availability. If a patient surge occurs during influenza season and the hospital is operating at a high bed occupancy, bed capacity may be limited in the hospital and delay transfers from the ED and further strain resources within the ED.

Practical Implications: Simulation to Help Providers, Teams and Facilities Improve Patient Safety during Patient Surges

Perhaps one of the most pivotal behavioral changes for all healthcare providers under stress while caring for multiple patients is as simple as asking the question, ***"does anyone have any ideas?"*** Safety improvement in other disciplines has evolved to a culture where each voice is heard and appreciated. In aviation there is "no rank in the debrief." Manufacturing urges that anyone can "stop the line" if there is a concern for safety on the assembly line. We often focus on leadership skills in experiential learning environments and followership skills are equally important to improve team behaviors. Simulation training encourages thinking out loud, planning or BRIEFING and of course DEBREIFING after clinical scenarios. These skills are difficult to incorporate into daily clinical care. Yet, perhaps the transition from a culture where the leader is supposed to know everything to a culture where everyone is encouraged to speak up with any concern can have enormous impact in healthcare by distributing individual workload, reinforcing the team workload and SMM, and identifying opportunities for improved system resiliency.

An equally important ethos is the ability to ***ask for help*** when unsure or overwhelmed. Knowing how and when to call for help is perhaps the most essential and reasonable skill to learn and reinforce. In multiple patient simulation encounters, participants have the opportunity to practice identifying where individual capacity has been exceeded, recruiting other team members to assist with tasks and check back with information.

Other skills and essential elements of effective SMM communication include closed loop communication and talking and thinking out loud to share information. Although seemingly counterintuitive to pause during surge, the practice of brief time outs or huddles are important to incorporate in any surge encounter. Reinforcing these skills in the simulation environment allows providers to practice awareness and coping strategies to decrease anxiety and stress during high pressure situations. When possible during patient surges, a designated team leader without independent tasks should coordinate and prioritizing care of multiple patients.

When designing an simulation intervention it is always imperative to adopt one of Covey's *Seven Habits of Highly Effective People* [23] and "**Begin with the end in mind".** What is the end goal that learners are expected to achieve after participating in the experience? Prioritization of care? Team communication? Calling for help? Task shedding? Cross checking? Morning briefs including census and plans to pull in resources if surges occur? There are three major simulation design elements that are beneficial for surge training strategies to achieve these goals (see Table 17.2).

Table 17.2 Surge training strategies: Elements of simulation exercises to prepare healthcare providers for multiple patients or surges

Simulation design elements	Why	How	Pearls
Use simultaneous patients to improve cognitive skills, history taking and differential diagnosis skills when managing multiple patients concurrently	The transition from classroom learning to real time information acquisition and processing improves with practice Building mental schemas can improve pattern recognition and decision making, and decrease bias and diagnostic error To increase situational awareness	Repeat and practice mental frameworks for cognitive and procedural skills, teamwork, and communication	Begin with the end in mind. What are goals and objectives for scenarios? Always include critical actions requiring teamwork and communication Bumper bowling – provide guidance with simulated participants to ensure that learners achieve desired outcomes
Increase complexity of simulation cases by increasing "signal" and "noise"	Practice, practice, practice to improve prioritization of tasks Develop mental schema and heuristic capabilities Inoculate against stress through Individual recognition and management Reliance on team workload capacity Identify systems-level redistribution of resources	Add multiple patients of varied acuity and complexity Each individual should feel empowered and practice asking for help, accessing available resources (team and system), and checking in. Build in opportunities for each trainee to recruit others to circle back to changing clinical conditions or delayed tasks (e.g., please let me know what the patient's blood pressure is in 5 minutes)	When possible designate a team leader without independent tasks to coordinate and prioritizing care of multiple patients Practice awareness and coping strategies to decrease anxiety and stress when interruptions occur Practice respect, humility, and approachability under duress.
Emphasize skills that enhance team function, such as developing a shared mental model, as critical actions	Reinforce that every voice is important Emphasize that safety is everyone's priority Demonstrate that other team members can be recruited to task share	Model calm behavior in chaotic environment Train teams to de-emphasize hierarchies and embrace deference to situational expertise rather than seniority Train providers on communication techniques to promote assertiveness without aggressiveness	Normalize asking for help behavior Normalize BRIEFING and DEBRIEFING communication in everyday clinical life **Think out loud –** encourage deliberate verbalization of experts Emphasize the importance of Closed loop communication Shared mental model/ huddles Emphasize asking for ideas and feedback from team members. Use the phrase: **Does anyone have any ideas?**

Concepts derived from Task Switching and Multitasking in Emergency Medicine. Skaugset et al. [24] and High reliability organizations articles: Weick et al. [25] and Chassin et al. [26]

Use Simultaneous Patients to Improve Cognitive Skills, History Taking and Differential Diagnosis Skills

Multiple-patient simulation experiences can become very complex. One method to ensure that learners achieve the desired outcomes is to use scenario rescue techniques akin to bumper bowling: if you can't bowl, you may begin to acquire bowling skills using bumpers along the sides of the bowling lanes that prevent the ball from going too far off course. The simulated participants within a scenario can help learners stay on track during complex cases with multiple patients. A designated crew chief can communicate with simulated participants to provide clues or guidance to ensure that learners are guided toward desired objectives.

Increase Complexity of Simulation Cases by Increasing "Signal" and "Noise"

When caring for multiple patients, providers face an increase in both "signal" and "noise". The *signal* includes the most important information that needs to be identified, de-coded, and prioritize to care for the patient. The *noise* is the information that not critical to the care and prioritization of the patients; however, it still needs to be identified and quickly de-coded to determine that it is noise and not signal. In simulation, this can be simulated through incorporation of high patient volume and varying patient complexity. Trainees should have realistic resources (team and system level) to allow for management of the high "signal" and "noise".

Uniformly Incorporate Team-Based Skills as Critical Actions

Safely caring for multiple patients during a surge increases the importance of teamwork skills and high reliability principles. This behavior may be as simple as asking ***"does anyone have any ideas?*** when situations become stressful or overwhelming. Thinking out loud with respect and consideration of all team member voices allows all team members to offer suggestions and ideas and express concern when necessary. Simulation based education offers opportunity for providers to practice key elements of a mindful organizational culture and team-based skills.

How Can We Measure Workload?

Measuring workload in healthcare simulation and in the field can be conducted objectively and subjectively at an individual, team and system level. One very common tool used in healthcare and in simulation is the *NASA-Task Load Index (NASA-TLX)*, which was developed by the U.S. National Aeronautics and Space Administration for assessing and managing astronaut workload during tasks [27]. This subjective tool collects workload from participants through six, 20-point visual analog scales including mental, physical, and temporal demand, performance, effort, and frustration [28]. Each of these scales has verbal anchors at the two ends of the scale. While this tool incorporates responses from individuals, it has been used to understand the distribution of workload across teams and collective team workloads [29]. Compared with other team workload tools, NASA-TLX displayed the highest correlation to performance [30].

Dual task analysis and physiologic responses are two common methods for objective workload measurement. *Dual task analysis* incorporates concurrent tasks to measure working memory and is used to understand the cognitive load of a task. [31] Tasks with higher demands require more mental resources, which hinders performance on the secondary and occasionally the primary task. In healthcare simulation, dual task analysis is most informative to cognitive load when the secondary task is clinically relevant and involves the same sensory pathway (auditory or visual) as the primary task [32]. Measuring *physiologic response* (such as galvanic skin response, heart rate variability, or salivary hormones) can also provide feedback on workload or stress levels for participants. For example, Hulsman [33] measured a reduction in stress through the analysis of changes in heart rate when trainees experienced subsequent opportunities to collect patient history and deliver bad news compared to initial interactions with patients. For all physiologic measurements, there are tradeoffs between the invasiveness of the measurement, the workload for data analysis, and the validity of the measures for comparison across individuals or within individuals and across different sessions.

The measurement of individual and team workload can help inform trainees about their individual capacity, opportunities for redistribution across the team, and the need for systems level resource support. Instructors can use workload information to compare to practice and adjust the simulation for realistic workload levels. Finally, institutions can work to ensure that the system supports workload management and availability of resources for providers asking for help in times of patient surge to ensure patient safety and provider wellbeing are supported.

Summary and Cost of Inaction: The Impact of Surges on Patient Care and Provider Wellbeing and Engagement

Prioritizing and managing the care of multiple patients is an essential skill when practicing in an ICU, emergency department or other complex environment likely to experience patient surges. The COVID-19 pandemic has brought this

critical issue to the forefront of healthcare. Many clinical care environments have been saturated and overwhelmed in novel ways. The health and wellbeing of our workforce was already in peril prior to the COVID-19 pandemic [34]. Providers who struggle to cope in a multitasking (task switching) environment risk fatigue, stress, and burnout [35]. How we prepare our workforce in the future can be greatly improved with the opportunity for practice with multi-patient care scenarios.

The safe and effective care of multiple patients requires that providers receive large amounts of information while managing numerous interruptions when interruption and workload reduction are not possible. While institutions should continue to pursue systems solutions to provide resources in times of patient surge, clinicians must identify what requires immediate attention and what responses can be delayed or managed by other members of the team. Learning what tasks should take priority and what can safely be delayed or re-allocated is a skill set infrequently practiced in healthcare. Deliberate attempts should be made to teach providers pitfalls and coping strategies of the care of multiple patients with formal curriculum, role modeling by faculty, and simulation training [35]. Clinicians working in complex settings would benefit from the opportunity to strategically practice the care of multiple patients and improve task switching skills with experiential learning.

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Using Simulation to Improve Neonatal Care

18

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Introduction

Neonates are a unique population of patients who require dedicated interprofessional teams, specialized protocols, and specific environments to optimize their outcomes. These patients are incredibly diverse, ranging from the extremely premature newborn in the delivery room, to the neonate with a complex congenital anomaly, to the several month old former extremely premature newborn "graduating" from the neonatal intensive care unit (NICU) to be discharged home. Approximately seven percent of the four million newborns delivered annually in the U.S. are admitted to NICUs, and an significant amount of health care dollars is spent on their care [1, 2].

Improving care of neonates using simulation is important to optimize patient outcomes. Simulation can be used to improve care provided to the patient by the hospital team and by the patient's parents, who are encouraged more and more to be part of the hospital team and will be the team at home. Simulation can also be used to develop, assess and improve systems of care for these most fragile patients.

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Using Simulation to Improve the Performance of Health Care Professionals

Acquiring and Enhancing Skills

Human performance refers to human capabilities and limitations which have an impact on the safety and efficiency of healthcare. Human performance is influenced by both extrinsic and intrinsic factors. Extrinsic factors are outside the individual and include the environment and system in which the individual, or team, works. Intrinsic factors are inherent to the individual. Intrinsic factors can be divided into three primary skill areas: cognitive, technical, and behavioral skills [3]. Cognitive skills involve an individual's knowledge, decision-making, and critical thinking. Technical skills involve attributes like strength, coordination, and dexterity. Behavioral skills deal with the capacities to manage stressors and function as part of a team. Limitations in either extrinsic or intrinsic factors will impact the ability of humans, as individuals or teams, to perform optimally.

For over 30 years the Neonatal Resuscitation Program (NRP) has taught thousands of care providers around the world the intrinsic cognitive, technical, and behavioral skills needed to resuscitate newborns [4]. The current NRP curriculum utilizes a blended learning approach, including online testing, screen-based simulations, and hands-on case-based simulation and debriefing [5]. Maintaining neonatal resuscitation skill requires continuous practice, and should be supplemented with simulation training given the rarity of full neonatal resuscitations and ever-changing members of the team. Team performance during neonatal resuscitation can be fostered by conducting post-event debriefings after each neonatal resuscitation.

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Using Simulation to Prepare Families for Home Care of the Neonate

Families are as much a part of the healthcare delivery system as any other professional, especially as they will be providing care for their infant at home after discharge. However, the education and training done to ensure optimal care by the hospital team is frequently not extended to the family. The transition to home of a neonate from the NICU can be a very stressful event for families. Many NICU patients discharged home in the care of their families have complex conditions and healthcare needs. They might be supported at home with supplemental oxygen, a cardio-respiratory monitor, a feeding tube or a tracheostomy and a ventilator.

Infants who depend on technology such as tracheostomies and ventilators may be particularly vulnerable as complications can lead to a cardiorespiratory arrest if not adequately managed. Studies such as one by Amin et al., finding incomplete home emergency tracheostomy kits, demonstrate the threats that exist for these patients [6]. Several studies suggest that improved responses by home caregivers might decrease the morbidity and mortality of adverse events for children at home with tracheostomies [7]. It is reasonable to assume that the same techniques, such as simulation, used to optimize performance of systems and healthcare professionals (HCP) in the hospital would be useful to prepare families and home HCPs to provide care to children with complex needs in the home environment. There is minimal literature surrounding the use of simulation to enhance the care provided by families, however simulation has been shown to improve parental confidence and competence in responding to emergencies [8] and is well accepted and appreciated by families [9, 10].

The largest body of evidence for the use of simulation to prepare parents for emergency events involves cardiopulmonary resuscitation (CPR). As with HCPs, there are reports that interactive modules with self- instruction are effective in improving parents' knowledge of infant CPR [11–13]. There are several reports of parents who received CPR training prior to their child's discharge who felt that this contributed to their ability to successfully resuscitate their child at home [12, 13]. In addition, there are kits, such as Infant CPRAnytime™ (American Heart Association, Dallas, Texas) that parents can be given to take home that encourage continued practice and maintenance of skills as well as the ability to train other members of the family at home. It remains to be evaluated whether the addition of instructor led simulation training will improve higher level outcomes compared to other less staff-intensive methods. However, as rates of initiation of bystander CPR improves outcomes in adults, it would be an appropriate course of action to ensure some infant CPR training is done for parents taking home an at-risk child.

The educational needs for parents to safely care for their children with technologic needs such as invasive and non-invasive respiratory support at home is by nature more intensive. Well-developed educational programs incorporating simulation to help ensure that parents can perform life-saving skills are of paramount importance for technology-dependent patients. The American Thoracic Society has published guidelines that suggest that the education of families taking children home with tracheostomies in place include not just sessions for acquisition of skills but also to maintain skills [14]. Tofil et al. describe a program which incorporated simulation-based education for parents taking home children with tracheostomies addressing both common and rare events. Families involved in the simulator training felt more prepared to care for their children at home and more confident [9].

Family education can include more than learning to manage emergencies. Frequently parents do not have the opportunity to independently care for their child for an extended length of time during their child's NICU stay. Simulation, in a setting that closely mimics the home environment, can allow families to be better prepared and improve their confidence as independent care givers [15]. This could be accomplished by changing the simulation setting to more closely mimic the child's room in the house and ensuring use of home equipment, which is often different from equipment used in the hospital.

While some NICUs offer overnight stays for families to fully care for their child in the hospital environment prior to discharge, this does not completely mimic the home environment. Ideally, simulations would be performed in the actual home to improve fidelity and identify safety threats. There are interesting reports of using simulation to help families identify safety threats [16, 17]. One study demonstrated an inability of some mothers to recognize safety threats such as overloaded outlets and non-functioning smoke detectors, which would be hazardous for patients requiring home oxygen and ventilators [18]. This type of simulation could be part of a larger curriculum to prepare the home environment as well as to ensure families are aware of these dangers that aren't considerations for them in a hospital.

Thus, the use of simulation to improve the care of neonates with complex medical needs in their home has promising benefits. More studies are needed to determine whether the simulation methodologies that show benefits for healthcare professionals and system improvements will translate to families or if modifications are needed to optimize the acquisition and maintenance of skills. However, as we are moving the learning curve of our trainees into the simulation realm and away from patients, we should do the same for the parents and move their learning curve into the simulation environment and away from their infants.

Using Simulation to Design and Assess Systems

Human performance is also influenced by elements extrinsic to the individual human, found in the surrounding environment [3]. In healthcare, simulation has most frequently been described as an instrument for enhancing the cognitive, technical and behavioral skills of the healthcare professionals charged with caring for patients. This definition is limited, however in that it fails to address both the importance of the overall system in the delivery of patient care and the utility of simulation in designing and assessing that system. Human performance in dynamic situations is typically defined in terms of speed, accuracy and attentional demand [19]; without a doubt, the system in which healthcare professionals operate often has tremendous influence on the speed, accuracy and mental workload displayed by those humans.

Designing and Testing Clinical Environments

A key component of any system is the physical and/or virtual environment in which the actions that define system performance occur. In most fields where the risk to human life is high, great attention is paid to the environments in which human beings work: the volume of the physical space, placement of equipment and supplies, design of user interfaces and other aspects of the environment are simulated extensively during the design process before the layout is finalized. This process is so sophisticated in some industries that the final working environment is designed entirely *in silico*. For example, three-dimensional computer-assisted design (CAD) allowed Boeing engineers to simulate assembly of a virtual 777 widebody aircraft without the need for traditional physical mock-ups [20].

Because the physical environment in which healthcare professionals operate can exert tremendous influence on how they perform in that environment, a great deal of attention should be paid when designing such environments so that they optimize rather than impair human performance. While NICU design remains largely a traditional process involving paper architectural drawings or CAD followed by life-size physical mock-ups, simulation is being used to assess those environments for latent safety threats before their operational deployment. Prior to opening a new NICU at Women and Infants' Hospital in Providence, Rhode Island, Bender employed six different simulated neonatal events conducted simultaneously to realistically stress all the components of the NICU system [21]. Because the participants consisted of HCPs who will care for patients in the new unit, buy-in was strong, debriefings were rich in terms of discovery, and motivation to address the safety threats identified through simulation was high. Similarly, Wetzel et al. conducted a series of five different realistic simulated clinical scenarios in both the NICU and the simulation center at Cincinnati Children's Hospital and Medical Center. They identified a number of latent safety threats that involved problems with processes and procedures, equipment and other physical resources, as well as individual and team knowledge gaps [22]. Most importantly, the safety threats that were identified via simulation were taken seriously by hospital administration, and appropriate resources were allocated to address these system weaknesses before they could cause harm to real patients. These studies indicate that *in situ* simulation readily identifies problems that have yet to become manifest during actual patient care and, if appropriate resources are focused on remediating those problems, patient safety can be enhanced.

Usability Testing of Medical Devices

When developing a medical device for use during patient care, it is extremely beneficial to frequently incorporate input from likely end-users during the design process. An example of the use of simulation to refine the design and assess the usability of a new medical device was described by Fuerch et al. [23] The device was a computer tablet that displayed the data necessary to guide neonatal resuscitation (heart rate, pulse oximetry, patient weight, and a timer) as well as a combination of visual and auditory prompts suggesting interventions based on the NRP algorithm (Fig. 18.1). While it may seem that more data and auditory prompts would be beneficial to healthcare professionals undertaking a time-pressured task such as neonatal resuscitation, the reality may be otherwise. Any additional data that is displayed still needs to be detected, interpreted and finally translated into actionable information. Auditory and visual prompts, delivered in a room already filled with multiple healthcare professionals speaking simultaneously (creating high ambient noise levels) and multiple data streams displayed on various monitors, may actually increase cognitive load and distract rather than aid those professionals.

In this study the investigators created a highly standardized simulated clinical environment in order to limit the number of confounding variables. This standardization also included scripting the responses of the confederates who played roles as bedside personnel during the scenarios. The decision support tool was inserted into this environment and its effect on the ability of healthcare professionals to adhere to the NRP algorithm was measured. In this study, the healthcare professionals who used this decision support tool exhibited significantly fewer deviations from the NRP algorithm compared to those working from memory alone. Despite the potential for further complicating an already challenging situation, simulation-based assessment of this device indicated that it likely reduced cognitive workload and improved situation awareness.

Fig. 18.1 Tablet with example of prompts for resuscitation interventions based on NRP flow diagram. (Image courtesy of Dr. Lou Halamek)

Trialing New Procedures and Processes

Before a new procedure in patient care is undertaken or a novel or revised process is implemented in the hospital it is wise to study how this procedure or process functions when subject to real world circumstances. The inherent value in practicing a complex task with a patient simulator under highly realistic conditions before carrying out that task with a real patient is clearly illustrated by an experience described by Yamada et al. as they planned for the resuscitation of omphaloischiopagus conjoined twins joined at the chest, abdomen and pelvis [24, 25]. Fetal magnetic resonance imaging performed at 32 weeks estimated gestation revealed the twins to be in a face-to-face orientation, fused from the sternum through the pelvis; there was a shared liver and diaphragm as well as a single umbilical cord with one umbilical vein, suggesting shared circulation. No peer-reviewed publications describing resuscitation of conjoined twins with shared circulation could be found, nor were there descriptions of how to manage the ergonomic problems inherent when two separate teams of healthcare professionals work in close proximity as they perform procedures on two patients who are conjoined. In order to prepare for all possible complications of delivery and the transition to extrauterine life, interventions such as airway management, cardiac compressions, emergency intravenous access and drug delivery were practiced via multiple *in situ* simulations in order to determine where the NRP algorithm needed to be adapted to the twins' unique anatomy and physiology. Debriefings conducted after the simulated resuscitations addressed key issues that arose during the simulations. The twins were born at 32 + 6 weeks gestation, stabilized within 8 minutes of birth and then transported uneventfully to the NICU. The simulation-based training of experienced healthcare professionals conducted in the actual delivery room environment prior to birth played a key role in enabling two resuscitation teams to function as one well-coordinated unit that effectively performed all necessary steps to care for these complex patients.

Summary

High-risk industries such as commercial aviation and aerospace have applied simulation-based training and research strategies to assess human and system performance for decades. By adopting and intelligently applying these same strategies to identify and remediate weaknesses, healthcare will begin to replicate the tremendous improvement in system performance experienced by those industries and will see reductions in errors, latent safety threats and ultimately risk to patients.

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Improving Patient Outcomes After Resuscitation with Systematic Debriefing

19

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Background

More than 200,000 adults and 15,000 children suffer from an in hospital cardiac arrest (IHCA) every year in the United States and receive cardiopulmonary resuscitation (CPR) [1, 2]. IHCA is associated with significant morbidity and mortality for both populations with only 20–26% of adults and 38–40% of children surviving with good neurologic outcomes [2, 3]. Significant evidence shows that as CPR quality improves (chest compression rate, depth and chest compression fraction) the odds of return of spontaneous circulation and survival to hospital discharge improve [4–7]. Simulation has been utilized to train individuals and multidisciplinary teams to improve the provision of quality of chest compressions as well as the teamwork required to deliver high quality resuscitative measures [8].

Resuscitation during a cardiac arrest requires a series of complex decisions and occurs in an often-chaotic environment; often with team members that do not work together on a regular basis, if ever (Fig. 19.1). Within these ad hoc teams, members must both be skilled at task work, such as placing intravenous lines, administering emergency medications, and performing high quality chest compressions, but also skilled at teamwork i.e. the ability to perform these tasks collaboratively in an efficient and coordinated manner. It is also important to note that even though resuscitative efforts and cardiopulmonary resuscitation occur with more frequency in some settings (e.g., Intensive care units (ICU), emergency department (ED)) in a hospital, they can occur anywhere and at unpredictable times.

Hospitals across the country require staff to attain and maintain resuscitation skills, mostly utilizing American Heart Association's programs such as the Advanced Cardiac Life Support (ACLS), Pediatric Advanced Life Support (PALS), or the Neonatal Resuscitation Programs (NRP; American Heart Association, Dallas TX. URL: cpr.heart.org). Recommendations for care are consistently updated by experts in the field of resuscitation and the current standard for these programs is recertification every 2 years. The hands-on skills required to perform a resuscitation, however, have been demonstrated to deteriorate within 2–3 months of training [9]. A recent study showed that the maintenance of delivery of high-quality chest compressions was optimal when providers practice the skill on a monthly basis [10].

The unpredictable nature and high stakes of resuscitation requiring CPR make simulation an ideal modality for training of individuals and teams. The American Heart Association has now recommended that just-in-time training and post-event debriefing should be incorporated into resuscitation programs, but there is little written on how to translate these programs from simulation to the patient bedside [11, 12]. After a brief exploration of the use of debriefing during simulation to improve learning and performance, we will offer insight into creating novel programs to bring simulation practices to the bedside and incorporate them into the daily clinical processes of a hospital. While this chapter focuses specifically on cardiac arrest and resuscitation events, the practice of debriefing can apply to a wide variety of infrequent events and hospital emergencies.

Debriefing in Simulation

Debriefing is a "facilitated or guided reflection in the cycle of experiential learning" [13]. It is a common tool used across industries including aviation, business, military and

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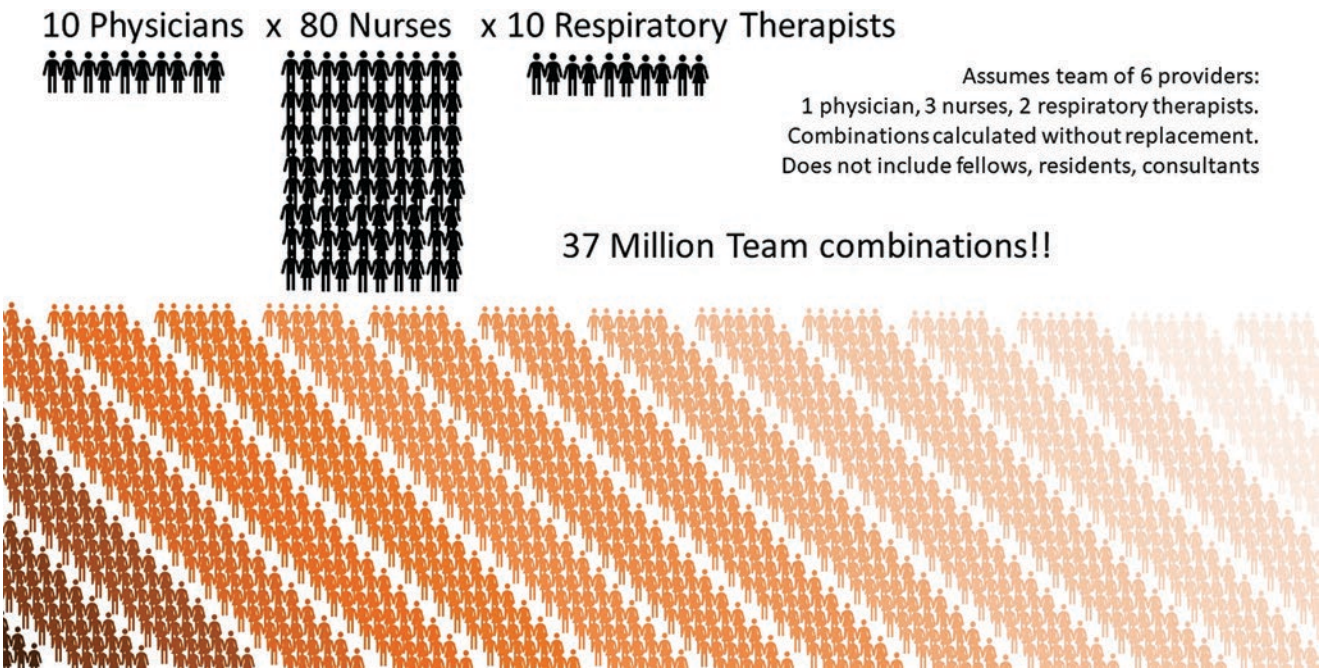

Fig. 19.1 Possible ad hoc emergency team combinations

psychology. There is often a blurred line between feedback and debriefing in medical education literature. For the purposes of this article, feedback involves returning data on performance to individuals (i.e. chest compression rate during a practice session) and generally comes from the facilitator to the participant. Debriefing is a guided, bi-directional conversation regarding the performance of both individuals and the team that drives further performance improvement and is a foundational element of the simulation learning process. For adult students, experience provides the primary source of learning; however, experience alone is not sufficient, and reflection on that experience leads to learning [14]. Post-event debriefing is often considered the most important part of the learning cycle [13, 15]. Multiple structures have been created for facilitators to follow (e.g., PEARLS, TeamGAINS and more) [16–20] however a complete review is out of the scope of this chapter. These structures can be helpful for facilitators to guide discussions and there is not sufficient evidence to support the use of one over another.

Debriefing during simulated experiences often occurs at the conclusion of a simulation event and these post-event debriefings can be either facilitator-guided or self-guided. In a recent review of simulation debriefing practices Sawyer et al. identified seven key elements for effective debriefing practice [21]. *Psychological Safety*, defined by Edmondson as "a shared belief held by members of a team that the team is safe for interpersonal risk-taking" is a foundational element to learning during simulation debriefing. The debriefing facilitator can lay groundwork of psychological safety with the use of the Basic Assumption. *The Basic Assumption* is a statement that sets the tone for the debriefing and puts all learners in the same frame of mind for the conversation to follow. *Establishing Rules* for the debriefing also can instill psychological safety. These often include the condition that all members should be active participants and that the discussion is for performance improvement and is confidential. *Establishing a Shared Mental Model* allows participants to review and ensure they have a shared understanding of the events that unfolded. *Addressing Key Learning Objectives* ensures that the educational highlights of the session are clear to all participants. It is important that the facilitator *Asks Open-Ended Questions* to encourage participation and understand the point of view of the participants. *Using Silence* is often important in the beginning of a debriefing session as it allows participants to reflect and self-assess. These seven elements are also key when translating post-event debriefing from the simulated environment to the clinical environment.

Translating from Simulation into Clinical Care

Debriefing After in Hospital Cardiac Arrest

Evidence Behind Value of Clinical Debriefing

A recent meta-analysis across disciplines of medicine, aviation, business and psychology has shown that teams that participate in debriefings after events have improved effec-

tiveness [22]. Debriefing after a clinical event can occur during two time frames. *Hot debriefings* occur in the minutes to hours following an emergency event and optimally include all members of the team present for the event. The goals of hot debriefings include allowing team members to diffuse emotions after a stressful event, establishing a mental model for the event and answering questions team members may have regarding how the event unfolded; and from a system standpoint identifying quality issues or latent safety threats that exist in the environment. Hot debriefings generally only include providers present for the event but are sometimes facilitated or attended by team members who were not present. *Cold debriefings* occur 1–4 weeks after a medical emergency or cardiac arrest and includes a comprehensive review of the events leading up to the cardiac arrest, quantitative data captured by the team and the outcome of the events. These debriefings ideally will include the members present at the event, but can also include non-participants, consultants and leadership. This structure allows non-participants to learn along with participants from rare clinical events.

For example, in order for hospitals and teams to improve CPR quality, it is critical to give them the ability to measure resuscitation quality and give that feedback to teams in real time, as well as in aggregate form after the event. Feedback enabled defibrillators give real time feedback to providers that includes data on chest compression rate, chest compression depth, and chest recoil, which has been shown to improve the chest compression quality delivered during simulated resuscitations [9, 23]. Data from these feedback enabled defibrillators can be downloaded or uploaded to a cloud environment, allowing the resuscitation leaders to review and track the quality of CPR provided across many resuscitation events. This data gathering and tracking allows institutions to understand their baseline CPR quality and specific opportunities for improvement.

Evidence exists that debriefing after clinical cardiopulmonary arrest events leads to improved performance in future events and clinical outcomes. Specifically, teams that debrief after events have demonstrated improved CPR performance including the delivery of high quality chest compression, decreased hands off compression times, and decreased delay to first compression [4, 24, 25]. These programs have also been associated with increased rates of return of spontaneous circulation as well as survival with good neurologic outcomes [4, 25]. This evidence has led the American Heart Association to recommend debriefing as a part of code response teams, however there exists little information on the best way to implement such programs. The following sections will present our experience with implementation of such programs and practical considerations when creating your own clinical debriefing program.

Hot Debriefing After IHCA

Hot debriefing after an IHCA or other emergency event is a natural extension of classic simulation debriefing sessions. It occurs in the minutes to hours after a resuscitation event and ideally includes all of the team members that were present for the event. While post-event debriefing is recommended by the American Heart Association, it infrequently occurs after resuscitations. A survey of Pediatric Emergency Medicine providers estimated that debriefings occur in their institution less than 50% of the time, and 91% of those surveyed were interested in learning more about post-event debriefing [26]. Institutions that have implemented hot debriefing programs report that debriefings are estimated to occur in 26–56% of all resuscitations (e.g. events including intubation), and 57–77% of events involving CPR [27, 28].

One concern regarding hot debriefings is the team's ability to accurately recall and address the events that occur during a resuscitation. Mullan et al. addressed this in a study of emergency medicine providers in institutions where teams perform hot debriefings and use video review of the resuscitations (intubations and CPR events). They found that the accuracy of debriefings improved over a 2-year period, with improvement from 84% to 91% accuracy in recalling time to defibrillator pad placement, epinephrine administration timing, and compression pause timing [29, 30].

In a multicenter, international CPR quality improvement collaborative Sweberg et al. described the content of hot debriefing sessions. Participants made positive comments about cooperation/coordination (60% of 108 events), communication (51%) and clinical standards (41%). Clinical standards addressed included correct applications of algorithms, medication errors, and delays in care. Areas needing improvement were mostly commonly cooperation/coordination (45% of 108 events), equipment (46%) and clinical standards (36%) [27].

Figure 19.2 depicts steps that simulation scientists and clinicians can use to develop a hot debriefing program within their hospital or unit. We recommend that centers that intend to implement a hot debriefing program develop or adapt a standard debriefing tool for providers to use. See Fig. 19.3 for generic example of a debriefing form that providers can consider; providers should discuss any new debriefing hospital form with their local legal team, as state and country medicolegal considerations may need to be taken into account for hospital forms. The tool should be paired with education providing a basic understanding of debriefing practice and the goals of the sessions with all providers expected to participate. Additional training for providers expected to lead the sessions is also ideal and should be brief and focused to the clinical provider, as described by Eaton et al. [31]. Eaton's group developed a short, 20-minute video that was well received by their clinical teams. Developing a system to collect and organize the content that

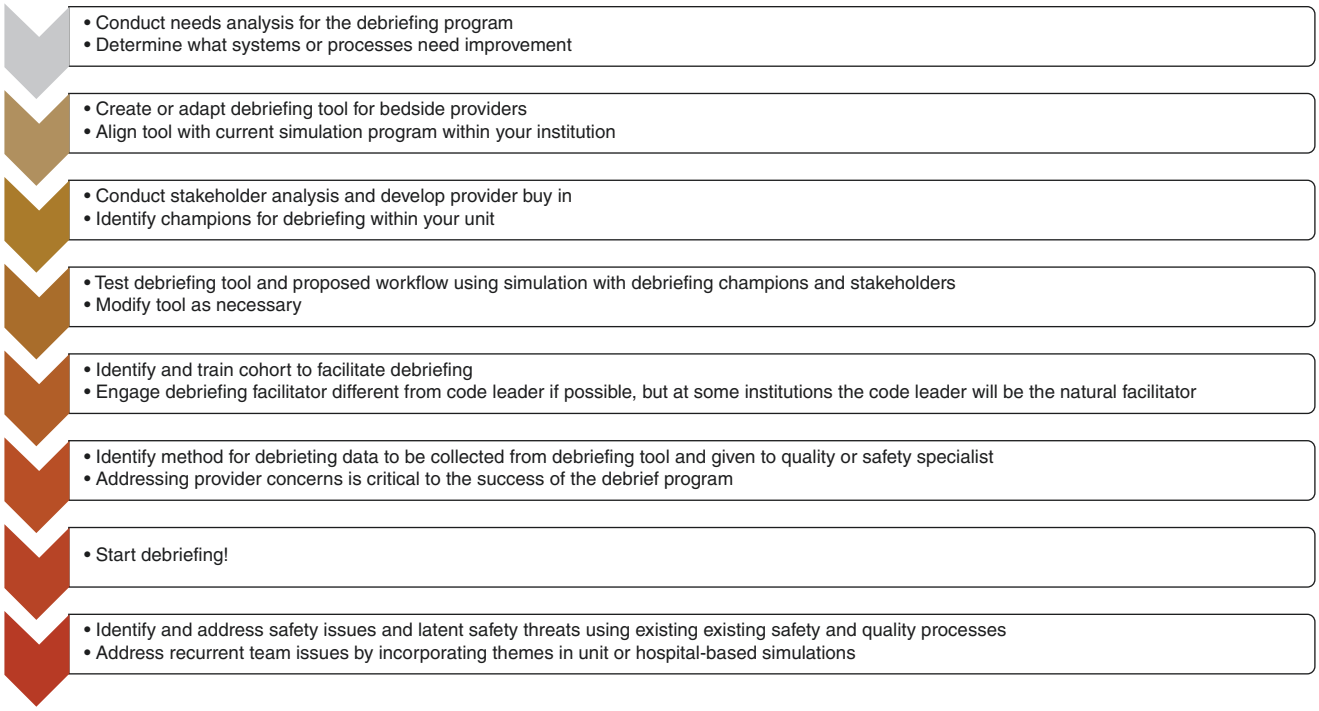

Fig. 19.2 Steps to start a hot debrief program

Example Hot Debriefing Form

Announce:
1. Try to find a quiet, isolated place. Anyone present during the event may lead the debriefing. Debriefing leader should start by thanking team members for being present.
2. State: "the purpose of debriefing is to improve the quality of medical care; it is not a blaming session. Everyone's participation is welcome and encouraged."
3. State "We will briefly review the patient's summary and then we can discuss what went well and what could have gone better. Please feel free to ask any questions."
4.State: "All information discussed during the debriefing is confidential."
5. Please limit tdeberiefing to 10 minutes

Ptient MRN:	
Date (MM/DD/YY):	
Location in Hospital:	

What went well during our care for the patient? Why? please select all that apply and add comments as necessary.

	Clinical care (ex. airway, access, CPR)
	Teamwork
	Communication
	Leadership
	Other (pleasw specify):

What could have improved during our care for the patient? What are potential solutions? Please select all that apply and add comments as necessary.

	Clinical care (ex. airway, access, CPR)
	Teamwork
	Communication
	Leadership
	Other (pleasw specify):

This form is NOT a part of the medical record.

Fig. 19.3 Example of a hot debriefing form

comes out of the debriefing sessions is important to be able to follow trends across events as well as follow up about issues raised. Also, having a system to provide the information gained to frontline care providers may assist with program buy-in and participation. Finally, clinical events that are debriefed may unearth strong emotional reactions; clinical debriefers should be aware of hospital resources for clinicians who need additional assistance and refer them to these resources or their clinical supervisors when additional assistance is required.

The following barriers and facilitators of hot debriefing programs should be considered:

Barriers to Implementation of Hot Debriefing Programs

1. Time – During a resuscitation, the team participating has often been pulled away from other clinical care responsibilities for an hour or more. Providers often feel the need to care for other patients or initiate post cardiac arrest care for a patient who has survived is more important than the debriefing. Keeping hot debriefings short (5–10 minutes at most) can help teams understand that this important activity will not delay other care significantly. When a patient survives the event and needs continued care by the team, scheduling and announcing a time for the debriefing should occur prior to the team disbanding and be performed before the end of that clinical shift.
2. Space – Hot debriefings can occur in the space the event occurred, or in another location in the clinical unit. Many hospital units do not have private, HIPPA protected spaces readily available close to clinical care. Identifying a consistent space for debriefings can assist the team.
3. Buy-in – Early in the implementation process providers may resist participating in hot debriefing sessions, out of concerns of ridicule or lack of belief that the debriefing process will be useful. Ensuring psychological safety and providing feedback to teams about changes or resolution to issues raised can help improve buy-in over time.

Facilitators to implementation of hot debriefing programs

1. Identification of both nursing and physician debriefing champions is key to the program's success. These champions should have some background in debriefing, often stemming from experience with simulation programs or an educational background and ideally should be senior level staff in the unit. It is important to cultivate and train champions that are present both during the daytime and nighttime, as events happen 24 hours a day.
2. A standard debriefing structure or script helps the facilitator lead the session and allows the team members to have a mental model of what will occur during the debriefing. Examples of hot debriefing scripts have been published and can be used as guides for local adaptation [28, 32, 33].
3. Training for debriefing facilitators
4. Leadership support
5. Follow up on important issues raised. Buy in will come when teams realize that actionable items are acted upon (i.e. the broken ultrasound machine is fixed). This requires follow up and a system to ensure that the issues raised are documented, addressed and the resolution is fed back to the clinical team.
6. Structured program for follow up for individuals having a difficult time emotionally after an emergency event. Nearly all hospitals have employee assistance programs available to staff and some have emergency assistance teams that can assist with emotional and psychological support for particularly difficult cases. Ensuring leaders know to refer those having difficulties and participants know how to access these programs is key. Some people will be reluctant to be debriefing facilitators if they believe that they have sole responsibility to deal with individuals experiencing duress. Developing a system for referral and follow up can help alleviate this stress for potential facilitators.

Difficult situations in hot debriefings

1. Death – the death of a patient is often devastating, and the debriefing may focus primarily on helping participants reflect and process emotions. A review of the clinical circumstances and medical interventions may help the team members better understand what happened during the event. Despite the challenging situation, it is important that the team at identify if any latent safety threats were present during the event so that they can be reviewed and rectified. It is important to take care to avoid action being translated as blame of any member of the team for the death.
2. The silent participant – unlike debriefing after simulated scenarios, our opinion is that not all who are present for a hot debriefing should be required to talk or participate. There is potential for the event to have triggered some past trauma and forcing conversation from that participant may lead to further emotional duress. If a participant is noted to be having a particularly difficult time after an event, follow up should be provided by the team leader or appropriate clinical staff (i.e. charge nurse, social worker) and the participant referred to appropriate hospital resources.

For further information about types of difficult debriefings and facilitation strategies for challenging debriefing situations we recommend "Difficult debriefing situations: a toolbox for simulation educators" by Grant et al. [34]

Cold Debriefing after IHCA

Cold debriefing is a larger leap from the traditional simulation practice where the entire learning experience occurs during one session. The delay between the event and the cold debriefing session allows time for: (1) participants to process emotions that often prevent clear reflection about an event (2) the debriefing team to collect quantitative data for review (i.e. the code sheet, data from physiologic monitors, data from feedback enabled defibrillators) and (3) the debriefing team to review systems issues and any resolution of those issues. Of course, the drawback is that more time from the

event can blur the participants' memory of the event. This makes it imperative that members of the cold debriefing team discuss the event with the participants within a few days after an event and refer to the hot debriefing information (if it exists). The addition of quantitative data from the review will often offset the memory degradation of the group. Outside of a few sporadic reported programs there is currently scarce information published regarding the frequency of cold debriefings in medical practice [4, 25, 35, 36].

Debriefings are built on the foundation of psychological safety, the knowledge that adult learners want to learn from mistakes and successes, and that actual clinical cardiac arrest events are relatively rare for any given member of a team. Many cold debriefing forums include participants that were not present at the actual event. The inclusion of non-code participants is important, as in many institutions cardiac arrests are rare events and this allows a larger group to learn even if they did not personally participate in an event. The inclusion of non-participants in cold debriefing sessions makes psychological safety even more important, as fear of criticism from non-participants may inhibit rich discussion of the event or drive away attendees.

It is important to set up a structure in the beginning of the debriefing that lays out the Basic Assumption and clarifies that the goals of the debriefing are to have open, honest, and respectful communication regarding performance and common understanding that all providers seek opportunities for improvement. The facilitator for cold debriefing sessions should have high emotional intelligence and facilitation skills that ensure psychological safety is maintained throughout the debriefing. As a program builds, and participants over time realize that the meeting is a safe space, the fears regarding these discussions often are diminished. It is important to balance discussions of suboptimal performance with highlights of exemplary performance, or 'what went well'. For instance, a team that was able to provide high quality chest compressions and have short pre-shock pauses can discuss how they were able to operationalize that in the code. When discussing sup-optimal performance or 'what could be improved/gone better", the focus isn't on criticism of the performance, but on how other teams have dealt with similar issues or ideas the group has to improve performance in the future or how systems can be redesigned to ensure future improved performance.

Barriers to implementation of cold debriefing programs

1. Time: Many units have busy schedules and finding time for a multidisciplinary group of physicians, advanced providers, nurses, and respiratory therapists to meet on a regular basis is challenging. The process of reviewing an event, gathering data and compiling this information into a logical presentation can take between 2 and 6 hours depending on the event and availability of data. The leader of the debriefing program must be highly motivated and enlist help to maintain this workload and will need protected time to do so.
2. Buy-in: Introduction of a new conference or meeting is challenging for providers. Incorporating cold debriefing sessions into already scheduled conferences (case conference, morbidity and mortality conference) is sometimes successful to encourage attendance
3. Space: Finding a space that is large enough to hold a medium to large size conference that is close to the clinical space can be challenging.

Facilitators of implementation of cold debriefing programs

1. Stimulating content: Make the session interesting and educational; the inherent curiosity of clinicians will often draw them to these meetings. To maintain attendance at these sessions is it important to facilitate high level discussions about patient physiology, new science and system processes affecting the clinical space.
2. Standardized debriefing structure and triggers for which events are debriefed: This can help streamline the meeting flow.
3. Ongoing educational credits: Cold debriefing programs are a great fit for physician part 4 maintenance certification as the outcomes of the conversations in debriefing lead to unit wide changes the entire group will work to implement.
4. Psychologically safe environment
5. Leadership support: Key divisional and resuscitation leadership presence at these meetings and support of the programs can improve buy-in from the rest of the group.

Difficult situations in cold debriefing

1. Significant medical error discovered: Rarely, significant errors are uncovered in the process of a detailed review of a resuscitation or clinical event. This error should be explored using root cause analysis, or other hospital system that is established for dealing with medical error or unanticipated patient harm. The error should be disclosed to the team and discussed with providers in a private one on one meeting. Debriefing this event with a larger group should be done with great respect for the team that participated, and often can be delayed until the results of the root cause analysis or investigation are known, so a systems level analysis of the solutions can be provided.
2. Death of a patient: Often in ICUs, particularly pediatric ICUs, patients may stay or return to units over months or years dealing with complex chronic critical illness or technology dependence. Some long-term patients die despite receiving the best medical care and deciding when to stop resuscitation or specific therapies can be difficult

for the team. Team members often become attached to these patients and their families and the review of these codes should be sensitive to the challenging emotional layers that this adds to the debriefing of the cardiac arrest or other emergency.

Next Steps

Implementation of hot and cold debriefing programs should be optimally done in the context of a comprehensive resuscitation program. Most hospitals will have a "code committee" or "resuscitation committee". Linking the output from debriefing programs to this committee structure is beneficial because these committees often have the resources and hospital support to remediate latent safety threats to the work of code teams that are identified, such as faulty equipment, lack of supplies, staffing. Similar programs have been shown to lead to impactful operational changes in hospitals such as educational initiatives, modification of policies/procedures and staffing models, and changes in equipment [36]. Evidence of the benefit that comes from these programs is key to enlist support of the hospital leadership and provide resources for such a project that can be time intensive. Keeping detailed records regarding issues identified and resolved can help garner such support.

The practice of transferring post-event debriefing from simulation to the bedside for actual clinical situations continues to evolve, and more research regarding structure, content, and best practices is needed. Combining simulation debriefing education with hot debriefing after clinical events within an institution can optimize the use of resources and increase the number of clinicians trained to debrief in both simulation and clinical care. The development of formal training programs for training on debriefing models, such as the hot and cold models, is the next evolutionary step for simulation in healthcare.

In conclusion, we believe that engraining debriefing after clinical events can improve care provided by resuscitation teams and improve patient outcomes. Incorporating debriefing into resuscitation programs and improving educational programs for clinicians who are expected to facilitate debriefings can help us improve patient care.

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Simulation in Unique Surgical Challenges

20

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Introduction

Several attributes are unique to simulation as a mode of learning, including the safety of a simulated environment, repeatability until mastery is attained, and flexibility to manipulate the environment. These positive traits make simulation quite useful for special challenges in medicine.

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Unique scenarios such as long-distance transport of a critically ill infant on extracorporeal membrane oxygenation (ECMO), surgical separation of conjoined twins, or a bilateral hand transplant in a child present challenges that are not encountered frequently. Healthcare teams involved in these complex procedures can benefit from opportunities to practice these tasks in simulated environments and benefit from the unique interactions that occur during the simulations. Simulation allows clinicians to achieve task mastery through practice and repetition while simultaneously identifying critical steps and areas of team improvement in clinical work. Simulation also allows clinical workers to practice their adaptive capacity and responses to work system variations and pressures that impact the delivery of clinical care.

Patients with unique medical needs pose additional challenges and questions that can be identified and addressed through simulation:

- How can a medical transport team prepare a platform capable of transporting a critically ill child on extracorporeal circulation across the Pacific Ocean?
- How can a team prepare an operating room for the separation of conjoined twins?
- How can a transplant surgeon identify whether an organ donor's hands are the appropriate size for a recipient child?

Each of these questions highlights a critical component from these scenarios. In this chapter, we will explain how simulation was used to answer these questions and the subsequent iterative approach that led to mastery in clinical practice. Mastery of skills was also influenced by recognition of environmental factors that were later addressed to support the goals of each unique scenario. Furthermore, we will discuss the role of additive manufacturing, also known as three-dimensional (3D) printing, in the design of anatomic models that can be applied for these unique simulation scenarios.

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Medical Transport of a Critically Ill Child Requiring Extracorporeal Membrane Oxygenation

Simulation played a critical role in the development and testing of the platform to support a pediatric patient on ECMO during long-distance transport. Patients are placed on ECMO for either respiratory, cardiac, or cardiorespiratory failure. ECMO) is a complex process that requires precise coordination and teamwork because of the intensive, hands-on medical needs of the patient and the complexity of the medical equipment. Multiple simulated scenarios were utilized to both build and test a transport platform capable of supporting a critically ill pediatric patient to be conveyed from the referring hospital to the destination hospital via fixed-wing, helicopter, or ground transportation.

Transport challenges included the vast amount of equipment required to support the patient. The patient was intubated and on a mechanical ventilator and would require multiple infusion pumps to deliver medications, including anticoagulants, via central and arterial catheters; a Foley urinary catheter; and a patient monitor capable of invasive blood pressure measurements, central venous pressure measurements, and full cardiorespiratory monitoring. The equipment for the ECMO) circuit included a roller or centrifugal pump, membrane oxygenator, heat exchanger, and the arterial and venous cannulae which connect the patient to the ECMO circuit. Not only can this medical equipment be bulky and heavy, but it also requires safe and steady attachment to the transport platform. In addition, all equipment must be easily accessible to the medical team, allowing for easy access to the patient within a confined transport space.

We initially used simulation during the build-out phase of the project. The first simulation model consisted of an intubated infant manikin. The manikin was fitted unprimed ECMO cannulae, and central venous and arterial catheters. The manikin and supportive equipment was placed in various positions on the platform. The array of equipment was distributed around the manikin based on its role and required proximity to the patient (Fig. 20.1a). This step was repeated multiple times, with multiple arrangements and each iteration was evaluated for weight distribution, ease of equipment access, equipment immediacy to the patient, and stability of equipment and manikin.

Once a specific arrangement was settled upon, the next phase included simulated scenarios of either routine or emergency tasks required to care for either the patient, the ECMO circuit, or both. For example, could the patient have their endotracheal tube routinely suctioned, without disrupting the neck cannulae? Was it possible to change a syringe or reprogram a syringe pump easily? Could the ECMO specialist examine the circuit, looking for clots, readily and often? The teams also practiced emergency scenarios, including an ECMO circuit oxygenator failure, which requires a rapid change of the oxygenator. This would require swift recognition and management of the circuit and the patient, which could include potential adjustments to ventilator settings, or switching the patient from the ventilator to a manual bag-mask ventilation tool, or administration of high-risk medications or performing CPR in the event of cardiac arrest. In each scenario, the actions were demonstrated on the low-fidelity manikin or the circuit components, in real-time and with real medical equipment. Timing, ease of accomplishing tasks, and success were discussed during and after each scenario. Even at this early stage of the project, the overall transport platform's design was evaluated and changes were made to the organizational schema of the platform. Finally, the mobility of the transport platform with an attached patient were tested. The platform was maneuvered in and out of buildings and onto an aircraft or an ambulance. The biggest challenge of this phase was the overall weight of the platform, and the ability to keep it steady during lifting and angling, so as not to disrupt any equipment or connections while keeping the patient safe and comfortable. Utilizing a simulated patient, this could be practiced multiple times, without putting a real critically ill patient at risk (Fig. 20.1b).

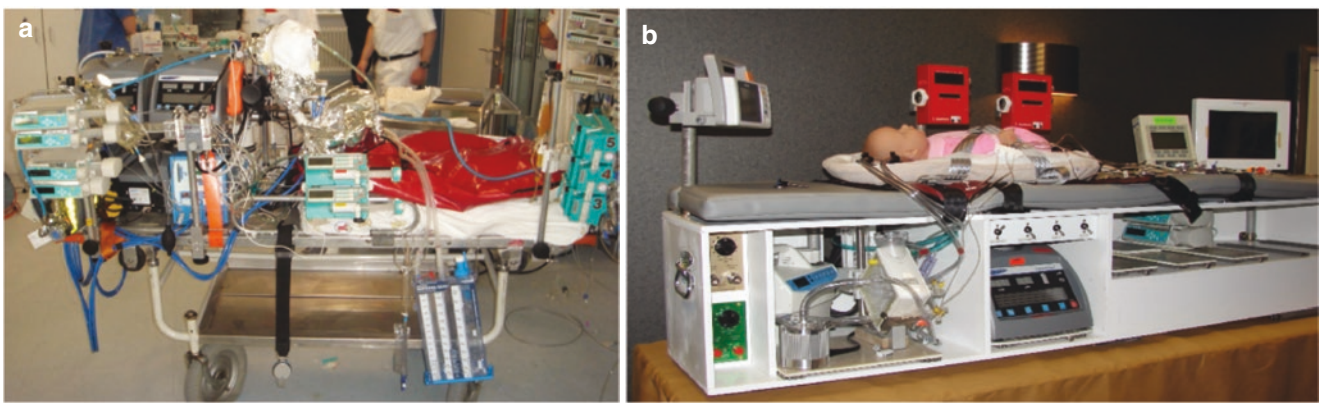

Fig. 20.1 (**a**) Early prototype of the infant transport platform that incorporates an extracorporeal membrane oxygenation device, infusion pumps, foley catheter, chest tube and simulated patient. (**b**) Finalized platform to support patient care including extracorporeal membrane oxygenation, medication delivery, and patient monitoring during long-distance transport. The platform was configured to fit in fixed-wing aircraft

A final phase included the evaluation of teamwork, with the goal of achieving an efficient and balanced workflow. The transport platform design needed to facilitate the best workflow possible in a restricted space since the transport of this patient could be in an ambulance, helicopter, or fixed-wing aircraft. Again, both routine and emergency scenarios were simulated, and the team discussed and practiced the ability to work together effectively, including positioning of team members in relation to the platform and the patient. Communication strategies, and roles of each team member were also critically evaluated during these simulations. The latter task was especially important, as the confining space may not allow for ready movement around the platform; team members had to clearly understand their role and the associated medical tasks assigned to their role. This step also included evaluating the location of ancillary equipment and resources in proximity to the transport platform and the team members. For example, if a bag of intravenous fluid was needed for the patient, where was the best place for it to be stored? How readily could the transport nurse access the sedation medications to prepare and administer medications to the patient?

This narrative describes a seemingly simple yet quite powerful use of medical simulation. Transport of a critically ill patient on ECMO requires the coordination and intertwining of a complex system of equipment, a patient, and various team members in an incredibly high stakes situation, and is daunting. Utilizing simulation to evaluate the platform build-out and test the equipment and the interplay among team, equipment, and patient was a unique use of simulation to create a system capable of providing safe and timely long-distance transport for critically ill children and infants.

Additive Manufacturing to Improve Healthcare Delivery

3D printing, also known as additive manufacturing, has been used increasingly in medical applications ranging from surgical planning to patient education to medical device prototyping. Computer tomography or magnetic resonance imaging are used to obtain electronic images of a patient's anatomy. Using computer software, areas of interest are selected from each individual image which are then compiled together to create a 3D rendering based on the patient's anatomy [1] (Fig. 20.2a). Software applications that specialize in 3D image processing for additive manufacturing include 3D Slicer (https://www.slicer.org/), an open-source platform, and Mimics (Materialise, Leuven Belgium). [A] The final model is exported as a stereolithography (STL) file, and can be processed with a 3D printer to create a physical 3D representation of the digital anatomic model. The 3D model can be printed to scale, and its properties are dependent on the printing process and materials [2]. The U.S. National Institute of Health promotes scientific collaboration in this field with a 3D print exchange (https://3dprint.nih.gov) where the scientific community can share models that are processed and compatible with 3D printers (Fig. 20.2b).

While 3D printing provides a physical representation of the anatomic model, it is also possible to explore the anatomic model in digital form. Segmentation software can be used to measure and dissect the anatomic model to guide surgical planning. Precise osteotomy locations can be measured and plates can be designed in advance of surgery to fit the bone and surgical cut planes precisely.

Types of 3D Printers

Additive manufacturing is a process that relies on the precise deposition of material in successive layers to form a 3D structure. 3D printers use a variety of materials for the model and the structure that is required to support the model during the printing process. The four methods of additive manufacturing are fused deposition modeling, inkjet printing, STL, and powder bed fusion [3]. Fused deposition modeling uses a heated nozzle to melt a filament that is laid down in successive layers to form a 3D structure. These printers create a support matrix for overhanging or hollow areas of the model (Fig. 20.2c) [4]. An advantage of inkjet printers is that they can use more than one material to create the model and support structure. STL and powder bed fusion are more complicated systems that use a laser source to cure liquid or powder raw material into a solid form. One advantage of STL and powder bed fusion systems is that support materials are not required because each layer is supported by the powder or liquid material and the printing platform. As the laser cures the powder or liquid, the solid model remains covered and supported in the liquid or powder base, which can be cleaned off easily in the finished product. In contrast, fused deposition and inkjet printers produce a model with denser support material that must be removed or else residue will remain on the final model. Hollow structures such as body cavities and blood vessels may require post-printing processing to ensure the desired model fidelity is achieved.

A 3D printer has constraints on the size of the models that can be printed. The maximum size depends on the surface area of the printing platform and the maximum height above the printing platform. However, a desired model that is larger than the printing surface can be printed as smaller components for later assembly. The minimum size and resolution of the 3D model depends on the material and deposition system. Generally speaking, large models require significantly more time and material to print than smaller models. Pediatric

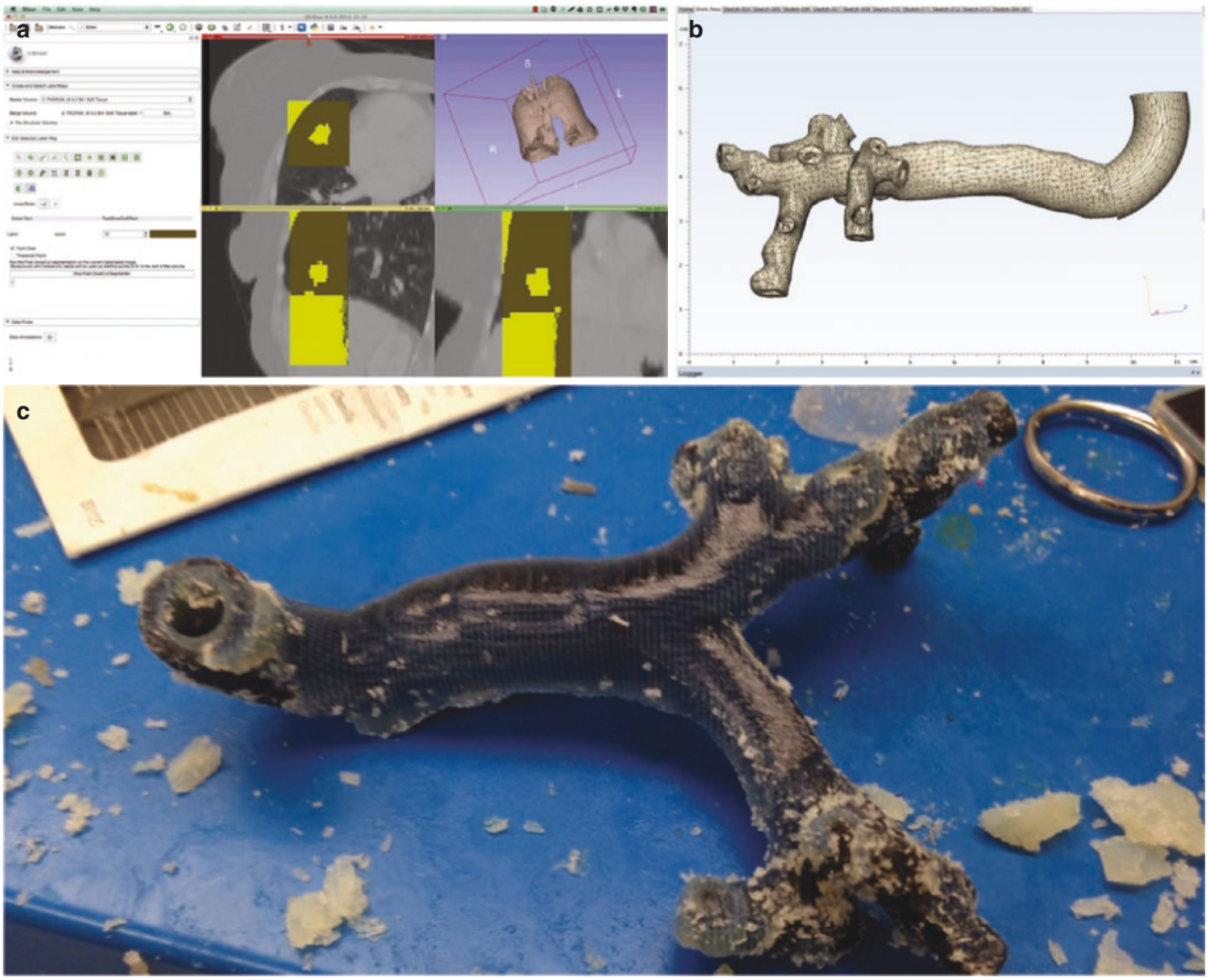

Fig. 20.2 (**a**) Image segmentation software (https://www.slicer.org/; an open-source platform) allows selection of regions of interest from diagnostic imaging studies such as the magnetic resonance imaging of the chest shown in panel (**a**). (**b**) A rendering of the trachea in stereolithography format (STL), the standard file format that enables three-dimensional printers to process the imaging file (https://3dprint.nih.gov) and create a high-fidelity print (shown in panel **c**). Note the support material that is being removed from the tracheobronchial model (black)

models are appealing because they are typically smaller and thus printed more efficiently.

The U.S. Food and Drug Administration (FDA) regulates medical devices and has provided documents for device regulation and guidance for 3D printing of medical devices (https://www.fda.gov/downloads/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/UCM499809.pdf). The FDA also regulates image processing software and the resultant anatomic models that can be used for procedural planning (https://www.materialise.com/en/press-releases/materialise-first-company-to-receive-fda-clearance-for-diagnostic-3d-printed-models), and in 2017, the FDA designated image processing software for 3D modeling as a class II medical device if the models are intended for diagnostic purposes.

Craniopagus Conjoined Twin Separation

Craniopagus conjoined twins have a rare defect that occurs in approximately 0.6 out of 1 million births [5]. The craniopagus classification indicates a partial or complete fusion of the skin, skull, dura or even cerebral vasculature or parenchyma [6]. Providing care for conjoined twins poses a unique challenge in each case.

Simulation can be used to optimize teamwork and physical accommodations for both routine and surgical care of conjoined twins. Simulation of conjoined twins can be accomplished with low-fidelity models such as two infant manikins (or even dolls) glued to each other at the head, or high-fidelity models generated from magnetic resonance imaging and image segmentation for 3D

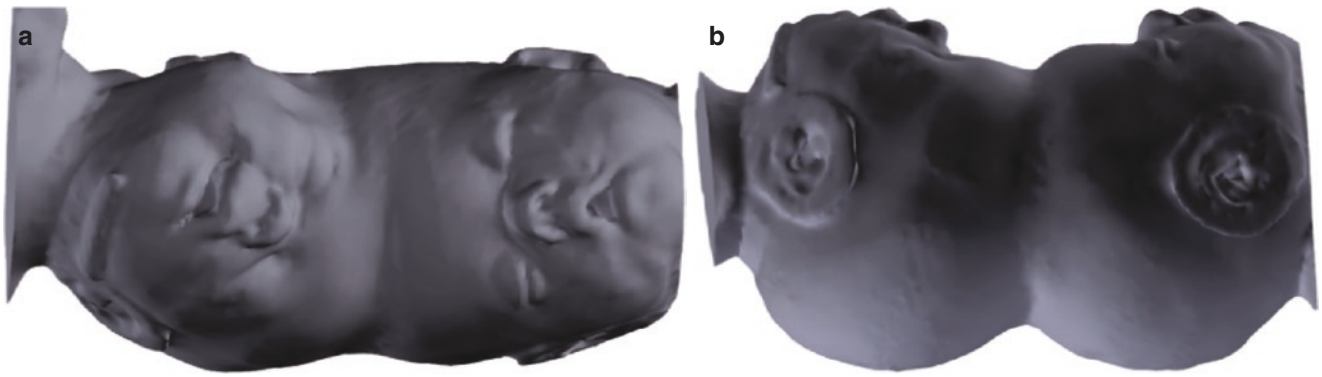

Fig. 20.3 (**a**) Surface rendering of craniopagus twins based on magnetic resonance imaging. Note the orientation is at a slight lateral angle. (**b**) Shows the lateral view of the same surface rendering

printing. Preparation of the clinical care areas requires meticulous attention to positioning devices to ensure that each of the twins is safely positioned to minimize patient injuries or harm. Supportive medical equipment including airway support devices, intravenous fluid lines, and monitoring equipment cables need to be carefully organized. Clinical care areas typically designed to care for one patient need to be re-designed to allow twice the number of medical devices, including physiologic monitors, infusion equipment and ventilators or anesthesia machines. Clinical personnel also need to become familiar with the organization of the shared workspace that is designed around the twins.

Clinical teams caring for conjoined twins are typically scheduled in a manner that provides continuity of care for each of the diagnostic and therapeutic procedures the twins undergo from birth until surgical separation. Procedures such as intubation and surgical separation are simulated multiple times to identify problem areas such as patient positioning, the sequence of events during airway management, vascular access, sterile preparation and organization of monitoring and patient support equipment.

Airway management can be particularly challenging during the surgical separation of conjoined twins. Simulation was used to define provider roles and arrange the various devices attached to the twins so that access and sterility were preserved at the time of surgical separation (Fig. 20.3a, b). Because these craniopagus twins were fused at a slight angle, one twin's head was slightly elevated so a 3-D printed [7] model of the twins' heads was used to optimize the patient's positioning devices in the operating room prior to the patient's arrival. Furthermore, the anesthesiologists in charge of providing mask ventilation and intubating each twin were able to practice their hand and mask placement in a low-stakes environment (Fig. 20.4). The lessons learned from the simulations were applied to the care of the twins through the time of separation.

Fig. 20.4 Anesthesiologists during induction of anesthesia. The anesthesiologist on the left is performing mask ventilation (on left) while the anesthesiologist on the right is performing video laryngoscopy simultaneously. The patient positioning and procedure was refined iteratively with low- and high-fidelity simulators

Bilateral Hand Transplant

A child undergoing a bilateral hand transplantation operation poses a unique challenge to the clinical team. We present the case of an 8-year old child evaluated for bilateral hand transplantation after previous amputation of both hands due to infection [8]. The surgical procedure requires extensive planning to assure precise coordination and timing between four surgical teams. The teams need to work in parallel to prepare the donor hands as well as the recipient's arms in a race against time to minimize the ischemia time for the donor allografts, thus maximizing the chance of a successful operation. Preparation also includes evaluating the size, shape and skin color of both the donor's hands and the recipient's arms to ensure that the donor hands are a good match [9].

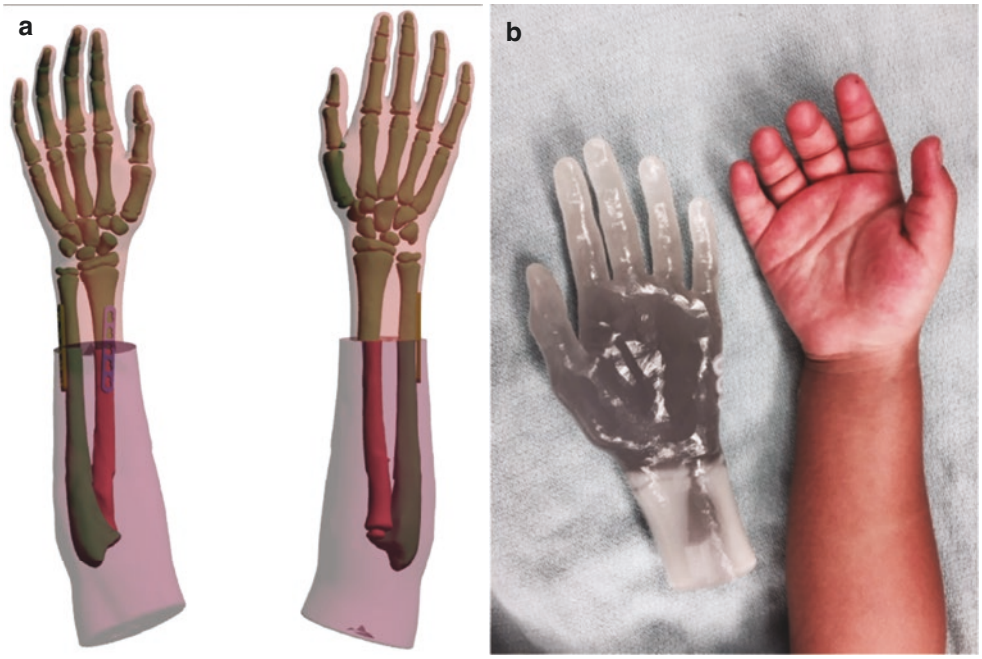

Fig. 20.5 (**a**) Anatomic models rendered in three-dimensional segmentation software (Mimics, Materialise, Leuven, Belgium). The recipient's forearms and respective ulna (blue) and radius (red) are shown attached to the donor's radius and ulna with a surgical plate. The plate size and screw positions were identified in the software suite prior to printing the anatomic models. (**b**) 3D printed hand model compared to the donor hand prior to activation of the transplantation team. The donor hand was an identical match. (Reproduced with permission of Ref. [8])

The surgical simulation began with the development of a 3D printed model of the recipient's forearms. The anatomic model was developed with image segmentation software (Materialise, Mimics, Leuven, Belgium), and used to determine the optimal site for the osteotomy and plate placement (Fig. 20.5a). Based on the model, the surgeons designed customized cutting guides to match the recipient's radius and ulna. The respective models of the radius, ulna and forearm were employed iteratively during surgical simulations of the transplantation procedure.

Using the same image segmentation software, a hand model was printed to match the recipient's forearm. The hand model was printed in three sizes (80%, 100%, and 120%) of the desired size as identified by the hand transplant surgeons. The hands were used during the simulation of the surgical procedures. Once a suitable donor was identified, the surgical team compared the donor's hands with the 3D printed models to ensure that the hand size was optimally matched to the recipient (Fig. 20.5b), because a donor allograft size mismatch could affect the functional recovery of the hands after transplantation. If the donor's hands are too large, the recipient's musculature may not be able to move the hand, and the hands' function may also be affected.

The surgical team was able to save critical time during the transplantation by practicing the surgery numerous times with 3D printed and cadaveric models [10]. One of the critical processes simulated multiple times involved the application of the custom plates to each of the donor's hands at the radius and ulna at the time of the harvest [11]. Each of the surgical teams used the corresponding customized cutting guide to make matching osteotomies on the respective radius and ulna. When the donor's hands were brought to the recipient, the plates were already in place on the donor's radius and ulna and readily aligned with the recipients' radius and ulna. The surgeons were able to efficiently attach the bones with the plate and promptly resume the microvascular anastomosis to restore blood flow to the hand allografts. Historically, this process could be prolonged if the osteotomies were not an identical match.

Lastly, hand models that were used to assess the donor's hands for a match were also used to create hand prosthetics for the donor. These prostheses were provided to the donor to honor and respect their gift.

Summary

Simulation continues to play an integral role in medicine. We describe a framework that incorporates medical simulation to address unique scenarios in medicine. Technological developments including 3D printing and rapid prototyping can provide tools to achieve high-fidelity simulation. Healthcare teams participating in simulation practice for unique environments have opportunities to identify challenges ahead of time.

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The Use of Simulation in Disaster Medicine Preparedness

21

Alison R. Perate, David L. Rodgers, Daniel J. Scherzer, and Joy L. Collins

Within minutes of learning that a mass shooting was in progress October 1st 2017, the staff of Sunrise Hospital in Las Vegas began the process of clearing trauma rooms, preparing operating rooms, relocating patients, calling in personnel, mobilizing blood products and unpacking resuscitation equipment [1].

Mass casualty events are high-impact events that have been occurring at an increasing rate over the last 15 years [2]. These events include natural disasters, such as earthquakes and tornadoes; unfortunate events, such as transportation crashes and building fires; and man-made terror events, such as mass shootings and explosions. Mass casualty events are categorized as disasters when they overwhelm routine resources. Thus, an inherent difficulty in disaster preparedness is the need to utilize resources that extend beyond the routine. Simulation can create familiarity with highly stressful situations that would require responders to apply their knowledge, make decisions, perform actions, and sustain their capabilities. Disaster training can help individuals gain knowledge about potential disasters, become proficient with implementing existing protocols, learn how to access additional resources, rehearse forming ad hoc teams, and practice functioning in dynamic distracting environments.

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Preparatory exercises for teams and institutions, such as tabletop and full-scale live drill simulations, have been utilized by hospitals and regional and federal agencies for many years. Live drill simulation is ideal for education and training in disaster medicine due to the realistic reproduction of an environment that requires medical reaction and concurrently provides information about the effect of patient surges and resultant resource depletions. However, preparing via live drill disaster training can be costly and time-consuming, and requires extensive planning. Furthermore, because of the unpredictability of mass casualty events, it is difficult to predict training needs and assess the effectiveness of training.

In addition to tabletop exercises and full-scale live simulation, traditional educational materials for individuals and institutions include written resources, webinars, and lectures. As the fields of both disaster medicine and simulation have rapidly advanced, and new simulation technologies have emerged, multiple platforms for disaster medicine training have been developed that are not cost-prohibitive nor labor intensive. This chapter will address disaster preparedness simulations divided into the following simulation categories: Computer, Paper, and Live simulations.

Computer Simulations

It is impossible, dangerous, or prohibitively expensive to conduct full-scale live simulations of a collapsed building, a raging fire, or a panicked crowd. At a less dramatic level, the same challenges are present when simulating a hospital's preparation for a mass casualty incident. Technological innovations, however, have made computer-based training for such events a possibility. Utilizing web-based platforms for group and interfacility exercises can eliminate some issues with scheduling and coordination barriers that plague current tabletop and live simulation exercises. Computer-based simulations can be injected into a curriculum that also includes tabletop exercises and full-scale live simulations.

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Computer-based technologies that are being adapted for facility disaster preparedness include screen-based simulation, virtual reality (VR) and multi-modal simulation. These modalities have been used to deliver content and to provide platforms for knowledge and skills application for individuals and multiple users. For the most part, the targeted learners have been first responders such as fire, emergency medical service (EMS) and law enforcement personnel. Recently, these technologies have been used as educational tools in medical education for both novice and experienced learners [2]. Exercises can be designed with unique objectives for different audiences (e.g., medical students, attending physicians, first responders). These exercises are increasingly associated with scoring rubrics and can be characterized as "serious games."

Screen-Based Simulation

Screen-based simulations (SBS) are the most common type of computer-based simulation and may be targeted to individuals or groups with multiple users or incorporated into multi-modal simulations. SBS are web-based and, when targeted to individuals, can be accessed via the participant's personal computer without geographical or time constraints. These programs are designed to teach and/or assess particular skillsets that fit into the broader scope of disaster management and are usually directed towards specific disciplines.

The University of Minnesota developed a screen-based serious game to assess knowledge and decision-making skills for public health officials and hospital administrators [3]. The game's objectives are similar to those of a tabletop exercise, but participants engage on their own time as individuals via their personal computers. Participants do not interact with other individuals, but the decisions they make engender standardized responses from reality-based characters within the program. The computer-generated simulation provides news reports, visual graphics, and audio such as weather sounds, crowd murmuring and telephone ringing. PennState Health's Hershey Medical Center has a similar program that allows an interactive incident command team to respond to a disaster with news cast updates and scene communications [4].

Screen-based patients can also be developed from the descriptions and timelines of actual patients [5] Commercially available software injects storylines, photographs, and sound to provide realistic scenarios [6] which can target specific aspects of the disaster response. Each stage, such as correct and efficient triage, can be individually drilled and analyzed. This form of simulation addressing pediatric disaster triage has been successfully tested on 1st and 2nd year medical students [6]. The program file is hosted on local learning management system software and tracks each player's actions and the time spent within each scenario.

Single-player screen-based serious game can also be utilized as a formative assessment tool [7]. Commercially available games provide various disaster triage scenarios [7]. EMS providers use this type of simulation to refine their ability to triage patients quickly and correctly in a mass casualty situation [7]. These can be used to measure and improve adherence to protocols and procedures. Players achieve scores based on a programmed rubric that considers accuracy and speed and receive in-game performance feedback immediately after completing each level.

Virtual Reality Simulation

VR is a more sophisticated interactive technology available for individuals [8]. One VR technique used a lab or specially outfitted environment comprised of a suite of sophisticated interactive technology known as a "cave automatic virtual environment" (CAVE) [8]. This type of enclosed VR environment is characterized by multiple projection screens, surround sound and wearable gear that enables the participant to perceive a 3-D and 360-degree view, hear intricate sounds and to feel haptic feedback. The wearable gear also provide feedback to the system as to the user's movements. In this project, the VR setting accommodated one participant at a time who interacted with "patients" represented by computer generated avatars. The VR environment and the avatars were programmed to mimic a contemporaneous live drill with moulaged standardized patients used to provide disaster triage training to Emergency Medicine residents.

Multi-user systems utilizing a virtual world provide the most realistic simulation of disaster scenarios outside of live drills [9]. This VR simulation utilizes a popular commercially available game engine to create the spatial imagery of a virtual online hospital that could be accessed via typical laptops. In these games, a screen-based virtual world is used to assess clinical decision-making and management skills among physicians. The virtual world is stable so that multiple users experience the effects of interacting with the world and with each other, in real-time within the world. If a participating physician examining a virtual patient (VP) in the ED decides to transfer the patient to another care area (such as the Intensive Care Unit) the ED physician is required to make direct transfer arrangements with the ICU physician. Only then can the patient be moved from one unit of the hospital to another. Participants are able to move through the hospital to accompany or provide continuing care for the patient. The online environment includes virtual casualties and virtual tools to simulate realistic limitations such as a finite number of beds and personnel. Critical actions, omissions and delays are recorded. This virtual environment (aka virtual world) is accessible via standard laptops. Participants interface with the environment via keyboard, mouse, and

headset. The headset is used to communicate with other participants using an in-world telephone system.

A VR-based approach which is accessible by multiple users via laptops, keyboards and headsets has been used for over a decade by municipal and federal agencies to train first responders in disaster management. This approach is similar in format to multiplayer online role-playing games. Participants using screen-based VR report high degrees of effectiveness, realism, and engagement. This is important, as using technology that is readily available and which participants are already familiar with, lends itself to dissemination and further extension into related fields. These serious games are used to rehearse incident command, communication rubrics, to improve familiarity with resources, and to create opportunities for problem-solving.

Multi-Modal Simulation

A particularly innovative and practical way to use computer-based simulation is as an adjunct to tabletop exercises. For example, the New York City Office of Emergency Management uses the Advanced Disaster Management Simulator (ADMS; ETC Simulation, Orlando, FL). In this case, the "simulator" is a series of interactive screen-based simulations presented within a large conference room. During didactics and tabletop exercises, small groups work through screen-based simulations. One person is assigned to man the interface (joystick) while others play roles such as incident commander, fact finders, coordinators, and advisors. The decisions of the management team are then translated into consequences that play out in the interactive simulation. These exercises are facilitated and debriefed.

Different levels of technological complexity can contribute to a curriculum that prepares hospital personnel for stressful events. At the simplest level, individuals can experience 360-degree video using a VR headset. The participant can hear audio from all directions and the headset detects as the participant looks up, down and all around, and thus provides the corresponding video fluently. This an observational experience that can be integrated with other educational modalities. Multiple participants or audience members can don headsets and experience the video simultaneously.

This 360-degree experience can be taken to the next level by adding a degree of interactivity. A facilitator can speak with the participant and add information to the scene in the form of text or photos at the participant's request. The facilitator or new information can prompt the participant(s) in decision making. Alternate endings to the scenario can be provided as a consequence of participant responses. For example, participants could witness the impact of an incorrect triage decision. To make the simulation more realistic, multi-user experiences in which participants interact with each other and with the environment are exemplified in screen-based role-playing games. Technology to combine a 360-degree experience with a multiplayer platform to create a healthcare game is still emerging, but demand is helping to drive its growth. Multiplayer video reality arenas comprise an emerging business. Players wear visual, audio, and haptic devices that interface with wireless signals from the arena program and from other players. Players can communicate and see each other as they interact within a virtual scene. Current programs are typically limited to escaping and shooting enemies (e.g., zombies), and the hardware is clunky. As the software becomes increasing capable of accommodating complex themes, and the hardware more accessible and user-friendly, it is economically friendly method of training that allows analysis of metrics.

Paper (or "Discussion-Based") Exercises

The development of a series of policies and procedures to be followed in the event of a disaster is a complex and monumental task. However, the larger job of evaluating the completeness and functionality of that plan is equally essential. As the cornerstone of initial plan organization and planning, discussion-based or "paper" exercises serve as a foundation for more complex exercise preparation and development. They are also invaluable tools to refine a disaster preparedness plan and prepare for its implementation.

Discussion-based exercises allow those tasked with disaster preparedness plans to:

- Evaluate the existing preparedness program
- Assess the capabilities of existing resources and identify any additional needed resources
- Identify planning and procedural deficiencies
- Develop new policies and procedures or amend existing ones
- Validate any new or recently changed procedures or plans
- Familiarize participants with current plans and procedures, and with their roles and responsibilities within those plans
- Develop more complex, high-fidelity preparedness exercises
- Elicit participant and facilitator feedback for program improvement
- Measure improvement compared to performance objectives
- Improve coordination between internal and external teams

Discussion-based exercises are typically categorized into three groups: seminars, workshops, and tabletop exercises, each of which is discussed in more detail below. Preparation for any of the exercises should be individualized to the needs

of specific institutions or learning groups, and may include e-learning modules or pre-exercise assessments.

Seminars

Seminars are discussions designed to orient the participant to new, existing, or updated plans, policies, and procedures. These sessions are led by a presenter, and the participants function as learners in an informal, low-stress, classroom-type environment designed to set the stage for more complex disaster-preparedness discussions and exercises.

Sessions tend to function as "basic training" for team members, with the goal of familiarizing participants with the concepts of emergency response and crisis management. Team members learn, define, and become familiar with their roles in an emergency response effort, with the help of other participants and the facilitator.

Seminar sessions can also highlight any previously undiscovered gaps in resources or deficiencies in proposed plans. Frequently, participants are the ones who discover such issues and thereby contribute greatly to the planning process even as they are learning.

Workshops

Workshops may resemble seminars in that they are informal discussions, but the focus is on understanding a specific issue or constructing a specific product, such as a draft plan or policy. In the setting of an institution or health system in need of a comprehensive disaster preparedness plan, the "product" might be new or updated disaster plans and procedures with comprehensive exercises and training schedules designed to ensure the efficient cohesiveness of a well-informed team. A specific goal or desired outcome should be well-defined. Workshops typically begin with a presentation by a leader or leaders followed by breakout sessions. Participants are encouraged to interact intensively, albeit in a low-stress environment without limiting time constraints. Multiple workshops may be required for completion of a complex plan with multiple goals.

Tabletop Exercises

A tabletop exercise is a focused activity designed to allow the participants to practice a set of skills by guiding them through a discussion of a relevant simulated scenario. The purpose of the tabletop exercise is to allow early and facile testing of policies and plans by training personnel and is recommended when a disaster preparedness plan has already been developed and staff members have been trained on its components.

Key steps in the development of a tabletop exercise include assessment of a facility's needs, establishment of a goal and objectives for the exercise, creation of a relevant and realistic emergency scenario or scenarios, identification of exercise participants, preparation of all relevant materials (including the facility's current preparedness plans and outline of roles and responsibilities, as well as relevant descriptions of the scenarios for the exercise), performance of the exercise with the aid of a facilitator, and evaluation of the exercise at its completion.

In order to conduct the exercise, an experienced facilitator guides the group in simulated disaster and a verbal "walk through" of their facility's emergency plan in an informal setting. Participants are typically representatives from the various groups expected to respond to a disaster situation in their hospital or clinical setting and will have been familiarized with their institution's disaster management policies and procedures and their roles within that framework prior to the exercise.

One or more scenarios is typically presented to the group members. The facilitator will then provide additional relevant information in "real time" about what is occurring in the scenario, control the pace and flow of the exercise, and encourage active participation and input from the group members. Video or slide presentations can be useful tools in presenting an evolving scenario and illustrating key teaching points. A robust discussion is ideal, with members providing input on how they would respond in their role(s), raising relevant questions and concerns about any missing steps in the scenario as it unfolds and commenting on how the disaster response should be implemented. At the conclusion of the exercise, the facilitator should debrief the group, with emphasis on identification of lessons learned and potential areas of improvement of the emergency plan. There may also be value in the presence of an observer who does not participate directly in the exercise but provides feedback at the conclusion of the exercise.

Tabletop exercises may be conducted using paper, verbal, or computer-based scenarios that are designed to encourage the sharing of information, the coordination of cooperating individuals, and the practice of complex decision making. Such drills are often useful in demonstrating how "response functions" work and, while they lack the realism of a simulated or live drill, they can be helpful in the early detection of systematic flaws in a response plan.

Discussion-based exercises are invaluable tools in all stages of the development of a disaster plan. They offer the advantages of being low-cost, low-stress for participants, and amenable to ongoing evaluation and evolution. While the three major categories are often presented as separate entities that lead to the development of a desired program if

employed in a stepwise fashion, these exercises may be most effective if there is some overlap or fluidity in their application. Some or all of these methods may best be used in parallel, particularly if participants are being trained on a rolling or repeated basis. For example, lessons learned in a tabletop exercise may result in a group's decision to re-evaluate and revise a plan or procedure in a workshop, with additional seminars needed to re-introduce changes. These exercises work best over time if they are evaluated on a regular basis and adapted to incorporate new information and to meet an institution's changing needs.

Live Drills

Full-scale, live disaster exercises or drills are the most visible and dramatic form of disaster simulation training, with simulated patients numbering in the hundreds for some scenarios. These exercises have been the mainstay of disaster simulation with the first reports of full-scale live simulation for disaster training published over 40 years ago [10].As with other disaster simulation modalities, the number of patients required to tax the health system's resources will vary based on the capacity of the system and the types of patients. The need to fully test a system's capabilities with a live exercise is crucial considering the infrequency of real-world events. While other modalities such as tabletop drills or online simulations can provide effective preparatory work and system analysis, immersion into a live scenario provides the opportunity to implement skills and practices while also serving to evaluate the system's response. Simulation drills at this level have been reported by participants to be integral to their ability to respond when faced with an actual disaster [11–13].

Disaster drills are frequently equated with mass casualty incidents (MCIs); however, there are other types of disaster events that can be conducted in a live exercise such as utility failures or patient and staff evacuations. MCI exercises can involve the entire healthcare system from first responders, to EMS, to hospital Emergency Departments, and then to internal hospital departments. Other disaster drills may involve only a segment of the healthcare system such as EMS (prehospital phase) terminating patient flow at transport, or an Emergency Department drill starting with introduction of patients at ED triage without EMS transport. Other drills may start even further along the patient flow pathway such as in the Operating Room [14].

Although live disaster drills are usually conducted in healthcare settings such as prehospital care or hospitals, they may utilize non-hospital locations such as disaster field treatment centers staffed with EMS and hospital personnel in addition to law enforcement, fire service, civil defense, and other community responders (Figs. 21.1 and 21.2). The inclusion of disaster training, including live drills, for preli-

Fig. 21.1 Aerial view of a large complex disaster scene in Wichita, KS, simulating a car bomb attack on a downtown building with a building collapse and several destroyed vehicles in the street. The scene, constructed by Rescue Training Associates (Deerfield Beach, FL), was part of a multi-agency disaster response involving fire, EMS, law enforcement, and hospital personnel as well as military responders and other government agencies

Fig. 21.2 Interior view of manikin trapped under vehicle. Hospital personnel participate as part of an on scene medical response team in a simulated bombing and building collapse. This drill featured mobilization of in-hospital care teams to go into the field and provide on-site care

censure healthcare providers is becoming common due to changes in education requirements in many health professions schools [15–17].

The preparation of "patients" in a live disaster exercise can take many forms and range from extraordinarily simple to very high tech. Selection of the proper patient simulator to be used will depend on the goals of the exercise. If goals are focused on patient flow and systems issues, a low technology simulator may suffice. But if goals include evaluation of patient physiology and require the physical stress of patient handling, other options may be required.

Among the simple low technology options are paper patients and inflatable patients. Paper patients are generally

descriptor cards that identify the patient age, injuries, and vital signs. A triage tag can be attached to the card and the card will often have space for the medical team to document interventions, triage information, and patient disposition. The card will be transported just as a real patient would be [18]. Inflatable patients provide a body to attach the patient information card. Inflatable patients give the responders a better sense of scope and scale of the disaster, and also provide a life-sized patient body to transport [19]. After the exercise, these can be deflated for easier storage. Paper and inflatable patients are commercially available [9].

The use of real people to portray disaster patients is the simulation modality most frequently used. These simulated patients may be volunteers with little to no medical background (often from community groups or educational institutions) [20–22], trained patient actors [23–25], or other medical professionals [26]. In this last group, Gofrit and colleagues used healthcare professionals as a means of making the patient responses as accurate as possible and as a way to evaluate provider care [26]. Even with live humans as the simulator, information is often supplemented by paper resources to describe injuries and clinical conditions. The use of moulage to create a higher fidelity immersive scene and represent injuries is also valuable [27]. Live actors allow drills to feel less artificial and can simulate real injuries with the aid of make-up and special effects. The cost of professional actors and the need for extensive pre-planning for scheduling purposes do present challenges compared to manikins.

The introduction of high technology simulators into disaster drills represents a new era in disaster drill realism. These simulators have the ability to exhibit the appropriate signs and symptoms and, combined with moulage, provide the healthcare providers a richer experience to evaluate, make triage decisions, and implement patient care procedures [23, 25, 28, 29]. With the evolution of wireless manikins, moving and transporting patients with physiologic responses is possible. These simulators also allow disaster drills to utilize patient populations that would be difficult to include such as infants and children (Fig. 21.3). While some high technology manikins can run in an independent automated mode, one drawback for many of these simulators is the need for an operator to accompany the simulator and make appropriate adjustments to medical conditions (Fig. 21.4).

While live exercises or disaster drills generally involve MCIs, other types of live drills have been conducted for situations that involve unique high-risk patients or unusual situations. Simulations can be used to test the response and teach procedures for an internal healthcare facility disaster such as a utility failure, facility evacuation, active shooter, fire, or hazardous materials incident where no new patients are introduced, and the primary goals is safety of existing patients, visitors, and staff. In contrast to MCIs, these disaster drills require activation of a system's emergency operations infrastructure and may involve just a few or even a single patient who presents with a high-risk illness, such as a highly infectious disease. Biddle and colleagues used simu-

Fig. 21.3 A toddler simulator is carried by an EMS provider and presented to the hospital triage team in a disaster drill. The simulator is moulaged with burns and exhibits signs of respiratory distress

Fig. 21.4 A Simulation Operations Specialist, wearing an orange Observer vest, accompanies a pediatric simulator through the triage process during a disaster drill. The operations specialist will use the control device in his hand to change vital signs and supply other information as the treatment or triage teams implement care

lation to prepare their hospital's response after an infectious Ebola patient was identified in their community [30]. In preparation for the potential arrival of additional patients, they ran a series of simulations to prepare staff, evaluate the hospital's emergency management response system, and refine practices.

As an example of an unusual situation, Gildea and Entengoff reported on a live exercise to test a hospital's ability move patients vertically from one floor to another [31]. Their report allowed teams of firefighters, nurses, and respiratory therapists to move 12 complex patients from the fourth floor of a hospital to the ground level outside. By conducting the live exercise, they were able to evaluate firefighter and healthcare provider stress and workload while determining that vertical evacuation required an average of 3.7 minutes per floor for each patient.

Live disaster drills offer another advantage – the chance to engage in interprofessional education (IPE). Due to the nature of the disaster event, it often includes resources from multiple organizations or departments which brings together healthcare providers from a variety of backgrounds [32–34]. Participants come from prehospital settings (EMS, Fire, and Law Enforcement), hospitals (physicians, nurses, therapists, and technicians), or the interface of EMS and hospitals. These IPE opportunities are especially important to the development of non-technical skills [35–37].

As with other types of simulations, disaster simulation offers the chance for experimentation and testing of new products or procedures. Beyond just testing system capabilities, this process provides opportunities to introduce new tools such as triage systems or patient tracking tools [24, 38–40].

Debriefing holds the same importance in disaster simulation as it does in other simulations [25]. However, the complexity of the debriefing due to the number of participants and the scale of the scenario adds challenges. Debriefings may need to be multi-staged with different focuses according to roles, responsibilities, and objectives for the exercise. Front line operational staff and responders may have different objectives than senior incident leadership and the goals of prehospital responders may be different than in-hospital participants. Nonetheless, debriefings are essential to the educational process for the exercise. Additionally, a thorough evaluation of the disaster exercise to discover system level issues is required [41].

There are criticisms for conducting large scale live drills. These include the planning time, costs (including personnel and material resources), impact on real patient care, and the potential for injury to participants [42]. On this last point, safety for simulated patients when using humans as simulators is paramount. Any disaster simulation using humans as simulated patients should have a Safety Officer in place to watch for any physical threats to the safety of the simulated patients. Having a "code word" that stops the simulation and is known by all participants is one safety practice that will reduce the potential of injury, especially where therapies such as direct pressure bleeding control are used (e.g., too much pressure creating pain) or when the patient is being transported (e.g., risk of fall or being dropped).

Regarding the impact of disaster simulations detracting from real patient care, studies have shown disaster exercise have minimal effect on real patient care [43–45]. Therefore, hesitancy to participate in simulations to avoid disruption in patient care within an institution is not supported with current literature.

Full scale live disaster exercises have been shown to be effective. To increase efficacy, planners must focus on goals and objectives of the exercise, utilize the best resources (including simulators) to achieve those objectives, and have effective plans for debriefing and evaluation.

Mass Casualty Incidents are an increasing occurrence for all hospitals, whether they are large urban quaternary centers or small rural or critical access hospitals. Disaster medicine training, using simulation, can help facilities prepare for mass casualty events. Situations in which the resources of the institution are overwhelmed by number of patients requiring treatment will be unique for each center, based on various levels of available resources. Live multi-participant and multi-specialty drills provide the most realistic preparation but are also the most expensive. With rapid advances in computer technology and virtual reality, computer simulation offers realistic virtual scenarios at a fraction of the price of live drills. Single-participant computer simulations have the added benefit of allowing participants to engage at their own availability, rather than requiring specific time and place restrictions. Paper drills, focused on policies and theoretical procedures, are the least expensive option as they require minimal investment in technology and personnel. Paper simulations can provide cost-effective training for resource-limited hospitals as well as allowing larger institutions to conduct more frequent drills. With the availability of all these simulation options, every hospital should be able to effectively prepare for disaster situations.

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Simulation to Improve Primary Care Systems

22

Veslemøy Guise and Siri Wiig

Introduction

Primary care has become a key setting for the provision of contemporary healthcare services. Globally, healthcare services are continuing to shift from specialist hospital settings to primary care-based models of care, with services increasingly being delivered in the community. While simulation is frequently used to prepare students and healthcare professionals in specialized healthcare settings, there is a comparative lack of research on simulation in the primary care setting [1–3]. In an effort to address how simulation can be used to improve practice in primary care systems, this chapter presents as an example a simulation-based training program for healthcare professionals in the home healthcare services. The example provided is in the context of the implementation of new telecare technology, where we used simulation to prepare staff for new ways of working.

Primary Care Systems

The structures and content of primary care systems vary between and within countries, but are usually associated with a broad range of generalist care delivered outside hospital inpatient settings [4], including in general practitioners' (GPs) clinics, in nursing facilities, and in patients' homes [5]. Primary care is commonly characterized by the provision of integrative, ongoing, and person-focused healthcare services [6]. A key feature of primary care is continuity of care, as patients will usually consult the same practitioner or team of practitioners for most of their healthcare needs, whether for new health problems, routine check-ups, preventive care, or long-term needs. Furthermore, primary care provision often necessitates coordination of care both across multiple levels of the healthcare system and between numerous primary care providers.

This chapter focuses on primary care as provided through home healthcare services. Home healthcare is comprised of a range of medical, nursing, therapeutic, and social services and assistance with activities of daily living that are delivered in the care recipient's home [7, 8]. The purpose of home healthcare is to promote, maintain or improve patients' well-being, quality of life, independence and functioning, and to maximize their ability to remain at or return home, while minimizing the effects of disability and illness and avoiding hospitalization or admission to long-term care institutions [9, 10]. Commonly, challenges in home healthcare provision are related to what are often highly interactive care processes likely to involve patients, families and multiple healthcare professionals, all with varying competencies and capabilities [11]. Furthermore, these processes usually take place in what are unregulated, uncontrolled and unpredictable settings in patients' homes [7], where nursing is frequently provided on an intermittent basis and care providers usually work alone, often with limited access to resources and patient information [12].

The complex contexts and characteristics of home healthcare can pose challenges to the quality and safety of such services. The intermittent and independent nature of homecare work necessitates a high level of clinical reasoning to provide safe and effective care for home-dwelling patients [12]. Practitioners may find that competencies relevant to acute care and other hospital settings do not always translate when applied to homecare settings [13, 14]. With more and more care being provided in patients' homes, there is a growing requirement to train and prepare future healthcare professionals for the unique challenges of complex homecare settings. Moreover, it is important to provide current home healthcare practitioners with sound continuing professional develop-

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ment opportunities relevant to the environments in which they practice. Simulation is valuable in this regard as it provides opportunities to learn and practice complex decision-making in healthcare environments characterized by high levels of uncertainty and low levels of information [12].

Using Simulation to Prepare for Home Healthcare Work

Simulation-based training is increasingly being used to teach a range of competencies relevant to healthcare provision in the homecare setting [12]. Simulation scenarios have for example been designed specifically with the aim of learning how to recognise and manage deterioration in home-dwelling patients between episodes of care [12, 14–18]. Scenarios have also been developed where the focus is patient safety concerns of particular relevance to the homecare context, such as medication management [19], and identification and assessment of unsafe environmental conditions [12, 17, 20]. Simulation has furthermore been used to prepare clinicians for transitioning patients between different levels of the healthcare system and into the home, with training specifically focused on conducting needs and risk assessments, as well as interdisciplinary communication [21].

Research shows that simulation-based training is linked to increased knowledge, understanding, and preparedness for providing healthcare in diverse home environments [12, 16, 22–27]. Many studies also note that trainees report increased confidence, or conversely, decreased anxiety in regard to conducting independent home healthcare visits after participating in simulation [13, 15, 28–30]. In addition, trainees in the home healthcare context consistently report high satisfaction with simulation as a teaching method, independent of the type of simulation modality used [31]. Simulation is therefore considered a valuable means of learning and rehearsing independent care provision including decision-making and successful problem solving in complex home healthcare settings [12, 22, 28–30]. A further key advantage of using simulation in the home care context is the ability to supplement real clinical placement experiences and uniformly prepare students for a variety of care settings, thus ensuring opportunities to rehearse patient encounters that may otherwise be missed [12, 32].

Case Study – Simulation-Based Telecare Training in Home Healthcare

One aspect where healthcare professionals are in need of training and professional development opportunities is in regard to the provision of home telecare services. Telecare is defined as "the use of information, communication, and monitoring technologies which allow healthcare providers to remotely evaluate health status, give educational intervention, or deliver health and social care to patients in their homes" [33]. Telecare provision often implies changes to care processes, including new ways of working for healthcare staff [34]. To facilitate the necessary competencies and adaptation of practice needed for sound telecare provision to home-dwelling patients [35], targeted staff training is increasingly seen as a necessary part of telecare implementation [36–38]. Simulation has been noted as a useful approach to telecare training for home healthcare professionals [39–41] but has not been widely applied.

Researchers at the University of Stavanger conducted a study to develop, test and evaluate a simulation-based training program to prepare home healthcare professionals for novel work tasks associated with the use of virtual visits [42]. Virtual visits are clinical encounters that involve real-time audio-visual communication between patients at home and healthcare professionals in a different location through a secure video communication system or device [43]. The study used a collaborative action research approach involving key stakeholders from two local home healthcare organizations to develop training objectives, materials, and an instructional approach grounded in local needs and concerns [44]. The organizational stakeholders involved in this process were registered nurses, auxiliary healthcare staff, service managers, and professional development managers. The study sample did not include patients or patient representatives as direct stakeholders. However, findings from a related study on patient experiences with virtual visits [45, 46] contributed significantly toward the design of the training program.

Fundamental to the design approach was discussion and joint decision-making focused on the needs of both patients and healthcare professionals as telecare users, as well as the prerequisites and requirements of home healthcare organisations as telecare service providers. Action research meetings and a workshop functioned as important inter-organisational meeting places. Here, stakeholders were able to discuss and clarify needs, expectations, desired outcomes, and various practical aspects of reorganizing services prior to the introduction of virtual visits. This included discussion of potential challenges associated with virtual visits, most notable of which were the reduced ability to conduct direct clinical observations of patients, which could impact treatment and care decisions. These discussions then led to joint reflection on possible solutions to the challenges identified, including the appropriate clinical application of virtual visits; the most relevant work tasks to focus on; which staff and patients to involve; and how best to organize "video shifts" and integrate them with current shift rosters and organizational routines.

Based largely on findings from a prior training needs analysis [38, 47, 48], the training objectives broadly focused on competence development relevant to undertaking clinical

tasks via virtual visits. This included how to prepare, initiate and end visits; knowledge and application of relevant communication principles and techniques; and a practical grasp of necessary technical skills. Training objectives also covered knowledge of legal, ethical and professional accountability; quality and safety implications; documentation processes; and relevant policies and guidelines. The instructional approach chosen for the training program was an adapted version of Dieckmann's simulation setting model [49]. The training content consisted of a course curriculum explaining the purpose and objectives of training, five simulation scenarios covering different clinical uses of virtual visits (topics included e.g. guided self-administration of medications and blood glucose management), and two course manuals meant to be read prior to participation in training sessions, one an introduction to simulation pedagogy and the other an introduction to clinical practice and core competencies relevant to virtual visits. Written information on simulation pedagogy was included after the training needs analysis indicated that most home healthcare staff in the organizations concerned had little prior knowledge and experience of simulation-based training.

An exploratory evaluation study [50] was conducted to assess trainees' opinions of the form and content of the simulation-based telecare training program and to explore whether it met intended training objectives. The evaluation found that the training program had a positive impact on trainees' knowledge and attitudes to telecare. Participation in simulation also provided trainees with practical knowledge and understanding of new ways of working in the home healthcare context. Participation in simulation was also found to facilitate valuable reflection among trainees on their own practice as home healthcare professionals, creating awareness of both current and potential future roles, interactions and communication with patients.

In addition, the evaluation found that simulation provided valuable insight into potential benefits and challenges of virtual visits [50], which can ultimately facilitate their adoption and implementation in clinical settings [51]. For example, virtual visits represented a more efficient way of working for staff, while making home healthcare services more punctual and predictable for patients. A further benefit was that virtual visits were seen to facilitate more self-care practices in patients. Challenges related to virtual visits included staff's perceived loss of control over medication administration, as well as the threat of technical problems like poor quality telecare equipment and faulty Internet connections. Participation in targeted simulation scenarios which addressed various challenging issues acted to pre-empt and minimise potential problems by providing both management and clinical staff with prior knowledge and hands-on insight without the risk of adverse implications to real-world practice.

Opportunities and Challenges of Using Simulation in Primary Care Systems

Research on simulation-based training for primary care practitioners is scant but the literature in this field is growing. The findings from this study in the home healthcare setting supports previous assertions [41] that simulation-based training is a valuable means of introducing prospective telecare providers to new ways of working. Moreover, aside from being useful for technical and non-technical skills training, simulation has the potential to ready both individuals and organisations for practice changes brought about by the implementation of innovation in complex healthcare systems [44]. Specifically, key processes in the design and development of simulation-based training can provide reflexive spaces for healthcare staff and managers to plan and prepare for important work system changes.

Reflexive spaces are physical or virtual forums where participants come together to reflect on current challenges, adaptations, and needs in shared work practices and the effects these practices may have on the wider structures and processes of everyday care work [52]. The reflexive dialogical practice that happens in reflexive spaces is key to learning, development and improvement. Not only can it facilitate reflection and feedback on concrete clinical or organizational practices among home healthcare care practitioners; it can also provide insight into the actions required from managers and clinical staff to support improvement efforts, including their own role in aiding these efforts, as well as the circumstances under which improvement may best occur [52, 53]. In this way, simulation can be used to facilitate and improve organizational change processes in primary care systems, particularly those concerned with practice innovation in the form of telecare implementation in home healthcare settings [54].

While there are clear opportunities associated with the use of simulation to improve primary care systems, there are a number of challenges hindering the widespread application of simulation-based training. First and foremost is a persistent lack of empirical evidence of the impact of simulation on outcomes in practice [55]. The demonstration of causal links between simulation and clinical outcomes thus continues to be an important aspect of healthcare simulation research [56]. Furthermore, not all trainees will feel comfortable about taking part in simulation scenarios and may prefer more traditional training methods [57]. Another limitation is that simulation-based training initiatives can be expensive and time-consuming to develop, implement and maintain [58]. Relatively resource- and cost-effective options are however possible, including peer role-play simulation [59].

A key challenge to the use of simulation as a pedagogical approach within the primary care setting is, however, a gen-

eral lack of simulation competencies among primary care practitioners and faculty [1], as well as a lack of authentic simulation spaces designed to replicate non-acute healthcare environments and procedures [60]. Primary care organisations should therefore consider investing in simulation competence by encouraging and supporting staff to attend simulation instructor courses in order to gain the ability to design, develop and facilitate simulation-based training initiatives. Not being dependent on external training designers and facilitators to deliver simulation-based training would make it a more sustainable, widely-applicable approach to staff training in a long-term perspective. Facilitating the development of broad simulation competencies within primary care provider organizations in this way will ultimately increase the quality of simulation-based training and education for both current and future primary care practitioners.

Conclusion

Simulation-based training, including a collaborative approach to training design, can be used to prepare healthcare organizations as well as individual staff members for organisational change and the implementation of practice innovation in complex primary care systems.

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Using Simulation to Understand and Shape Organizational Culture

23

Mary D. Patterson, Eric M. Eisenberg, and Alexandra Murphy

Introduction

This chapter describes the impact organizational culture has on everyday work activities in healthcare organizations, and the role that simulation can play in helping practitioners to better understand the nature of the culture and potentially shape and change it. In the first section, we define organizational culture as the set of shared attitudes, values, goals, and practices that characterizes an institution or organization [1]. Anyone who has worked for or been a patient of a healthcare organization understands that different hospitals or clinics simply "feel different." For example, some organizational cultures are highly welcoming while others are closed and cold. Some are optimistic and celebratory, while others focus on failure and the assignment of blame. Some cultures promote and reward individual effort and achievement, while others foreground teamwork and collaboration. We show how each of these unique qualities can be gleaned through ethnography, or a "writing of the culture".

Ethnography is a method of research that allows for close inspection of what members say about their work and examines through observation the repeated activities and practices (rites and rituals) that members regularly perform. Research shows that positive organizational cultures are linked to higher employee engagement and improvement in patient outcomes [2]. That said, it is both challenging and time consuming to conduct a comprehensive ethnography of an organization.

A more efficient approach would be to develop a simulated microcosm of the organization to examine its cultural elements, the feasibility of which is described in the second section of this chapter. Healthcare simulation has the potential to afford insights into broader organizational culture using a discrete sample of people, activities and time. Simulations, especially *in situ* simulations that take place in the same environment as the actual work, closely mirror "work as done" for the clinician and the observer. When *in situ* simulation provides clinical and environmental cues to healthcare workers similar to those they would experience during a critical patient event, the observer is likely to see and hear the same types of behaviors and communication that would occur during an actual clinical scenario. Team performance is reliably reproduced in a simulated scenario compared to an actual clinical event [3]. In addition, *in situ* simulation surfaces the unsanctioned processes that are part of healthcare delivery including workarounds and interactions influenced by power and status.

Defining Organizational Culture

The idea that organizations can be characterized as social entities referred to as "cultures" was borrowed from anthropology and gained general usage in the 1980s with the publication of two highly influential popular books, "In search of excellence," and "Corporate cultures." [4, 5]. The main reason for the popularity of the culture concept at the time is that it offered an explanation for why Japanese manufacturing organizations were producing higher quality products and out-competing the United States in the global marketplace. In contrast to earlier theories of employee motivation, and based on comparative studies of American and Japanese companies, William Ouchi proposed what he called "Theory Z." [6] This theory maintained that the Japanese competitive edge stemmed from factors that had more to do with values and interpersonal dynamics than incentives or working

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conditions. Specifically, he stressed the importance of mutual trust, open and honest communication, collective decision-making, and a holistic concern for employee well-being which extends to their family. Taken together, these elements suggested that a particular kind of work or cultural community—a trusting, engaged and caring culture—would also be more productive.

In their landmark book "In search of excellence," Tom Peters and Robert Waterman [4] conducted a large-scale study of successful companies to see what they had in common. Eight characteristics were identified as common traits among the superior companies. These include the following:

1. a drive for action, decision-making, and getting the job done;
2. an emphasis on serving the customer and providing quality and reliability;
3. providing an atmosphere to foster creative thinking and product innovation;
4. respecting and treating every employee as an important contributor;
5. maintaining the basic philosophy of the company;
6. operating businesses with which management is familiar;
7. keeping top-level staffs very simple;
8. decentralizing and centralizing certain functions [4].

Notice that many of these principles—notably the first five—have less to do with what an organization does and more with how they do it, which is the essence of culture. Making an analogy to a more traditional comparison, people all over the U.S. hold ceremonies when people die, but a funeral in Boston looks and feels very different from a funeral in New Orleans. Culture is the unique way that people do things together.

Viewing organizations through a cultural lens is a relatively new phenomenon, but interest in how people interact at work is not. The long history of leadership studies reveals a preoccupation with employee motivation and the kinds of environments that are most likely to produce higher levels of performance. The earliest analyses following industrialization (approximately 1850–1950) gave short shrift to communication and employee well-being, focusing instead on strict hierarchy and division of labor. Employees were not expected to think for themselves but rather to do what they were told. But the latter half of the twentieth century—particularly between WWII and the 1970s—was characterized by a growing recognition of employee wants, needs, and potential to contribute. Thousands of studies sought to measure "job satisfaction" or employee morale, and in the aggregate "organizational climate." The feeling at the time among most researchers was that a more positive climate and more satisfied employees would lead to greater productivity and organizational effectiveness.

Surprisingly, the research did *not* support this idea, and both academics and practitioners had to wrestle with the fact that happy employees were not the key to success, nor was a positive climate. This set the stage for the identification of the importance of organizational culture which we have described above. What did seem to be true—and has now been empirically demonstrated—is that particular types of cultures, i.e., those that are fanatic about customers and engage employees in decision-making **are** more successful. For this reason, many organizations across diverse industries employ anthropologists to regularly observe, describe, and if needed intervene to shape organizational culture.

Writing Culture

Researchers typically use ethnography as the technical methodology for studying the rites, rituals, and practices that constitute an organizational culture. Ethnographers will often take months or even years to complete a study and "write a culture." We use the term "writing culture" purposefully to recognize that organizational cultures are dynamic and any cultural description is an incomplete snapshot. An observer should be mindful of the fact that they are choosing a lens that will yield particular—and hopefully useful—insights.

Therefore, it is very important to not essentialize the culture concept by suggesting that organizations "are" or "have" particular cultures. A better approach follows the notion advanced by Gareth Morgan in his landmark work on "images" of organization, in which he maintains that culture is one of many useful metaphors for viewing organizations (others include machine, organism, brain, etc.) [7]. Each metaphor or way of seeing highlights different aspects of work. The culture metaphor, as we have already mentioned, foregrounds the assumptions, beliefs, and practices that make a work organization unique and identifiable.

Moreover, there can be important variations within the cultural approach that can further differentiate one's findings. The work of Stanford professor Joanne Martin is especially relevant here. She identifies three approaches to writing organizational culture that she calls the integration, differentiation and fragmentation perspectives [8]. An ethnographer can choose an approach with the aim of highlighting different cultural elements.

The **integration perspective** is closest to the lay understanding of culture. Just as people are comfortable saying things like "New Yorkers are like that" they may also make similar sweeping generalizations about Microsoft or Google employees. From this angle, culture is what people in an organization – or even a nation - share, the glue that holds them together, and represents an overarching, con-

sensus view. The **differentiation perspective** is quite different and begins with the notion that organizations rarely if ever can be described as have a singular and homogenous culture, but ought be seen instead as a collection of subcultures (think: the emergency department vs. an inpatient med/surg unit, or anesthesiology vs. orthopedics). Finally, the most different variation is the **fragmentation perspective**, which maintains that it is best to see culture as inherently unknowable, a collective fiction that members create to retrospectively make sense of what are in fact random and unrelated actions and events. Martin advanced this last perspective during a period when postmodern theory was in ascendency in organizational studies, and there was growing appeal to the idea that much of the work of organizations was chaotic and a kind of muddling through, which belies the pat stories members may tell themselves about how things all go together.

All organizations contain elements from each of these three cultural viewpoints. At times, organizational cultures may be seen as integrated, unified, and harmonious. The same organizational culture can exhibit signs of difference (particularly among subgroups) and conflicts of interest. Finally, at times, the meanings and values attached to shared cultural practices, may be difficult to determine across organizational participants. This has significant implications for how one attempts to understand an organization's culture. The challenge becomes how to promote and shape the more positive aspects of an organization's culture as these are linked to more positive patient outcomes.

Linking Organizational Culture to Patient Outcomes

All of this is still very abstract. How can culture, the unique way employees approach their work in an organization, affect real patient outcomes? The answer is in a myriad of general and specific ways. To use a general example, imagine a hospital that has invested heavily in equipment to differentiate themselves in the marketplace, but has paid little attention to employee on-boarding, training, or continuing education. In this hospital, it is likely that patients will report that while their procedure was a clinical success, their total experience was a disaster. There are so many touch points where a lack of patient-centric communication can create a bad impression that lingers, from the pre-admission phone calls to valet parking to the financial counselor. The tragedy in this case is that individuals may be motivated to treat patients well but have never been trained or expected to do so. Moreover, individual providers typically do not see the cumulative effect of their interaction from the patient's perspective.

To use a more specific example, imagine a hospital where doctors have all of the power and nurses and other clinicians are both formally and informally discouraged and even sanctioned when they challenge physicians. In this case, one can likely observe numerous examples of interactions where domineering communication fails to make room for alternative perspectives and where specific categories of employees are fearful to speak up if they hold a different view. During a research study, we observed a patient brought into the trauma unit with a suspected neck injury [9]. The paramedics had difficulty and decided not to manipulate his neck into a cervical collar. The nurses knew of this decision, but when the consulting physician arrived in the unit, he got angry that the protocol had not been followed and forced the patient into the collar resulting in further risk to the patient including possible paralysis. When the physician asked why the nurses didn't stop him, they told him that he was the physician and "in charge".

Impact on patients can range from annoying to catastrophic, as the cultural prohibitions on open dialogue can lead to seriously suboptimal decision-making. Relatedly, in Tompkins analysis of the causes of NASA's Challenger disaster, he places blame squarely on an organizational culture that emphasized schedule and cost over the need to pause and consider threats to safety [10]. People knew about the vulnerabilities that caused the explosion that led to a major loss of life, but they did not feel comfortable sharing them with others.

Like NASA, healthcare organizations aspire to be high-reliability organizations, where lives are on the line. Therefore, while you can learn a lot about the influence of an organizational culture by analyzing past mistakes, it is difficult to catch them in the moment and you hope that they won't happen. Therefore, the next section argues for the value of simulation as one method of staging these kinds of situations in order to observe and influence the broader organizational culture.

Using Simulation to Observe Cultural Practices

The practice of simulation involving teams of healthcare providers produces a microcosm of the broader organizational culture, or what Martin describes as a "cultural nexus"—the intersection of internal and external cultural influences [8]. During a simulation exercise, it is possible to observe processes, behaviors and practices that are thought to be very close to "work as done". Although "routine" processes and procedures are simulated, simulations tend to skew toward critical events. The effect of this is that simulation evokes the same types of stress and affective responses as the actual clinical event and healthcare professionals tend to speak and act as they would during an actual critical event [3]. It is possible to see and hear the behaviors and language that reflect the broader organizational culture.

Rites and Rituals

Although it may be a stretch to describe a trauma evaluation or a cardiac arrest code response as a ritual, these are events that are highly protocolized in most healthcare organizations and are also frequently simulated to train novice healthcare professionals and improve team performance. For example, where each professional stands relative to the patient often defines the healthcare professional's role and to some extent their status. There is some variation in this from organization to organization, but also significant standardization. The team leader (typically an attending physician) stands at the foot of the bed and may not actually touch the patient. For many years the team leader was viewed as the "captain of the ship" and his (usually) or her orders were not questioned. A trainee physician examines the patient from one side of the patient and a nurse starts an IV and draws blood from the other side of the patient. Other professionals are stationed around the patient to manage the patient's airway, medications and to record the activities. Additional healthcare professionals may enter the process for specific tasks (i.e., the radiology technician who obtains portable x-rays).

In a trauma resuscitation, the surgeon is viewed as having the highest level of authority. How embedded this authority is was demonstrated in a simulated trauma resuscitation in which the attending surgeon was scripted to direct the rest of the team to perform a procedure incorrectly. In the debriefing it emerged that the team members recognized that the request was incorrect, but they did not question the surgeon in real time for a variety of reasons. These included that as the attending, the surgeon must know what he (in this case) is doing and perhaps the surgeon knew something that the trainee or nurses did not know. Similar unquestioning obedience to medical team leaders during code simulations has also been observed.

In recent years, an emphasis on team training has resulted in a less hierarchal approach in many but not all institutions. The medical hierarchy remains deeply embedded in many organizational cultures. The medical hierarchy is introduced during professional training which is also siloed. For example, in the United States, nursing students on clinical rotations rarely speak to a physician or even a medical student. Nursing students communicate about the patients that they care for through their nursing instructors. The new graduate nurse may never have spoken to a physician prior to graduating.

Rounds, the daily formal evaluation of patients and discussion of the plan for care still exist. However, given the complexity of many patients and the number of consultants often involved in a patient's care, rounds tend to be less comprehensive today than in the past. There is an emerging trend towards interprofessional family or patient centered rounds that incorporate all the disciplines involved in a patient's care including dieticians and social workers. As these types of rounds are new to some organizations, these have been practiced and the "norms" for these types of rounds have been established in part through simulation training, often with standardized patients or families playing the role of patient or family member.

Symbols and Signs

At one time, there were a significant number of generally identifiable symbols and signs in healthcare. These included the nurse's white caps, the attending physicians long white coat and the medical student's short white coat and even the patient's paper chart. Surgeons were the only physicians that routinely wore scrubs. In recent years there are fewer outward symbols that point to the healthcare professional's role or status. It is true that some healthcare organizations require a certain color scrub suit for nurses on a particular unit but this is not widespread. The stethoscope is now ubiquitous among healthcare professionals, so the stethoscope draped around an individual's neck no longer conveys any particular meaning. It is often difficult to determine an individual's role (and therefore their standing) by outward appearances. The one exception seen in some hospitals is an addition to the identification badge that identifies the individual's role in large letters. These may say RN or RN certified, MD or attending MD, pharmacist, etc. Aside from this there is little that outwardly distinguishes the individual's role. The implications of what would seem to be a small or insignificant change can often be hard to see but may be surprisingly impactful across an organization. The absence of easily identifiable outward symbols that indicate the individual's role and skill set can be problematic, particularly for ad hoc teams who may not know one another. One of the key aspects of simulation-based team training is the emphasis on shared knowledge of individuals' roles and skills. It is considered a "best practice" for team members to introduce themselves to one another. But even with introductions, there is often a lack of knowledge concerning the skill set of each role.

The physical workspace an individual occupies is a major indicator of that individual's role and status in the organization and impacts inter-professional communication. With the introduction of the electronic medical record and the ability to complete records anywhere, there are more workspace "silos." Physicians no longer go to the nurses' station to see the patient's physical chart and at the same time interact with nurses. Often doctors now have dedicated workrooms to work on the electronic record and at times these rooms restrict access to physicians only. Nurses may chart in a variety of locations including outside the patients' room. Administrative and organizational implementations to meet an important goal (access to electronic documentation)

resulted in an unanticipated "siloing" of expertise and knowledge as organizational relationships changed with the workplace layout.

Shared Mental Models

Organizational culture, as created and sustained by the rites, rituals, symbols and practices described above can influence the development of discrete mental models among the organizational members. Mental models are frameworks of understanding based on underlying assumptions, socialization, and experiences. Put simply; a mental model determines how individuals assign meaning to any given situation. In a team-based environment, such as healthcare organizations, it is important for the organizational culture to promote a "shared mental model" has been defined as "understandings or mental representation of key elements of a team's relevant environment that is shared across team members" or as team members being "on the same page." A more healthcare specific definition developed by Floren, Donesky and Whitaker references the common goals for the patient:

A shared mental model is:

> an individually held, organized cognitive representation of task related knowledge that is held in common among healthcare providers who must interact as a team in pursuit of common objectives for patient care. [11]

The shared mental model includes: "Common understanding of the 'situation, the plan for treatment' and the roles of the tasks and individuals in the team." It "enables anticipation of other's needs, identifying changes in the clinical situation and adjusting strategies as needed" [12].

To develop a shared mental model, individual team members must share information with one another. Yet the method to share a mental model with team members is not something that is typically trained in professional school. A physician may be operating with mental model of a patient with congestive heart failure. If the nurses and other team members are working with an alternate mental model, such as sepsis, the rest of the team may expect orders for fluids and antibiotics, while the physician may be requesting diuretics and drugs to improve cardiac function. When a team's mental model is shared, the team members can anticipate next steps. Mental models that are not shared lead to confusion and inefficiency. Creating a shared mental model requires that the organizational culture not only allows, but welcomes individuals to share their mental models and openly discuss any differences in perspectives.

In a recent series of simulation exercises involving a child with an obstructed tracheostomy, we found repeatedly that physicians were unaware that nurses from a particular unit are proficient in managing tracheostomy problems. On the other hand, nurses believed that all physicians were familiar with tracheostomy problems and waited for the physician to "give an order" or fix the obstructed tracheostomy themselves.

Simulation is an imperfect representation of a clinical event, but potentially allows for deeper study of the conditions that facilitate the development and the accuracy of the shared mental model among team members. Salas *et al*, identified the shared mental model as one of three key elements linked to team performance [13]. Patterson *et al*, conducted interprofessional simulation-based team training with emergency department staff that incorporated training on shared mental models and practice of the shared mental model during simulated critical events. This included the physician team leader explicitly announcing the shared mental model as well as inviting other team members to suggest alternative mental models or management plans. The outcome of this simulation was that the voicing of the shared mental model was viewed as so helpful by nursing staff that it was incorporated as one of the required elements of the medical record. If the physician team leader had not shared a mental model during the initial 3–5 minutes of a resuscitation, the nursing leader would request it [14].

Power, Status and Inter-Professional Simulation

As noted earlier, very clear occupational roles exist within medical and healthcare cultures. The educational systems are distinct and the occupational contributions are often not seen as equivalent allowing for the emergence of subcultures and political factions within the culture. A number of studies examine the way in which medical students and residents learn to "talk like a doctor" and nurses learn to defer to them and/or work around them [15]. Each are given socialization cues throughout their everyday communication and cultural practices to teach them appropriate professionalism for their fields. However, these professional lines can also create barriers to creating a collaborative, patient-safety focused culture. Each party must recognize that their individual decisions and actions impact the organization as a whole and the ultimate patient experience. Inter-professional simulation can encourage a collaborative culture where individuals operate, not just from their own perspective, but from the broader perspective of the whole organization.

Hierarchy is deeply embedded in healthcare. The hierarchy is often most perceived by nurses and trainees and less so by attending physicians [16, 17]. With a rigid hierarchy comes difficulty in speaking up when there is a problem, or a mistake is about to be made. One way this may be addressed

is through team training that includes simulation. In interdisciplinary team training, first names are frequently used instead of titles "to flatten the hierarchy". In the emergency team training described previously, individuals used first names only on their name tag and in their respective introductions. The mandatory debriefing likely also affects the perception of hierarchy through the discussion and development of deeper knowledge about the skills each role brings to clinical care.

During simulation training, facilitators often hear, "this is the first time that I have trained with a doctor (or a nurse)". This again reflects the singular role and impact silos play in professional training. An associated issue with single role training is the difference in the ways that physicians and nurses are trained to communicate with each other. Physicians are typically trained to describe patients using a system based or SOAP format (subjective information, objective information, assessment, plan); the focus is on the "bottom line." On the other hand, nurses are trained to present the patient's more complete story. The outcome can be a mismatch or miscalibration in perceptions of the relative severity and/or focus of the patient's problem between the caregivers. This contributes to nurses articulating a feeling of being tuned out, while physicians convey annoyance—neither recognizing that while they may be triaging the problem differently, they are looking at the same problem and have the same goals. Given that there are fewer opportunities for the different discipline to interact in person, the communication challenges may be worsened.

One of the benefits afforded by simulation training is the opportunity to standardize and practice various communication techniques. An example is the SBAR technique. SBAR stands for situation, background, assessment, recommendation. This technique is no longer novel but is a standard way for one healthcare professional to voice concern to another. Often it is a nurse who uses the SBAR to voice concern to a physician. When the technique has been practiced, it provides nurses a way to escalate concerns and physicians learn to listen for and recognize when SBAR is being used. Another example of a standard communication technique is ARC (Ask a question, Request a change, escalate up the Chain of command.)

The use of simulation in healthcare training can aid in observing and addressing some key challenges in healthcare cultures. Some of these challenges have been evident for quite some time, such as hierarchy and power associated with occupational roles. Some have emerged with the advent of and increased reliance on new technology (the electronic healthcare record or texting to communicate). Given this, we believe the prevalence of the electronic health record deserves some additional attention.

Electronic Communication

The proliferation of electronic methods of communication has also affected organizational culture. For example, the development and widespread adoption of the electronic health record has fundamentally changed how healthcare professionals work. The difficulties of the paper record are well known - poor legibility, loss, single access point. However, while the electronic health record solves some of the difficulties associated with the paper medical record, it has raised new challenges.

The role of the nurses' station as the central hub of communication and interaction has diminished. Prior to the use of electronic health records, physicians physically went to the nurses' station to access the medical record, provide announcements, write notes and give orders. Often, coffee and cookies or other treats were found at the nurses' station. This provided an opportunity for interaction, questions, discussion, as well as getting to know the individuals in other roles. The electronic health record requires more time to complete and charting can now occur anywhere. There is no central meeting place and the opportunities for informal discussion are much fewer [18, 19]. Though the electronic health record was not *intended* as a primary communication tool, especially in real time work, it has functionally become a means of communication--albeit mainly in an asynchronous fashion. In addition, questions and clarifications often occur via texts rather than face to face. There is an overall decrease in direct communication which also negatively affects the development of a shared mental model concerning a patient's diagnosis and clinical course [15].

This relates to the old adage, "It's not what you say, but how you say it" indicating two dimensions of communication in social systems: content and relational. The content dimension refers to the "data" aspect of the message-- "what" is being said. The relational dimension relates to "how" it is said and speaks to the relationship between the communicating parties. The increase in emphasis on technological, asynchronous modes of communication privileges the goal of a more efficient transfer of data, but it also shifts "how" communication is accomplished and has relational consequences for the parties involved. Sherry Turkle warns about the ability of digital technologies to simultaneously connect us to more data and yet through this reliance, we lose our ability to have valuable face-to-face conversations. A more synchronous process bespeaks a collaborative relationship—a negotiation—in which each party has had the opportunity to influence the direction of patient care [20].

Realistically there is little time for these interactions to happen in everyday healthcare settings. Simulations, in particular *in situ* simulations, provide an opportunity to practice

"how" something is said—to pay attention to how it is interpreted and understood by each person in the interaction so that individuals are prepared when this collaboration is required. The debriefing that occurs following simulation provides an opportunity for the healthcare professionals to check the affective and objective understanding of the communication that occurred during the simulation scenario.

Using Simulation to Experiment with Cultural Change

As healthcare simulation has evolved, there has been a concerted effort to measure the effect of simulation interventions based on changes in healthcare worker behavior and patient outcomes [21]. Some simulation studies have used the Safety Attitudes Questionnaire, [22] or the Hospital Survey on Patient Safety Culture [23] and a number of these have demonstrated improvements in these scores associated with simulation interventions [14, 24, 25].

In situ simulations bring the healthcare team members together at the bedside to address a clinical issue and solve a discrete problem. It is an opportunity to practice clinical reasoning, but perhaps even more important to experiment with and develop the communication and teamwork behaviors that are necessary for good patient care. In this respect, simulation is not only a means of observing organizational culture but is a rich venue for experimenting with shifting cultural practices in a "safe" environment that can both mimic and produce broader cultural norms.

As seen in the examples above, simulation is a vehicle that allows for the exploration of conversational models such as SBAR. It also facilitates face to face communication and the development of relationships between individuals in different roles. As described previously, due to increased technological developments, these opportunities have diminished in recent years. Appropriate debriefing creates a safe psychological space that promotes understanding of what was said as well as the impact of the way in which it was said. The debriefing also provides an opportunity for a "do-over". Individuals can practice a more functional way of communicating the same information immediately following the debriefing, which provides an opportunity that is not possible outside the simulated environment.

The simulation and debriefing can also fundamentally change how communication occurs and the responsibilities and recognition of the expertise of individuals in the team. Simulated environments allow the "working out" of differences that can then translate to better communication practices in the clinical setting.

For example, in the emergency medicine training described previously, the role of the nursing team leader changed, and the expectation that the nursing team leader shares responsibility with the medical team leader for maintaining situational awareness emerged. The previous role of a "recorder" was formally transformed into a "nursing team leader," which changed the responsibilities of the individual from those of a scribe to those of a co-leader.

Once these changes became part of the emergency department, they spread to the intensive care units and eventually to the acute care units, at least in part due to ongoing simulation training. The type of simulation training described was mandatory and frequent. It seems, not surprisingly, that a significant dose response relationship exists in terms of the effect of simulation. In addition, it would seem that the desired behavior change must be viewed as beneficial by a majority of the team members for this change to become part of routine clinical practice.

Utilizing Simulation to Improve Sensemaking and Decision-Making

Simulation also provides an opportunity to test different techniques for collective sensemaking. For Weick and Sutcliffe, reliability is not about mindlessly repeating standardized routines. It is in moments where routines are disrupted that they are most easily seen and can be challenged. They refer to these moments as "sensemaking." The challenge for high-reliability healthcare organizations where lives are on the line, is that sensemaking most often happens in moments of crisis when we tend to revert to our learned and repeated patterns of behavior and there is precious little time to pause and consider alternatives [26].

Simulations provide a safe space to create a deliberate disruption where individuals can collectively reflect on the ambivalence, uncertainty, anxiety, and sense of risk they may experience in a patient-setting. Through these deliberate pauses, simulations can provide a context and culture for what Weick and Sutcliffe call "mindful organizing" that includes five key principles particularly important for high-reliability organizations. First, simulations allow for a *preoccupation with failure*. Rather than assuming errors will not happen, simulations encourage the acceptance and examination of potential failures, highlighting such things as symptoms of malfunction, small errors that could grow and spread, and opportunities to speak up and be listened to. Second, simulations allow individuals to be *reluctant to simplify*. In the moment, people will need to simplify to stay focused and coordinate activities. However, simulations allow healthcare practitioners learn to avoid prematurely simplifying. They have the freedom to consider a wider range of alternatives and possibilities for what might be causing the unexpected to happen. Third, simulations, par-

ticularly inter-professional simulations, allow people to develop *sensitivity to operations*. Learning about all aspects of the organizational operations, from the perspective of physicians, nurses, and admissions, bed management, and housekeeping personnel, creates a complex awareness and allows a collective, collaborative problem-solving. Fourth, not only should individuals be thinking about how to prevent a mistake or failure, simulations can help create a culture *committed to resiliency* where individuals learn to bounce back from unexpected events. As Weick and Sutcliffe note, it is "not that it is error-free but that errors don't disable it" [26, p. 12]. Finally, simulations allow a chance to challenge the embedded hierarchy and *defer to expertise* of the varying occupational roles and experiences. In a simulated activity, residents can learn to respect the expertise of a nurse who might recommend an increased dose of medication for a particular patient. And, through the simulation and especially the debriefing, the nurse may learn to trust that the physician will listen and the nurse will be more likely to voice a concern in the future.

Conclusion

All healthcare delivery systems have cultures, and they act as powerful but often unseen drivers that compel and constrain behavior. Organizational analyses that focus solely on rational action and ignore the inherent variability and ambiguity in human behavior will always be incomplete. But an expanded focus that includes an examination of culture can yield important insights about how individuals work together to make sense of a situation and ultimately take action.

A deeper understanding of culture will help to both explain and improve care coordination, healthcare delivery systems, and ultimately patient outcomes. That said, a full-scale ethnographic description of an institutional or professional culture is a massive undertaking. New developments in highly realistic healthcare simulation provide an alternative method to describe, interrogate, and change current cultural practices. Through reflection and debriefing, simulation also provides an opportunity to model more desirable behaviors that can positively shape the organizational culture.

Continuous improvement of processes and outcomes is at the center of contemporary healthcare research and practice. A commonplace observation is that policies and technologies are necessary but not sufficient to ensure effective coordination and delivery of care. To the contrary, it is variability in human behavior and failures to communicate effectively that most often lead to failures. Significant insights into behavior can be garnered by using simulation as a window into organizational culture.

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Simulation for Quality Improvement

24

Travis Whitfill, Todd P. Chang, Wallis T. Muhly, and Jessica K. Hart

Introduction

In 2001, the National Academy of Medicine (formerly the Institute of Medicine) published *Crossing the Quality Chasm*, which stated that the United States healthcare system does not provide "consistent, high-quality medical care to all people." [1] While improvements have been made in healthcare delivery in the past two decades, the quality of healthcare remains inconsistent and variable due, in part, to increasingly complex healthcare delivery systems and rapidly changing technology and information systems. The methodology of quality improvement (QI), a system of process improvement and quality control initially developed for industrial or manufacturing sectors, has been applied with increasing regularity in the last two decades to improve healthcare delivery and outcomes. Similarly, simulation has become standard in healthcare education and training in recent years. In this chapter, we will explore how simulation can be used in both the design and implementation of healthcare-related improvement projects and how this approach can improve healthcare quality.

In their 2007 article, Drs. Paul Batalden and Frank Davidoff wrote that quality improvement involves "the combined and unceasing efforts of everyone—healthcare professionals, patients and their families, researchers, payers, planners and educators—to make the changes that will lead to better patient outcomes (health), better system performance (care) and better professional development (learning)." [2] By nature, QI methodology consists of systematic and continuous activities that lead to measurable improvement in healthcare services and the health status of specific patient groups [3]. Healthcare quality improvement can be understood as an effort to effect change in a healthcare system (macrosystem) through innovation and improvement within the individual care delivery units (microsystems) that make up the healthcare system. Thus, much of the focus of QI is directed toward the microsystems, which include the various stakeholders (patients and care givers, nurses, physicians and other allied healthcare providers) that comprise the clinical care unit. Often underutilized in QI projects, simulation can serve as a robust tool to both measure and improve the quality of care delivered. Used as an assessment methodology or educational intervention (or both), simulation can be an important complement to established QI methods. In this chapter, we will briefly review the theoretical foundation of quality improvement and provide examples of how simulation can be integrated into QI projects with some practical suggestions about how to use this approach for maximum benefit.

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Theoretical Framework for Simulation-Based Quality Improvement

A framework for quality improvement entails continuous efforts to achieve stable and predictable process results in addition to using data to assess whether an intervention leads to improvement. A number of models for quality improvement have been described, including The Model for Improvement [4], lean [5], six sigma [6], total quality management [7], and others. Central to many QI frameworks, the plan-do-study-act (PDSA) cycle [8–10] is a quality improvement method designed to rapidly assess whether an

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intervention is effective. By design, PDSA cycles are meant to be iterative and adaptive to allow new learning to be built into the experimental process [11]. The PDSA model mirrors the scientific method in several ways: [3, 11, 12] formation of a study question and hypothesis while defining measures and organizing a team (*plan*); data collection and study execution (*do*); analysis and interpretation of data (*study*); and planning the next iteration and/or deciding whether the plan should be implemented or not (*act*).

In line with the scientific method, PDSA cycles include the collection of data (qualitative or quantitative) to measure whether an intervention results in a change or improvement [3]. However, in contrast to the scientific method, which controls for as many variables as possible through strict inclusion and exclusion criteria and randomization, a quality improvement approach using the PDSA method typically does not try to control for all variables, allows for data incongruity, and supports evolution and adaptation of the intervention. PDSA cycles are often conducted within microsystems which allow for iterative, small-scale tests, rapid assessment of results, and refinement of interventions [13, 14]. In short, the purpose of PDSA for QI is to clearly establish a relationship between an intervention and its impact on outcome [3]. This relationship is better defined with rigorous documentation of each stage of the PDSA cycle. Additionally, analysis of data over time allows for better understanding of variations in a complex system and potentially increases confidence that an intervention and the outcome are correlated (either positively or negatively) [12].

However, the PDSA method is not designed to operate as a standalone method [11] and is often used in combination with a suite of other research tools. For example, PDSA could be combined with a framework that focuses on the system, such as the Dartmouth microsystem improvement curriculum model [15, 16], which breaks down a health system into clinical "microsystems"—the building blocks of larger organizations and of the health system. A framework that combines the PDSA model and the Dartmouth microsystem improvement curriculum model in the context of simulation is presented in Fig. 24.1. This model combines PDSA cycles for repetitive improvement cycles while contextualizing the iterative improvement changes in a systems-level approach using simulation-based methodologies. Considerations for simulation-based PDSA methods are presented in Table 24.1.

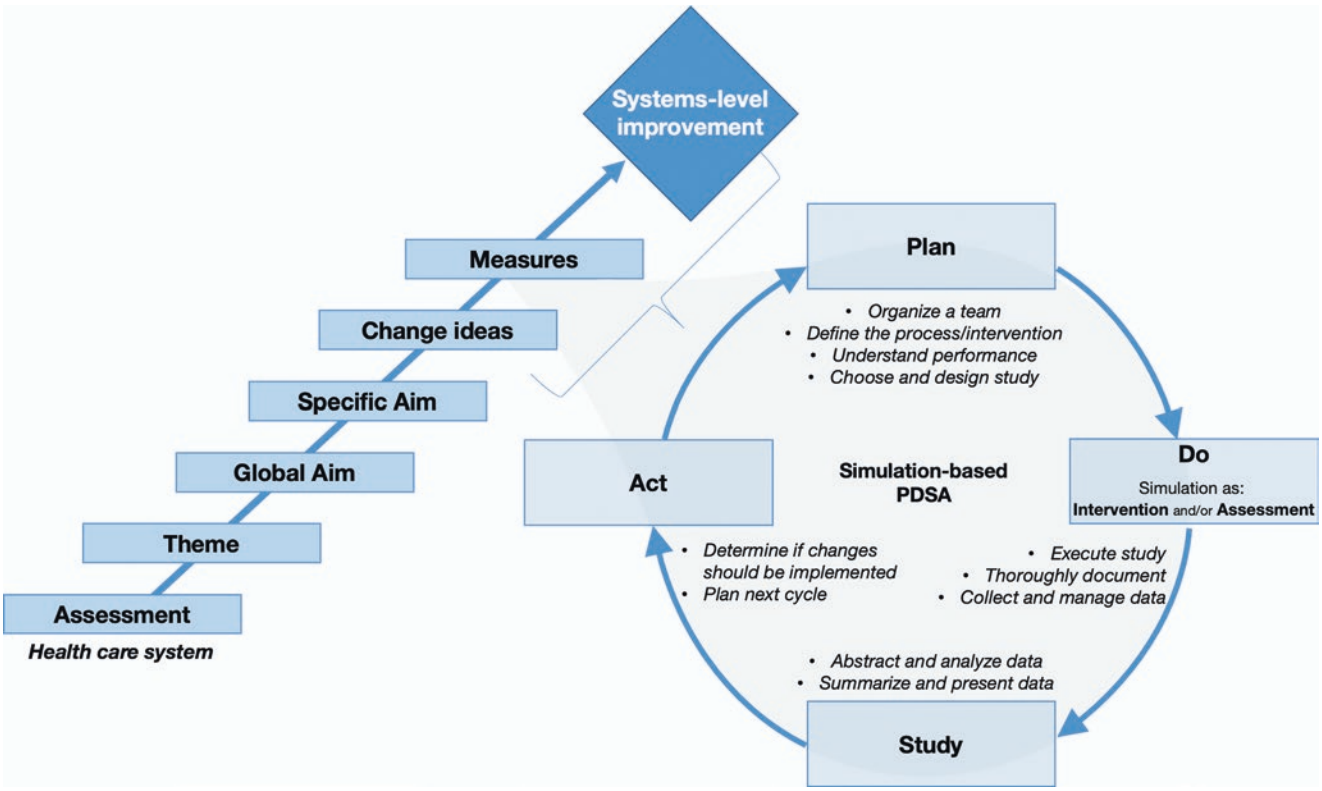

Fig. 24.1 Framework for simulation-based, systems-level quality improvement. A combination of a Plan-Do-Study-Act (PDSA) quality improvement cycle and the Dartmouth microsystem improvement curriculum model is presented. (Modified with permission from The Dartmouth Institute for Health Policy and Clinical Practice, Dartmouth Microsystem Improvement Curriculum)

Table 24.1 Phases and activities of executing a simulation-based QI study

Phase	Activities	Considerations
Pre-PDSA	Understand the system Identify a problem Choose a specific aim	What is the process(es) or outcome(s) of interest? What are microsystems/units that comprise the system? Is PDSA the right QI study method?
Plan	Organize a team Define the process/ intervention Understand performance Choose and design study	Is simulation the right tool for the PDSA cycle? Will the collected data measure the relationship between a process and outcome? What type of study design is most appropriate, and will it be able to capture a measurable change? What is the hypothesis/ prediction?
Do	Execute the plan Thoroughly document the methods and data Collect and manage the data	Is simulation being used as the assessment tool or the intervention? Is documentation sufficient?
Study	Abstract the data Analyze the data Summarize and adequately present the data	Were data collected over time? Were statistics used to test the effect of change and control for possible variations over time?
Act	Decide whether to adopt change and/or implement new PDSA cycle	Are multiple PDSA cycles needed? Should the PDSA method be continued?

Before PDSA: Understanding the System

Even before beginning the "plan" phase of a PDSA cycle, an understanding of the system and goals of improving the system is imperative. Many successful QI programs conceptually deconstruct the larger organization into microsystems that are the smallest replicable clinical units that provide care to patients [17]. The concept of microsystems is derived from the work of W. Edwards Deming [18] (as are PDSA cycles) and expanded by Paul Batalden and Eugene Nelson at Dartmouth [19]. Implementing a change at the microsystem level offers a feasible way to effect change at the organizational level, as the organization is a sum of microsystems. For example, a microsystem change for a small subset of patients with a common diagnosis may provide proof of concept to expand the change to other patient subpopulations within the same organization.

Plan

The "plan" phase of a PDSA cycle involves the identification of a change to be implemented and involves the following: (1) organizing a team; (2) defining the process/intervention; (3) understanding performance; and (4) choosing and designing a study. A key component of any QI project is the development of a broad and engaged multidisciplinary team. The involvement of multiple stakeholders, especially those who participate in the frontline of the process, is key to correctly understanding the root causes of a problem and improving the likelihood of success of an intervention [20]. Once the team has a better understanding of the system it is trying to improve, the team must identify a problem, choose a specific aim, and define the outcome they plan to track. When defining the process or intervention, the team might consider whether simulation would be a useful tool for the project. Simulation can be useful to understand a process by allowing for role play that may help identify areas for improvement. It can also be used as an intervention if the goal is to improve team performance through simulation-based education.

The specifics of QI study design are beyond the scope of this chapter, but a number of approaches of varying complexity have been developed and have been summarized in the literature [3, 12, 21]. The simplest study design is a pre-post test (i.e. before and after). Designs that resemble traditional research methodology include multiple baseline design, or an experimental design [3]. For example, a randomized controlled trial (RCT) may be used in QI studies but are often difficult for studying improvement since many interventions are generally implemented in "real world" settings and are difficult to design and implement [21]. As variants of RCTs, cluster-randomized trials have been advocated by some given their randomization of units rather than individuals, which may be more suitable for systems-level interventions or outcomes [22, 23]. Another variant of an RCT design is a stepped-wedge design, which consists of a sequential roll-out of an intervention to clusters, where all clusters receive the intervention at the end of the study. This study design offers several advantages over other study designs, such as logistical benefits and assurance that all groups will receive the intervention [24].

Do

The "do" phase implements the change and involves executing the study while thoroughly documenting the methods and data. During this phase, simulation can be used as the

intervention and/or the assessment tool depending the goal of interest. We discuss the applications of simulation for QI studies in detail in the next two sections of this chapter.

Study

The key to the "study" phase is data analysis. This may involve various analytical tools including run charts, statistical process control charts [25], or other statistical approaches such as interrupted time series analyses [26]. The central aspect of the data summary and analysis is anchoring the data to a temporal representation relative to the intervention. This is an important consideration if the outcome is simulation-based (i.e. simulation is the assessment and measurement of the effect of the intervention) and repeated measurements may not be feasible due to resource or study limitations.

Act

The final phase of the PDSA cycle involves assessing next steps based on the findings of the study phase. The investigator has several options: [11] (1) fully implement and sustain the intervention; (2) begin a new PDSA cycle at the "plan" phase; (3) revisit the pre-PDSA phase; or (4) end the project without further effort. A hallmark of the PDSA method is the ability to rapidly assess whether a change worked or not, and to learn and act upon new information.

Using Simulation in Quality Improvement

Simulation as an Intervention

Simulation can be an effective tool in the context of quality improvement [27]. We offer two broad categories of simulation for QI: simulation as an intervention and simulation as an assessment tool. A number of studies using simulation as an intervention tool have been reported in the literature for quality improvement. In Table 24.2, we provide some examples of simulation-based QI studies categorized by various domains along the QI spectrum: policies/procedures, medications, equipment, knowledge, decision-making, teamwork/communication, patient safety, and clinical performance.

A growing body of evidence has strongly suggested that simulation can be an effective educational tool [28, 29], and a review by Cook et al. suggests that, compared with no

Table 24.2 Examples of studies using simulation for QI

QI component	Example of study	Sim as intervention	Sim as assessment	Summary of study
Policies/ procedures	Whitfill et al. 2018 [45]	X	X	Participation in a simulation-based quality improvement collaborative was associated with improvements in pediatric readiness for emergencies.
Medications	Harris MA et al. 2014 [50].	X		A simulation-based intervention led to significantly higher scores of students in the medication administration exam versus a didactic medication administration review session.
Equipment	Davies M et al. 2014 [51].		X	The implementation of a sealed tray system led to a significant and sustained improvement in resuscitation equipment availability but had no effect on resuscitation trolley checking frequency.
Knowledge	Starr M et al. 2017 [52]	X		A quality improvement intervention with three rapid PDSA cycles improved senior pediatric resident confidence and competence with ACGME required procedural skills.
Decision-making	Murray DJ et al. 2015 [53]	X		Simulation can be used to provide teams with decision-making experiences in trauma settings and could be used to identify diagnostic skills for improvement as well as study the decision-making process.
Teamwork/ communication	Fransen AF et al. 2012 [54].	X		Team performance and medical technical skills may be significantly improved in hospital obstetric departments after multiprofessional obstetric team training in a medical simulation center.
Patient safety	Yajamanyam PK, Sohi D. 2015 [55].		X	*In situ* simulation training was implemented as a quality improvement initiative and was able to detect and mitigate several latent safety threats, thus improving patient safety.
Clinical performance	Draycott T et al. 2006 [33]	X		Simulation-based obstetrics emergency training led to a decrease in the incidence of hypoxic-ischemic encephalopathy from 27.3 to 13.6 per 10,000 births.

intervention, simulation can improve knowledge, skills, and behaviors of healthcare providers [30].

Simulation may be used as an educational intervention to improve the quality of care. For example, Wayne et al. described significant improvements in the quality of cardiac arrest clinical care provided by third-year residents who trained on a simulator versus those that did not [31]. In an interrupted time-series study, interprofessional team training led to significant improvements in safety culture in surgical wards [32]. Additionally, in a pilot study in the Netherlands, simulation-based obstetric team training led to significant improvements in patient-reported quality of care [32].

Several studies have reported how simulation-based training at the microsystem level can improve on patient outcomes at the macrosystem level. For example, a multi-professional simulation course at the Southmead Hospital in the United Kingdom was introduced to all hospital midwifery providers in 2000 and was subsequently associated with improved neonatal outcomes across the hospital. The incidence of hypoxic ischemic encephalopathy was nearly cut in half [33], and there were decreases in neonatal injury [34] and improvement in neonatal outcomes throughout the hospital [34]. However, literature describing systems-level improvements in patient outcomes as a result of simulation-based interventions is relatively rare, and more work is needed to demonstrate the effectiveness of this approach to improve patient outcomes.

Simulation as an Assessment Tool

Simulation can be utilized to study effects of changes that may otherwise could be unfeasible, unsafe, unethical or untimely to assess in a clinical setting [27]. Simulation-based studies can serve as an assessment tool for patient safety [35, 36], as studying medical errors in the clinical setting may not be feasible due to ethical concerns or practical restraints [37].

Simulation can be used as an opportunity to test systems and prepare staff before a hospital opens [38] or can be used on an ongoing basis for detecting latent safety threats [39] and other patient safety events. For example, a 1-year investigation using *in situ* simulations in an academic pediatric Emergency Department (ED) identified 73 latent safety threats (including 22 related to medication storage and delivery, 26 related to equipment, and 25 related to resources or systems) [40]. Another study used *in situ* simulations to assess 30 hospitals to describe safety threats during care of infants with hypoglycemic seizures [39].

Simulation can also measure quality of care in a simulated setting. For example, Auerbach, Whitfill et al. assessed 30 hospitals using *in situ* simulations to describe the quality of care for pediatric resuscitation in EDs [41]. Other simulation-based studies have focused on assessment of CPR delivery and resuscitative care for cardiac arrests [41–44].

Simulation as Both the Intervention and Assessment Tool

In certain cases, simulation can serve as both the intervention and assessment tool, where the results of a simulation-based assessment are used to drive systems-level changes. For example, Whitfill et al. [45] describe a program in Connecticut that uses simulation to assess the quality of care in pediatric emergency departments, and uses data to improve policies and procedures at those EDs measured by the National Pediatric Readiness Project (NPRP) through the Pediatric Readiness Survey (PRS) [46]. A similar program in Indiana has been implemented by Abulebda et al. [47, 48] and Abu-Sultaneh et al. [49] These programs have resulted in significant improvements in ED-level pediatric readiness.

Conclusions

While major improvements have been made in healthcare delivery systems in the past two decades, the quality of healthcare remains inconsistent, and measuring and improving the quality of care across healthcare delivery systems is complex. However, implementing changes in smaller microsystems, and using simulation to safely test change ideas using a plan-do-study-act (PDSA) model, can have substantial positive effects on the larger health system or organization.

Simulation has been used to improve the quality of care, including policies/procedures, medications, equipment, knowledge, decision-making, teamwork/communication, patient safety, and clinical performance. Simulation is a powerful tool that can be adapted into numerous types of QI programs to improve systems-level quality of care.

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How Many of Those Things Do We Really Need? Discrete Event Simulation

25

Theodore Eugene Day, Yue Dong, and Balagopal Gopakumar

Introduction

Most healthcare executives can attest to the fact that decision-making in this industry is intrinsically challenging. The underlying uncertainty of unpredictable demand, ambiguity of disease presentations, and variability of the diagnostic process and treatment options is further complicated by the pressures of policy and management. The decision-making process also needs to be spread across diverse, often siloed areas within this sociotechnical work system - from the OR to sterile processing to billing and beyond. It is precisely at the interface of these multi-faceted features of healthcare work where computer simulation can be another source of valuable information to make sense of the complex environment, and can provide support for difficult work system decisions. The goal of using computer simulation in complex healthcare environments is to aid in the engineering of transparent systems: those systems that liberate providers from managing systems, and allow them to return to providing care.

Table 25.1 provides a list of alternative approaches to an illustrative example: *Expansion of the emergency services footprint within a medical center is being considered but is difficult to map to existing quantitative data related to utilization and patient volume. The options for improvement include (a) add additional ED beds; (b) increase the number of ED staff (e.g., non-clinical personnel); (3) increase the number of clinical providers (e.g., physicians, nurse practitioners, physician's assistants); (4) create a separate area for treatment of low acuity patients,(5) consider diversion to an off-site location (e.g., Free standing Emergency Department (ED)) or (5) combine the aforementioned interventions.*

Table 25.1 Ways to Study a System

Options	Example	Feasibility
Study & experiment with *actual system*	Schedule additional staff and measure wait times & other metrics	***Low*** Difficult to test across sufficient days. Prohibitive cost of intervention.
Experiment with *physical model* of the system	Add extra ED beds and study the metrics of interest	***Extremely low*** Building models of physical systems is expensive, time consuming, unrealistic.
Experiment with *mathematical model* of the system	Utilize a spreadsheet and conduct sensitivity analysis on system parameters.	***Moderate*** Mathematical models may not have closed-form solutions, are not adaptable to changing parameters.
Experiment through *discrete event simulation*	Use a computer model to test number of beds, staff needed at different times of day	***Very high*** Test all permutations of factors before making changes in the actual system.

How might we go about evaluating potential options?

A Brief History of Discrete Event Simulation

> "*Simulation is the process of designing a model of a real system and conducting experiments with this model for the purpose either of understanding the behavior of the system or of evaluating various strategies (within the limits imposed by a criterion or set of criteria) for the operation of a system.*" [1]

Simply stated, Simulation can be defined as a process in which a system to be studied is replaced with an equivalent

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replica (model), such that the relationships existing in the real system can be approximated [2]. The results created from the simulation can then be used to analyze and draw conclusions about the system. The earliest form of simulation can be traced back to 1700s in the form of Monte Carlo (MC) Simulation, in which the simple idea of a series of coin flips (randomness) was used to study different phenomenon [3]. Major advances in this area occurred in the 1940s due to advent of general purpose electronic computers and the utilization of computers in the Manhattan project. Computer simulation, such as Monte Carlo models, were used to study the neutron diffusion models as part of the hydrogen bomb development process [4, 5].

Discrete Event Simulation (DES) combines the historical concepts of simulation described above and implements them in a computer environment. This allows us to build realistic models of complex environments in a short time, employing a graphical user interface, and providing a visualized model of the simulated system that operates at greatly accelerated speed, so as to drastically reduce the time required for analysis compared with real-world experimentation.

Why Use DES Rather Than an Exact Mathematical Solution?

- It is often possible to capture the exact behavior of a real-world system using complex mathematical models, such as Linear programming, Queuing Models, Markov chains, Differential equations, and so on. However, the analytical solutions may be intractable, and DES provides a numerical approximation of the solution [6].
- In many instances, formulation of a mathematical model is not feasible due to system complexity, solution computation time, or nonlinear systems dynamics that cannot be solved in closed form; DES again provides an approach to create a useful replica of the system.

In most healthcare processes, there are many possible outcomes along the progression of care of the patient (Fig. 25.1) based on the clinical condition (e.g., triage level based on severity of illness), ED capacity (e.g., availability of staff, lab, imaging equipment, beds) or operational considerations (e.g., patient's isolation status, temporary ED closure for new patients based on excessive patient volume, high inpatient census).

In systems such as these where multiple variables can generate a large variety of potential outcomes and connections, DES is a well-suited technique [7].

What Is Discrete Event Simulation

DES consists of two keywords: 'Discrete Event' and 'Simulation'. Consider these healthcare specific descriptions of components of DES:

- **System**: the process or facility which is the focus of the study. *An OR, inpatient nursing unit or an entire hospital are all examples of systems*. Hence, the concept of a 'sys-

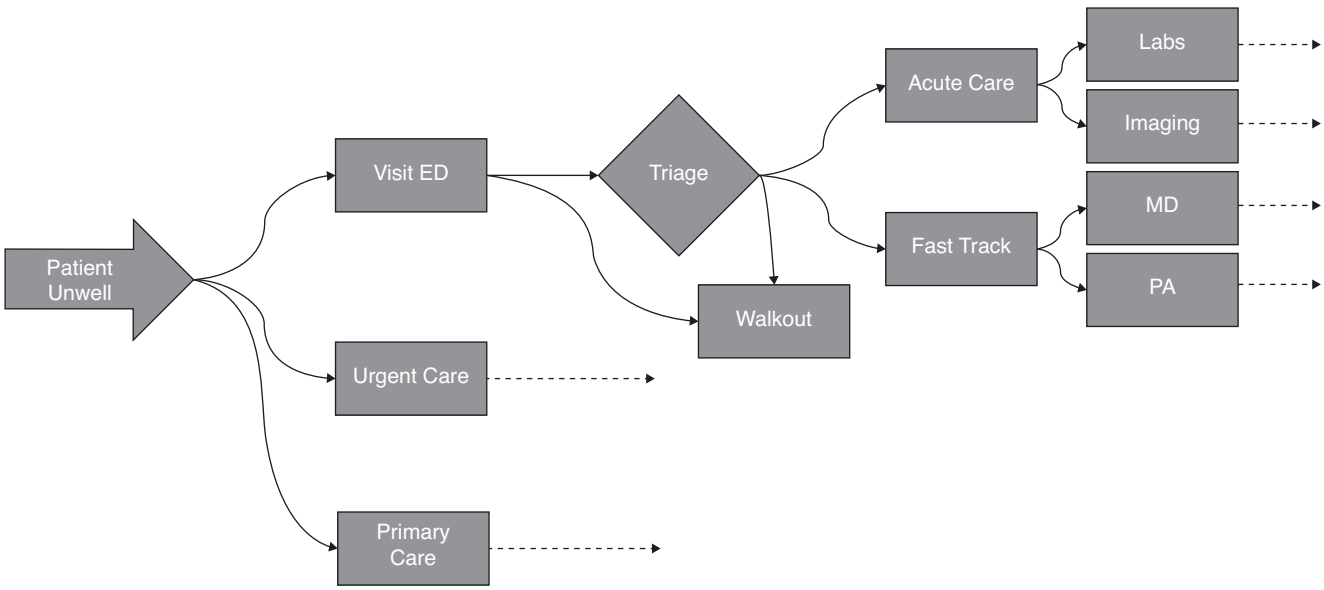

Fig. 25.1 Possible outcomes during the progression of patient care pathway

tem' is fairly generic since it depends on the objective of the study or analysis.

- **Model**: a representation of an actual system, created with the objective of furthering the understanding of the very system it mimics. *Although it may sound complex, a spreadsheet with the forecast of monthly inpatient admissions is an example of a model.*
- **State**: a 'Collection of variables necessary to describe a system at a particular instant of time relative to the objective of the study' [8]. *The number of patients waiting in the ED, or number of occupied beds in a hospital at any given time are all examples of state variables.*

Now, let us look at a technical definition [9]

"*Discrete event simulation utilizes a mathematical/logical model of a physical system that portrays state changes at precise points in simulated time. Both the nature of the state change and the time at which the change occurs mandate precise description. Customers waiting for service, the management of parts inventory or military combat are typical domains of discrete event simulation.*"

The history of DES can be traced to the 1960s, when it was developed as a way to model and study industrial and business processes [10]. Ever since then, it has found applications in almost every industry – from factory shop floors to airports to hospital ORs. Although some applications of DES in healthcare can be found in the 1960s and 1970s, its use in healthcare has accelerated in the past decade, with increasing use in almost every domain – from surgical suites to ambulatory clinics. The approach is being increasingly adopted due to its ease of explanation to non-engineers, its capacity for team model-building, and its speed and utility in providing solutions for system challenges not amenable to real-world experimentation.

In a DES approach, the state of the system is assumed to change at different points in time, instantaneously. Using the previous example of the ED: the occupancy changes at discrete points in time, such as when a patient is discharged, or when a new patient arrives. Hence DES can be defined as a methodology for modeling systems in which the state variables changes only at discrete set of points in time [11]. It can mimic the behavior of a system over a specific period of time as it evolves from one state to another.

"DES is a popular alternative to queuing models [a type of exact mathematical model] because it is possible to study applications with large scale and scope and to relax many of the assumptions necessary in queuing models". The DES literature most often focuses on a single unit of a hospital (e.g., ED, OR) and/or on a single type of patient (e.g., trauma, surgery, cardiac).

Examples of healthcare applications of DES include:

- Patient flow: Reducing wait time in EDs and clinics
- Capacity planning: Determining the optimal number of additional beds, staff and equipment
- Scheduling: Improving clinical and surgical scheduling
- Disease transmission: Developing Standardized Infection Ratio (SIR) infectious disease transmission models
- Policy evaluation: Predicting the impact of changes in budgets or discharge planning processes

Table 25.2 provides a non-comprehensive list of available DES software packages with strengths and weaknesses for the reader's consideration.

Table 25.2 Available Simulation Packages

Package	Interface	Visualization	Other Models Supported	Strengths
ARENA	2D	2D/3D		Most widely used packages & general-purpose simulation tool Large user base and community
AnyLogic	2D	2D/3D	ABM/SD	Availability of all simulation frameworks in one platform Growing user base
FlexSim	2D/3D	2D/3D		3D visualization Healthcare specific module available
Simio	2D/3D	2D/3D		3D visualization
SIMUL8	2D/3D		Monte Carlo	Ease of use Visualization
GoldSim	2D		SD	
MedModel	2D	2D	N/A	Healthcare specific
NetLogo[a]	2D	2D/3D	ABM/SD	Large user community & available models
SimPy[a]	Coding (Python)	n/a	Only DES	Allows integration with data, if other analysis is also performed in Python

Table adapted from [4]
2D 2 dimensional, *3D* 3 dimensional, *SD* System dynamics, *ABM* Agent based modeling, *DES* Discrete event simulation, *N/A* Not applicable
[a]Open source applications

Other Types of Computer Simulation Models

Two other types of closely related computer simulation techniques, **System Dynamics** and **Agent Based Modeling** provide slightly different perspectives.

System Dynamics (SD)

System dynamics (SD) is a technique which was developed at the Massachusetts Institute of Technology in the 1950s by Professor Jay Wright Forrester for the purposes of studying the behaviors of complex systems over long periods of time. SD incorporated the concepts of feedback control used commonly in engineering into management situations. It uses the relationships ('causal relationships') between the key variables in the system to capture and simulate the behavior of the system over time. The use of causal relationships allows the SD framework to capture variables or relationships which are otherwise hard to capture in more traditional DES techniques. This feature of SD allows the development of an intuitive model of the system under study, enabling a better understanding of the complex interrelationships existing. This 'system centric' view of SD has made it appealing to policy planners and managers.

Hence, SD is well suited to as a methodology to strategize and analyze policy interventions [12]. In healthcare, SD is popularly used in analyzing policy decisions such as patient pathways [13], bed capacity & discharge planning [14–16].

Agent Based Modeling

Agent based modeling (ABM) is another simulation modeling approach, which has become increasingly popular in the recent years. Unlike other simulation techniques (e.g., DES, SD), ABM approaches the system to be modeled from the perspective of the individual units constituting the system. The collection of entities in the system (patients, nurses, doctors, imaging machines etc.) are called agents. Agents are provided with a basic set of rules (behaviors), and they can individually assess their current situation and execute appropriate behaviors. In essence, ABM models the system as collection of agents (with their individual behaviors or states) and their interrelationships [17]. Given the autonomous nature of the agents, ABM can sometimes provide a more realistic representation of the system. For additional information on ABM, the reader is referred to the works of Railsback and Grimm [18], Wilensky and Rand [19].

Developing a Model

For the purposes of this text, we restrict ourselves to the discussion of DES models specifically. DES Model development tends to follow a basic four step process: (1) system decomposition, (2) flow development, (3) coding and testing, (4) validation. Each of these steps is further subdivided into process steps that will vary by system modeled, the intended use of the model, the stakeholders' desires and participation level, and the scope and granularity of the overall project. Generally speaking, modeling a system is a bespoke affair; there are very few general models which are capable of being sufficiently specified for a wide variety of individual use cases. Thus, we approach model development in this test as it is conducted for modeling specific clinical environments from scratch. To do this, we focus on two recent case studies from the medical literature.

In the first case study, Chepenik and Pinker [20], modeled a psychiatric emergency service of a hospital in order to ascertain the value of adding additional provider resources to support patient flow. This model was coded in MATLAB (MathWorks Inc, Natick, Massachusetts) and represents a useful application of DES: the ability to quickly model complex queueing systems at a relatively coarse granularity in order to draw important conclusions about the high-level properties of the system. This allows stakeholders to make rapid, informed decisions about the system, the consequences of intervention, and trade-offs between action and inaction.

The second case study, by Day *et al*, [21], represents a detailed, in depth model of a cardiac operative and imaging center with associated cardiac intensive care unit, cardiac step-down unit, and perioperative services. It is an example of a large and finely grained examination of a complex system with a more open-ended exploratory purpose: to identify a strategy to minimize surgical cancellations and develop evidence for a real-world intervention that will be adopted by potentially reluctant staff and providers. This model was coded in MedModel (ProModel Corp, Allentown PA), a commercially available DES software tailored to simulating medical systems that require modeling beyond ordinary queueing analysis.

Authors of both models describe their process of development:

System Decomposition

This is the process of identifying the constituent elements of the system to be modeled. This means creating a mapping from real-world structures and elements to computer data-structures that represent them in simulation. These elements include:

"*Locations*" are both the physical location that medical care takes place (or is planned and discussed) such as exam rooms, beds, operating rooms (ORs), linen closets, medication rooms, etc., as well as virtual locations as needed, such as computers storing electronic medical records, lab test results, radiology venues, etc.

"*Resources*" are the objects in a simulation which perform the work required to process the flow of the simulation. These include human resources (Physicians, nurses, technicians, environmental services staff, etc.) as well as durable objects – those not used up in the course of care – such as portable X-ray machines, EKG machines, and other such items which are scarce but necessary for patient care.

"*Entities*" represent the things which are processed, generated, or used up during the course of care. Thus, entities are used to represent patients, lab samples, radiology film, medication, supplies, medical records, and related items.

"*Networks*" represent the physical layout of the space, and the paths on which resources and entities travel between locations.

Flow Development

Developing the flow of a simulation model requires answering a basic, but often deceptively complex, question: "How do entities consume resources at locations, and then proceed from one location to the next?" In the first example, Chepenik and Pinker [20] develop the flow as a system of queues, which, from the patient's perspective, are in series. Patients arrive, await evaluation, and then are observed, admitted, or discharged. Observed patients are then reevaluated periodically, until a disposition is determined. In the model by Day *et al*, patients may arrive via a variety of avenues: elective admission for surgery or catheterization, emergency admission for surgery or catheterization, or direct admission to the Cardiac Intensive Care Unit (CICU) or step-down unit. Patients then receive care as defined by their arrival process: perioperative care, possibly imaging, a procedure, recovery and inpatient care. Directly admitted patients will occupy space in the CICU or step-down unit, and may transfer from one to the other, or require a procedure as an inpatient. In both models, the flow is determined by each entity behaving according to a probabilistic path determined from real-world observations of patient movements in the systems modeled.

Coding and Testing

This aspect of DES development is generally the least described in the published literature. For example, Chepenik and Pinker [20] state only that they coded their model in MATLAB programming language, while Day *et al* used MedModel, as described above. Coding the model is the process, generally using a commercially available DES engine (Table 25.1), of creating the necessary structures described above in an object-oriented programming environment. Arrivals, flow, queueing, and interactions of all entities, resources, and locations are duplicated in order to mimic the behavior of a real-world system. Tools available for this include the local and global variables which can be attached to entities or locations (usually referred to as "attributes"), arrays and files with stored data generated by the model for analysis, and the statistical distributions generated from the data analysis required to build the stochastic processes on which these models rely to reflect real-world operations.

Validation

Validation is the process of ensuring that a model is accurate, reliable, precise, and appropriate for the system modeled and questions pursued. This generally consists of a combination of verification that the model accurately represents the real-world clinical area it is based upon and statistical or mathematical analysis showing that its results are within acceptable limits of real-world system performance. Validation is described comprehensively in Section 3, below.

Interviewing Stakeholders

One of the most crucial aspects of modeling healthcare delivery systems with DES is the ability to engage and rely on partnerships with clinical and administrative leaders. The best and most accurate model in the world is useless if the physicians, nurses, and decision-makers charged with the operation of the real-world system being simulated are not committed to participating, gaining insight, identifying improvements, and implementing solutions. DES is a natural tool to help drive engagement, given its graphical nature and intuitive representation of clinical environments. However, it is paramount that modelers leverage this natural advantage.

The first thing is for modelers to recognize and acknowledge that as good as our solutions are, there will always be medical processes and implications we cannot influence, control, or govern. No discrete event simulation of a clinic is going to tell physicians how to treat patients – that is not its goal. Rather, the purpose of a DES of a clinical system is to identify improvement opportunities which liberate care providers to practice in an environment that supports them instead of thwarting them. Therefore, modelers need to stipulate our limitations prior to building models and making recommendations.

Providers and administrators should be interviewed for their knowledge of system processes, their understanding of system dynamics and bottlenecks, their intuition about systemic improvements, and even their complaints about policy or process that they believe are unproductive. These insights are invaluable. Modelers should ask them to describe their day from beginning to end, to describe patient encounters, and all other work that they do. Then, modelers should request to shadow the care providers through their work pro-

cess in order to understand how they accomplish the tasks that will be modeled. The most important part of the process is listening to how providers care for their patients, how they operate, and what they wish could be changed about the system.

Once a process map of the system is built, all stakeholders who participated in the process (and others if possible) should again be approached and asked to validate the work done prior to beginning to code the simulation. This ensures not only that the model is as accurate as possible, but also that the system stakeholders understand the assumptions being made, the capabilities of the final product, and the time and effort invested in tailoring a model to a specific clinical environment. They should feel ownership of the final product, and thus will be more likely to be invested in seeing the overall project through to implementing improvements.

Data Gathering

Data acquisition for DES models generally comes from two basic sources: hospital data warehouses, and hand-collected observational data. Data collection can involve similar timeframes as other performance improvement products where data and processes must be determined by hand. It is generally advisable to physically embed a data collector in the area they are observing for a few days or even a week or two. Occasionally, data may also be hand-abstracted from electronic medical records. While protected health information (PHI) is generally not needed to produce DES models, it is wise to consult privacy experts prior to model-building, and to be familiar with the Health Information Portability and Accountability Act (HIPAA). There are ethical issues associated with model-building and the data needed to produce models, and with the data governance, storage, and retention that should be considered prior to beginning a project.

Collecting data from data warehouses tends to be the easiest method for beginning model-building. Generally, large amounts of data on patient admission/discharge/transfer (ADT) can be collected rapidly, and then cleaned and formatted for use in a simulation. The specific amount and type of data, as well as the format needed, will vary by the system being studied and the simulation software being used. However, several factors influence which fields to collect and how to interpret them.

For example, time-stamp data that is not automatically recorded should be treated as suspect. If the time stamp is recorded based on when a physician or nurse enters a note into an electronic medical record, it should not be treated as reliable, as the EMR may record when the note was entered, and not when the actual care process occurred. The simulation requires the time the process required, not when it was recorded, and there may be a large discrepancy between the two. Similarly, medical examination times as entered to fulfill billing criteria are not necessarily useful for simulation purposes – more important is the actual room time that the patient and provider share. Attempting to capture the amount of time a physician or nurse spends conducting a patient exam should be observed personally, so as to ensure that the data captured from the real world is useful in simulation. Entities consume resources differently in simulation than in the real world, due to the impossibility of capturing every individual action a resource must undertake throughout an exam. Thus, it is generally better to consider the entire time a physician is in a room with a patient as the "exam time" rather than attempting to tease out each individual action. The crux of the interaction is that the physician is unavailable for other tasks while engaged with the patient.

The collected data is then used to develop the statistical distributions for the random events which will occur in the model. It is important to collect enough data for each point to be usefully modeled, but not so much as to overfit the processes being observed. Power calculations may be useful to determine how many observations are required to ensure that the means of real-world and simulated data are not significantly different.

Validating the Model

In 2012, the Society for Medical Decision Making (SMDM) published a series of seven papers on the use of modeling and simulation to support decision-makers in the world of healthcare delivery [22–28]. This series, published in the journal *Medical Decision Making*, is now commonly referenced as the standard best practices for this field. Two papers from this series are specifically relevant, Karnon *et al's* "Modeling using Discrete Event Simulation: A Report of the ISPOR-SMDM Modeling Good Research Practices Task Force-4" (2012), and Eddy *et al's* "Model Transparency and Validation: A Report of the ISPOR-SMDM Modeling Good Research Practices Task Force-7" (2012). In these papers, SMDM set out *five types of validation.*

1. *Face Validity* – The agreement from stakeholders and modelers that the model is appropriately representative of the system modeled.
2. *Internal Validity* (or verification) – The validation of the model code and mathematics to assure that the model is operating correctly and performing as designed.
3. *External Validity* – Testing to ensure that when provided with realistic inputs, the model produces realistic outputs; that is, the model accurately and precisely calculates real-world trajectories of system performance.
4. *Cross Validity* – Assures that when two different models of the same real-word system are compared to one another, they agree with one another.

5. *Predictive Validity* – The gold standard of model validity. This level of validation reports that when an externally valid model is used to predict the effects of a systemic intervention, and then that intervention is tested in the real world, the prediction is correct.

In considering the two papers, we observe two different approaches to the reportage of validity.

Chepenik and Pinker [20] do not mention the words "validation" or "validity". They present mean-based data on the external validity of their model. Their paper does seem to describe that a validation process was undertaken, as in their Results section they note that their model produced values "similar" to the real-world system. They describe these ranges and means as satisfying "general agreement", which seems to indicate a face-validation procedure.

Day *et al,* by contrast, include a section on validation, and describe face, internal, and external validation procedures. The paper itself describes an attempt to produce predictive validity, and where the outcome of the real-world trial and simulated experiment vary, the discrepancy in results is explored and explained (there was a pronounced difference in patient arrivals between the original prediction based on the prior year's demand and the demand on the real- world system after the intervention was simulated).

It is of value to stakeholders, the general reader, and future modelers to be as explicit as possible with respect to validation metrics, procedures, and results. This supports confidence in the model's realism, and thus can lead to more engagement with adopting results suggested by model outputs.

Deploying the Model

Once a model is built and validated, it can be used in several ways. Many simulations are used for hypothesis generation: essentially playing with the simulation's parameters and attempting to identify improvements through trial and error. Generally, we advocate a more systematic approach. Simulations can be used as a hypothesis testing environment in the same manner as any scientific experiment. One copy of the simulation is held as a control, while a second copy is configured to a proposed future state. Then, data can be taken from multiple runs of each simulation and traditional hypothesis testing can be used to determine if the future-state data is statistically distinct from the current-state data.

For example, Chepenik and Pinker [20] consider alternate potential allocations of provider resources in order to optimize care provision in a complex clinical environment. Day *et al* vary the day of the week on which surgery is performed in the hybrid catheterization lab/Operating Room (OR) suite, and test how many canceled surgeries would likely be necessary in the simulated system. In both these cases, the original system is perturbed in simulation, which allows the analysis of a potential improvement.

It is important to use a validated simulation as a control, and not the real-world system. Similar numbers of simulation runs can be compared from both the experiment and control scenarios. Thus, similar amounts of data can be generated for each scenario. It is generally easy to create simulated data, and difficult to collect real-world data. Vast quantities of simulated data can be generated in a very short period of time. When conducting statistical hypothesis testing on such data, one should take care to recognize that with large n's, arbitrarily small differences in means may be statistically significant. Thus, experienced engineers and physicians should partner in order to be assured that interventions are predicted to have not only statistical significance, but also clinical and operational significance.

Adoption and Implementation

Many clinicians are simply not aware of the systems-based approach employed by industrial engineers in other industries. While there has been wider adoption of (QI) methods such as Lean and Six Sigma, simulation is only now gaining more general acceptance among hospital administrators and providers. In combination, these can offer numerous strategies for improving effectiveness and, at the same time, decreasing waste. Healthcare delivery is complex, dynamic and time-dependent; systems-based simulation may be better than traditional QI tools (e.g., Lean, Six Sigma and value-stream mapping) for managing random variability, interconnections and interdependencies between sub-systems such as patients, providers and processes.

Another barrier to adoption of simulation can be cost and expertise of software and engineers. It can be challenging to see the return on investment for large outlays of hiring personnel and licenses for software - which can be expensive. However, our experience is that the application of simulation to performance improvement initiatives will rapidly pay for itself. Consider the results from Day *et al* (2015): it requires only a small reduction in annual cardiac surgical cancellations to recoup the cost of a few months of an engineer's time.

Desire for Change

Incentivizing change in hospital systems is a topic that would benefit from its own longer treatment. However, it must be briefly noted that insurance companies, regulators, and government programs are attempting to bring quality of care to the forefront through new reimbursement incentives. Hospitals are looking at new ways to pass this urgency for quality on to providers. We have found that the most effective

tool for encouraging the adoption of improvements, however, is success of prior implementations. Nearly all care providers are naturally inclined to provide high-quality care, but the discouragement associated with futile efforts at improvements can lead some to disengage with new implementations. Using DES to guide change can focus large-scale QI and process improvement (PI) efforts on those projects likeliest to be successful, resulting in an energized medical staff when it comes to engaging with new efforts. We also support providing incentives for staff through a variety of means; indeed there should be a path to tenure for QI faculty just as there is for research and administrative faculty.

Knowledge for Change

Hospitals frequently lack personnel with the expertise to lead DES initiatives, as most clinicians lack engineering training and background knowledge, and the cost of dedicated staff for systems or industrial engineering is frequently seen as prohibitive for a hospital. So the interdisciplinary discussions and collaborations are not happening as they should. Thus, often we see partnerships between academic departments at affiliated universities, rather than in-house dedicated staff. This has advantages and drawbacks: educator-led projects employing students are a means of improving systems and providing student learning opportunities [29]. However, external modelers can be challenged by having limited access to the clinical environment, and thus may lack the integrated knowledge necessary to truly understand the systems, and have a stake in their outcomes.

Reinforcement

It should be noted that professional rewards and cross-disciplinary opportunities can be difficult to articulate. Physicians, administrators, and engineers all have separate incentives, reporting mechanisms, metrics of success, and professional ladders which may not reward collaborative efforts. The siloing of these workstreamsDiscrete Event Simulation (DES):implementation can allow for important specialization, but also can hinder building a culture of collaboration and collegiality. We thus advocate that positive reinforcement for collaborative successes be appropriately recognized.

Funding agencies do support this kind of research, and the National Institutes of Health and the Agency for Healthcare Research and Quality have issued requests for applications to study systems and DES implementationsDiscrete Event Simulation (DES):implementation. Similarly, the Veterans Administration Office of Research and Development has funded DES studies in the Veterans Health System, and the authors have had success with smaller foundation and internal mechanisms as well. Thus, using DES to improve health systems may have return on investment both in terms of improved systems performance, and in terms of external funding availability.

Future Directions for DES

Although the field of DES is over 50 years old, there are a still a lot of exciting developments.

- DES can be used within process improvement frameworks such as Six Sigma or Lean (Kaizen). Bal *et al*, [30] presented a case study in which DES was used as part of a Lean improvement event focused on improving the efficiency of an ED. Once a future state model was developed by the team, DES was utilized to evaluate it. In traditional QI efforts, it is not possible to obtain detailed information about the consequences of a change; DES was used to determine the potential impact of changing the processes within the system. For additional details, the reader is referred to the work of Baril et al. [31]
- Traditionally, DES and Virtual Reality (VR) have had different trajectories. However, with the ever-increasing computational power and recent advances in VR technology, there is interest in combining DES and VR. One example is the concept of a "virtual factory" that utilizes DES to model the factory and uses VR to explore the simulation environment. Although current use is limited to manufacturing, it can easily be extended to various areas in healthcare (e.g., ORs, EDs). Readers are referred to Turner et al. [32] for an excellent literature review in this area.
- Integrated DES solutions for inpatient flow and access management is a developing area as well. DES engines which communicate with the electronic medical record are being developed. FutureFlowRx (ProModel Corp, Allentown, PA) uses this link to provide detailed predictions of future hospital states, in order to manage census, flow, staffing, and potential problems. These allow administrative teams to manage hospital systems based not only on what is happening, but on what will happen in the future.

Conclusions

This chapter introduces the concept of DES, which is a tool to understand interactions involving utilization and flow within real-world systems using a mathematical logical model. DES can capture the connections between multiple sub-systems. We have used two healthcare specific case studies to familiarize the readers with the steps

to be undertaken when conducting a DES study. As these case studies highlight, DES can be applied to improve understanding and predict the impact of resource and attribute changes on many real-world systems. Since DES is also very flexible, systems can be modeled at different levels of granularity. Hence, DES provides an excellent tool to support process and systemic improvements in healthcare.

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Part III

Resources to Translate Ideas into Actions

Working with Simulation Experts

26

David O. Kessler, Christiane C. Schubert, and Aaron W. Calhoun

Introduction

Case

Your hospital is planning to open a new Emergency Department (ED) in a year, and it will be twice as big as the prior unit. You are concerned that enlarging the space will generate safety hazards in the new, unfamiliar environment, potentially compromising processes of care. You have heard that simulation methods can be used to uncover latent safety threats in a new environment before harm reaches the patient, but you are not sure about the best way to find simulation resources. You would like to work with simulation experts to design cases, implement assessment programs, and measure outcomes that will help you identify and mitigate issues with the space prior to move-in day.

In this chapter we will discuss (1) what types of simulation relationships and services are available, (2) where to find simulation centers, programs, and experts, (3) how to develop a relationship with simulation experts, and (4) how to find funding to sustain your relationship.

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Types of Simulation Relationships and Services

Simulation comprises a broad and adaptable variety of tools and techniques. When approaching potential collaborators who have expertise in simulation, it is important to communicate the objectives and goals of your project clearly along with any associated training, expertise, design and technology needs. Depending on the nature and complexity of the project, you may choose among multiple types of simulation support services. Numerous chapters in this book address additional principles and specific examples of simulation used to improve patient care at a system level. Important considerations when making these choices, along with relevant examples, are presented in Table 26.1.

In terms of content expertise, it is important to differentiate between simulation-based content expertise and healthcare field-specific expertise. Some simulation programs may specialize in simulation as a training modality, while others may have more experience with simulation as a tool for patient safety, environmental assessment, and systems testing. In addition to this, their faculty clinical backgrounds (if any) may vary widely. Therefore, do not assume that a given faculty member has the specific content or methodologic expertise you need without explicit discussion.

With regard to physical space and equipment, simulation exercises can be conducted within a simulation center that offers training in a variety of staged clinical spaces. These may include pre-hospital set-ups, emergency rooms, operating rooms, intensive care units, pharmacies, general inpatient rooms, or even simulated space-flight environments. Simulation training can also be conducted *in situ* within a clinical (patient care) unit. More recent developments in medical education include the use of virtual and augmented reality. Virtual reality (VR) is "the use of computer technology to create an immersive three-dimensional world in which the objects have a sense of spatial presence" and augmented reality (AR) is a variant of virtual reality

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Table 26.1 Key considerations when engaging simulation experts (with examples)

Considerations	Examples of responses			
What safety or quality issue am I trying to address??	Assessment of environment for latent safety threats during cardiac arrest case	Safety of a new medication process	Standardizing training on new catheters to reduce CAUTI	Failure modes effect analysis for overriding medication checks during arrest
What healthcare content knowledge and/or expertise is needed on the project team?	Inter-professional expertise (MD, RN, RT, etc.)	Administrative knowledge and expertise	Subspecialty-specific medical knowledge and expertise	Information technology expertise
What type of simulation expertise do I think is needed?	Space or system testing expertise	Human factors & ergonomics analysis expertise	VR development expertise	Quality and safety experience
What type of simulation(s) will be required?	In-situ (point of care)	Center-based	VR + center-based for remediation as needed	Table-top + center-based
What physical space will I need?	Actual clinical space (in-situ)	Simulation Center mock-up + live patient actors	Simulation center with capacity for immersive VR	Mixed: Simulation center + conference room space
What equipment or resources will I need?	Code or medication cart should be authentic	Actual care teams	VR headsets, manikins for center + procedure related equipment	Actual electronic medication delivery system + Actual care teams

MD Medical Doctor, *RN* Registered Nurse, *RT* Respiratory Therapist, *CAUTI* Catheter-Associated Urinary Tract Infection, *VR* Virtual Reality

"in which synthetic stimuli are superimposed on real world objects or places [1]." Both hold tremendous promise to advance the types of environments we can meaningfully recreate. Simulation Programs vary significantly in terms of the type of resources they have and how those can be deployed. It is critical to remember that the lack of a physical space does not imply the absence of adequate resources. In quality improvement simulation specifically, simulation programs frequently employ in-situ or mobile modes of simulation that may well provide experience more germane to quality and safety topics than programs and services located in physical centers. It is also important to remember that these simulation modalities are not mutually exclusive, and your specific project may require multiple approaches (e.g. pre-simulation online modules, followed by in-center training and ongoing *in situ* refreshers) to meet your particular needs.

Simulation is more about the technique than it is about any specific technology. Relationships with experts can help find the balance between desires, needs, and resources to meet specific objectives for a project. The different phases of a project (needs assessment, curricular design, implementation, and assessment) may all benefit from one or more experts in the techniques associated with that phase of development. If you and your team intend to collect research data, it is also important to consult a simulation expert with research expertise who is able to advise on research-specific aspects of the project, such as research design, Institutional Review Board (IRB) requirements, data collection, data analysis, and result dissemination.

A number of different factors could determine the ideal choice of simulation collaborator. To continue with the initial example - evaluating a new clinical space for the ED - seeking out experts who have specific experience in the simulation domain of system and process testing, the specific content area of emergency medicine, and the optimal simulation modality of in-situ simulation will be critical to the project's success. These considerations should thus be at the forefront of your mind as initial contact is made. Ideally, simulation collaborators should be involved early in the planning process in order to conduct a comprehensive needs assessment and to make recommendations accordingly.

Where to Find Simulation Centers, Programs, and Experts

In our experience, the simulation community is remarkably open, collaborative, and eager to partner across professional, disciplinary, and institutional lines. Given this, the biggest barrier to locating an optimal simulation expert for your project is simply knowing where to begin the seach. One good place to start is by contacting the simulation center at your particular institution. In many cases, the leadership of such centers will help triage your request and connect you to the resources that best fit your needs. In many enterprises there may be more than one simulation center or program that individually, or jointly, serve the needs of various learner groups. These diverse learner groups may include medical students, graduate medical learners, nursing students, allied health pro-

fessionals, pharmacists, physicians, nurses, social workers, and chaplains. Understanding the unique mandate and goals of the simulation center will ensure that you select a partner whose mission is aligned with the project you wish to initiate. In addition to formal simulation centers, it is also common to find groups of experts within a clinical department that may lack a physical training space but offer *in situ* training. Depending on the objectives of the project, it might be advantageous to work with such simulation experts directly, particularly if they have relevant content and domain-specific expertise. However, when a project requires a substantial commitment of equipment and personnel, or these resources are being utilized long-term, creating a relationship with a larger simulation center might increase access.

Professional simulation societies and organizations are another excellent resource for locating simulation experts (Table 26.2). Simulation societies often bring together experts from diverse clinical and academic backgrounds, and can serve as a clearinghouse for contacts and other resources. Additionally, other professional societies often have special interest groups dedicated to simulation (e.g. the Section on Simulation and Innovative Learning Methods of the American Academy of Pediatrics). In many cases, networks have been categorized and incorporated into the web-sites of these societies to facilitate professional connections. Some societies provide listings of simulation centers [2, 3].

Searching the simulation literature is an additional means of identifying leading experts on a specific topic. To return to the original example, a quick literature search would reveal several published peer-reviewed studies that use simulation to evaluate new and existing environments [4–8]. While these studies may not address new space modeling and design in your particular environment, the principles involved may be similar. Reaching out to authors or individuals from the institutions where such interventions were carried out may lead to valuable discussions and facilitate building partnerships. It is important to remember that simulation spans a wide range of professions and, in addition to traditional medicine and surgery journals, simulation-related manuscripts can also be found in journals from such disparate fields as human factors and ergonomics, psychology, and sociology. Searching key words and key terms in any of the myriad available academic databases can yield results pertinent to your specific project. Given the above diversity, however, we strongly advise searching multiple databases.

Finally, there are many commercial and consulting practices within the simulation domain and sometimes these may even be directly connected to the academic centers or societies themselves. Keep in mind that simulation expertise encompasses a broad set of skills. An individual who knows a lot about debriefing methodology may not necessarily know how to write session objectives or the best instruments

Table 26.2 Select examples of Simulation Contact Points

Name	Website	Scope
Simulation Oriented Professional Societies		
Hong Kong Society for Simulation in Healthcare	http://hkssih.org.hk/index.html	National: China
International Nursing Association for Clinincal Simulation and Learning	https://www.inacsl.org/	International
International Pediatric Simulation Society	https://www.ipssglobal.org/	International
Latin American Federation of Clinical Simulation & Patient Safety	https://www.flasic.org/	Regional: Latin America
Pan Asian Simulation Society in Healthcare	http://passh.org/index.html	Regional: Asia
Society in Europe for Simulation as Applied to Medicine	https://www.sesam-web.org/	Regional: Europe
Society for Simulation in Healthcare	https://www.ssih.org/	International
Simulation Networks or Consortiums		
Human Patient Simulation Network	http://www.hpsn.com/	International
International Network for Simulation Based Pediatric Innovation Research & Education	http://inspiresim.com/	International
Association for Simulated Practice in Healthcare	https://aspih.org.uk/	Regional: Europe
Pedistars	https://www.pedistarsindia.com/	National: India
Other Professional Societies		
American Academy of Pediatrics Section on Simulation and Innovative Learning Methods	https://www.aap.org/en-us/about-the-aap/Sections/Section-on-Simulation-and-Innovative-Learning-Methods/	Regional: North America
Human Factors and Ergonomics Society	https://www.hfes.org/home	International
Society for Academic Emergency Medicine Simulation Academy	https://community.saem.org/communities/community-home?communitykey=ad59e13e-79e6-4ea5-b0ba-fbf4de29dfcb&tab=groupdetails	Regional: North America

to measure a specific construct. Identifying experts starts with knowing what you are looking for, along with an open-mind for the things that you may not know about simulation. Reaching out to a simulation center, contacting professional societies, and searching the literature are all steps that can lead to identifying the best partner for a specific project and start making the needed connections (Box 26.1).

Box 26.1: Places to Find Simulation Expertise
- Simulation Centers
- Professional Societies
- Simulation Literature
- Research Networks
- Formal Consulting Groups

How to Develop a Relationship with Simulation Experts

Once initial contact has been made, and your team has determined that some individual or program offers the particular expertise that you need, it becomes vital to establish a strong and mutually beneficial partnership. In the fast-paced world of modern academic medicine the creation of such relationships can be difficult given the time investments involved. Even if a program has sufficient resources to be able to assist in a project without purchasing new materials, the time involved can be significant and, as the old adage suggests, time itself is still a financial resource. Therefore, it is important to identify the reasons why a simulation expert (or group of experts) would find involvement valuable to them or their program. Establishing reciprocity from the 'get go' makes it easier to develop strategies that are mutually beneficial and designed for long-term success.

In many instances the expertise needed to conduct and evaluate safety related simulations as outlined in our example will be found at larger academic centers. This is fortunate, because there are a number of value structures in play at academic centers beyond simple financial concerns that can be used to make a case for support. These are:

- Congruence with programmatic mission
- Opportunity for academic advancement
- Direct financial reimbursement

Perhaps the most crucial aspect of a successful collaborative relationship with a simulation center or group is the level of concurrence with their programmatic mission. Like all organizations, simulation centers and programs often have a specific mission, vision, and values that shape their organizational framework and determine the kinds of projects they may consider. Given the significant overlap between simulation and patient safety as disciplines, explicit discussions of healthcare quality and safety are often foundational [9, 10]. Thus, many programs see it as part of their 'DNA' to engage in projects that will enhance patient care and outcomes. In case you and your consultants work for the same enterprise this may be sufficient to establish a long-term project that benefits the mission of the entire organization, which may be more willing to allocate resources toward the partnership. Even in the case of an external expert or program, however, establishing congruence of mission during initial discussions may result in a collaboration based on mutual benefit as opposed to financial transactions.

Case, Continuation #1

Your team reviews the goals driving the project for overlap with the mission of a neighboring simulation program at an academic institution with considerable simulation-specific experience and expertise. This process reveals that the mission of this simulation program explicitly contains language regarding the enhancement of care within the region, an issue that you believe is clearly addressed by your proposed space assessment project. You contact this program and they readily agree to consult on the project for free on the basis of these shared goals.

For long-term projects, the ability of a program or an individual expert to support the project will likely require some recompense that goes beyond shared values. It is here that the academic environment may offer possibilities beyond simple financial reimbursement, as many academic simulation experts have scholarly requirements for promotion which participation in your project may help satisfy. Depending on the academic center, these requirements may range from dissemination of abstracts through peer-reviewed publications, and may also include local or regional leadership roles. The value of this academic recompense should not be underestimated; one in-situ program was able to grow for several years largely on the basis of academic reward [11]. While there are ultimately limits to this approach in terms of the time that collaborators may be willing to offer, it can be an effective means of obtaining support for many projects.

If the project involves research, a rigorous review of scientific merit is necessary. This is best accomplished by consulting the research faculty of a simulation program or a simulationist who is proficient in research . Any project (with or without human subjects) that will lead to publication requires review by an Institutional Review Board (IRB) or

other relevant Ethics Board. More complex or comprehensive projects might be broken down into subgoals that can each be disseminated as a separate publications, thus increasing the teams' overall scholarly productivity.

Case, Continuation #2

A review of the literature reveals that the design and implementation of simulations for in-situ ED systems testing is under-reported. You feel that your proposed project may fill this gap and contribute to the body of knowledge on human-centered design. You thus submit IRB proposals for two studies. The academic value provided by these potential publications results in significant ongoing engagement by the members of the consulting center (faculty with expertise in Emergency Medicine, in-situ simulation, patient safety, and quality improvement) throughout the project.

Kotter's model of change provides a helpful conceptual framework for the principles we have discussed (Table 26.3) [12]. While typically applied to large-scale change, this model is particularly useful in highlighting collaborative processes characterized by engaging multiple stakeholders, developing relationships, and sustaining relationships over time. The model has successfully been used to guide change processes in patient care settings where patient safety is paramount [13, 14].

Projects based solely on shared values and academic rewards, however, may fall prey to competing and better resourced projects over time. Moreover, the use of academic productivity as an incentive for collaboration is most useful for simulationists working at academic centers and may not help with engaging simulationists from commercial for-profit or not-for profit centers without an explicit academic commitment. With this in mind, we turn to a consideration of direct financial reimbursement.

Table 26.3 Kotter's Model [12] as a framework for understanding simulation expert engagement in safety and quality projects

Project phase	Steps for implementing change	Engaging the simulation team
Planning and design	Create a sense of urgency	Develop a clear sense of the mission, vision and values of the simulation program or experts with which you are engaging. Use this to create a shared understanding of the safety problem you wish to address.
	Form a guiding coalition	Form a collaborative relationship based on this understanding. Be sure to schedule regular meeting or collaborative time to discuss and move the project foward.
	Create a [project] [mission] and vision	Create a clear set of goals for the project congruent with the entire team's sense of what is important to accomplish.
	Communicate the [mission] and vision	Use this set of goals to convince stakeholders (in this case the organization(s) involved as well as those with direct supervisory responsibility over consultants) of the value of the project for all involved.
Implementation	Empower others to act on the vision	Ask stakeholders to allocate sufficient time and (if needed) programmatic resources to enable the project to be implemented.
	Create quick wins	Based on the "value structure" being used to facilitate involvement, create clearly defined milestones that bring value to the simulation expert consultant. Examples include preliminary data showing the Return on Investment (ROI) for participation and scholarly work products.
Evaluation and Sustainability	Build on the change	Utilize these smaller successes to determine whether the project is complete, or, if not, what changes are needed. This can then be used to determine whether further engagement of the simulation content expert is needed or advisable.
	Institutionalize the change	If necessary for the ongoing success of the project, explore the possibility of a long-term, financially sustainable relationship with the simulation expert or program.

Funding and Sustaining the Relationship

For projects that require a long-term commitment, time demands will eventually outstrip the utility of shared values, and the promise of academic productivity becomes less appealing. It is here that project funding becomes critical. The following section outlines examples of funding opportunities that may support long-range simulation projects.

A 2011 survey of simulation programs reported that over half of simulation centers associated with medical schools were allocated an annual operating budget above $500,000, while most simulation centers associated with teaching hospitals had smaller budgets. The majority of simulation centers are supported by their associated school, whereas only half of teaching hospitals fully finance their simulation facil-

Table 26.4 Select funding sources for simulation-based quality initiatives

Sources of Internal Funding:
Direct professional school funding
Administrative grants
Training fees charged to specific departments within the institution
Credentialing reimbursement from physician practice plans
Funding by risk management for specific quality improvement projects
Sources of External Funding:
Corporate and industrial sponsorship
Reimbursement for conducting professional recertification (e.g., the Maintenance of Certification in Anesthesiology program (MOCA) of the American Board of Anesthesiology)
Fee-for service continuing medical education (CME) or continuing education unit (CEU) training open to outside enrollees
Philanthropic donations (e.g., money, equipment, supplies)
Private foundation funding (e.g., Robert Wood Johnson Foundation, Laerdal Foundation for Acute Medicine)
Government Funding Options:
National Institute of Health (NIH)
Agency for Healthcare Research and Quality (AHRQ)
The National Science Foundation (NSF)
Department of Defense (DOD) (primarily through the Joint Program Committee-1/Medical Simulation and Information Sciences research program)
Local, state and federal public health departments

ities. External grants and philanthropic support represent other key funding mechanisms. Passiment, Sacks and Huang report that 40% of medical school based simulation centers and 25% of centers in teaching hospitals receive funding from corporate grants and foundations, and that 26% of the medical school-based simulation centers and 16% of simulation centers in teaching hospitals relied on philanthropy as a significant source of funding [15]. A survey of surgical skills training centers revealed that 68% are supported by industrial sponsors; many of which provide equipment grants [16]. Finally, the government is another potential funding source, as the demand for simulation-based research in the civil and military healthcare realms has significantly increased in recent years. One particularly relevant government source is the Agency for Healthcare Research and Quality (AHRQ), which aims to improve patient safety by generating evidence to make health care safer, higher quality, more accessible, equitable, and affordable. Table 26.4 provides a list of funding sources. Patient safety experts wishing to access funding sources for specific projects are advised to first review the relevant websites or organizational descriptions to determine whether the specific goals of their project fit with the mission statements of the potential funding organization.

Case, Continuation #3

The patient safety team establishes and develops a relationship with a regional university-based simulation program using opportunities for academic advancement. This relationship enables the implementation of the final project, which detects a number of latent safety threats that are mitigated prior to opening the renovated unit. Academic products include a conference abstract and a publication accepted by a premier simulation journal. Based on this success the institution chooses to devote funding from their patient safety division to maintain the relationship with the simulation experts. Aditionally, the combined patient safety and simulation team decided to submit a grant proposal to AHRQ to fund future work in this area.

Conclusion

Engaging effectively with simulation experts begins with establishing a clear sense of the needs and goals of your particular system improvement project. These needs and goals can then be used to guide you to the best potential simulation experts or programs to contact. Simulation experts are typically quite collaborative, and welcome opportunities to partner across disciplines and institutions. While initial project development may be possible on the basis of shared goals only, ongoing program development generally requires funding. Funding sources abound, but financial support needs to be selected carefully in order to align with the goals and objectives of your collaborative simulation program. Collaboration between patient safety and simulation experts has tremendous potential to expand the implementation of new and innovative ideas in quality improvement.

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Working with Healthcare Subject Matter Experts and Clinical Stakeholders

27

A. Joy Rivera, Grace L. Good, and Marc Auerbach

Introduction

The earlier chapters of this book describe the importance of ensuring if and how a project would benefit from the application of simulation (e.g., to inform design, conduct testing, improve workflows) (see Chaps. 7 through 25 in Part II: Practical Applications). The first chapter of this section discussed how to work with simulation experts (see Chap. 26). In this chapter we will focus on how to engage healthcare subject matter experts and stakeholders. We begin with a case presentation of a clinical redesign project that will involve the application of simulation-based methods, then we focus on strategies to identify and engage subject matter experts and clinical stakeholders. The next chapter of this section will discuss how to work with experts from non-clinical fields (e.g., human factors experts, safety scientists, operations engineers).

Definitions

Subject matter experts –

Authoritative and knowledgeable figures with specific and relevant knowledge in a particular area or topic as well as organizational recognition for their expertise.

Healthcare Stakeholders –

Individuals with an interest in or concern with the healthcare process and outcome that either can affect or be affected by changes to the system.

Case Presentation

The Emergency Department (ED) of a local community hospital is looking to redesign three existing patient rooms to better accommodate the care of behavioral health patients. You, in your role at the simulation center, have been asked to assist the nursing manager of the ED with organizing simulations and implementing tests of a redesigned clinical space to determine how these changes might impact clinical practice. This change was spurred by a recent sentinel event involving an agitated patient in the ED. The current ED rooms were designed for the care of urgent and acute medical patients but with the growing volume of psychiatric patients they are more often being used for behavioral health emergencies. The nursing manager has been charged with this work by the chief nursing officer. Whom should the nurse and you/your simulation team engage in this work and how will you get these individuals engaged?

Needs Assessment and Planning

The above case involves a request for the use of simulation in a project. In this case the nursing manager may have been mandated to use simulation by his/her supervisor or has developed this idea independently and needs to gain leadership's support. It is important that the individuals responsible for system improvement understand the diverse applications of simulation. This helps the clinical project team ask for simulation that will best meet their needs. Likewise, it is essential that the simulation team learns the details of the

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context and objectives of the proposed project to help guide the clinical project team.

A structured intake form and/or brain-storming meetings with the project leaders, the nursing manager and/or the chief nursing officer in this case, should be used to create a working document describing the potential applications of simulation to the project. This needs assessment will inform the planning phase of the overall application of simulation across the project activities and provide a shared mental model and clear expectations. This work will guide decisions on how to most efficiently and effectively apply simulation-based techniques, resources, and technologies to achieve goals of the project and simulation teams.

Understanding the context of the problem or problems that has prompted a request for redesign of this clinical space for behavioral health patients will guide the prioritization of the objectives for the individual simulation activities. For example, if the driver for this work was a safety event related to a staff injury, then identifying potential staff safety risks would be an important area of focus. A simulation involving an agitated patient actor would be helpful to test whether a particular design would facilitate staff safety. If the driver for the work was an adverse patient outcome, such as a severe reaction to a medication leading to harm, a high technology simulator with vital signs that can change over time may needed. Alternatively, if the driver was related to the improper application of physical restraints, a lower-technology model may be sufficient. Often there is one main driver that sparks the beginning of a project like this, however, after some investigating the motivation becomes more complicated and less defined with underlying and competing objectives. For example, any of the above drivers could be the instigating cause for redesign, however, it is also known that new regulatory requirements will be published soon, the closest competitor is redesigning several of their ED rooms to behavioral health rooms, the local state behavioral health facility is losing funding in the next two years, and there are rumors that the ED staff may call Occupational Safety and Health Administration (OSHA) due to feeling more unsafe in recent months.

Depending on the timing and timeline of the work, the simulation may take place on site in the clinical environment or off site in a simulation center. For example, if the simulation occurs early in the redesign it could involve a full-scale cardboard set-up of the proposed physical redesign in the simulation center. If the clinical space has already been redesigned and now needs usability testing the actual clinical space for the simulation would be preferred. Additionally, a longer timeline would allow more end-users to participate and make it easier for off-site scheduling, whereas a shorter timeline may force the simulation to occur in the clinical environment or an empty conference room nearby the clinical environment to make it easier for clinical end-users to participate. The purpose of the project will also inform what kind of simulation is needed, where the simulation should be set up, and who needs to be involved.

Identifying Subject Matter Experts and Stakeholders

When identifying who needs to be involved, the project and simulation teams should discuss all the roles who are impacted by the redesign and which roles are essential to involve in simulation. At this point, these roles can be categorized as SMEs or Stakeholders of the redesign. It is important to note that not all stakeholders are SMEs, and depending on the situation under investigation the stakeholders for one simulation exercise may become the SMEs for another area of focus. Table 27.1 provides examples of roles that could function as SMEs and/or stakeholders.

Clinical Staff These diverse inter-professional and multidisciplinary groups of individuals care for the patient at the bedside and also perform many components of the care process away from the bedside (ex: documentation, obtaining supplies). In general, front-line clinical staff serve in the role of stakeholders. Senior staff that function in both administrative and clinical roles may serve as either stakeholders or subject matter experts. These individuals work as teams and often as teams interacting with other teams. These teams can function geographically in the same place on a regular basis, or as in the case we described above, be an ad hoc group of

Table 27.1 Subject matter experts and stakeholders to consider engaging

Clinical Staff	Physicians, Advanced Practice Providers, Nurses, Patient Care Technicians, Counselors, Social Workers, Pharmacists, Respiratory Therapists, Radiology Technicians, Dieticians Emergency Medical Service Providers ** Include experienced and less experienced team members to obtain diverse perspectives: example attending, fellow, resident, student doctors)
Non-clinical Staff	Clerical staff; Environmental Services, Security, Information Technology, Supply Chain, Biomedical Engineering, Plant Operations, Food Services, Clergy, Interpreter Staff
Patients/ Family/ Caregivers/ Advocates	Patients, Parents, Partners, Adult Children, Caregivers, Patient Advocates, Family Members, Community Organizations/Advisory Councils, Outside Clergy
Leadership	ED Medical Director, ED Nursing Director, Psychiatry Medical Director, Facilities Director, Public Safety Director, Quality Director, Pharmacy Director, Social Work Director, Chief Medical Director, Chief Quality Director
Other Experts or expertise	Human Factors Engineer, Patient Safety Expert, Infection Preventionist, Process Improvement Expert, Architect

clinicians who rarely interact together. In the case study, these providers would likely come from diverse healthcare disciplines including pediatrics, emergency medicine, psychiatry, anesthesia, radiology, critical care, pharmacy, social work, and nursing.

Non-clinical staff Taking a macro view of a clinical process with the patient at the center always reveals other diverse groups that should be engaged in the simulation activities. For the case described, examples of non-clinical staff include environmental supply coordinators, administrative staff, security, plant operations and telecommunications staff. Non-clinical staff often have never experienced simulation. Establishing a shared understanding of the simulation goals is key to creating a safe, no-blame simulation culture. We have found that starting with these individuals observing a simulation and participating in debriefing is a good strategy for engagement. As simulations are evaluated and changes implemented these individuals can provide input into system feasibility and environmental changes. Ask the question, "Is there a group that was not represented in the care of the patient or as a supporting role that would benefit the team going forward?" Keeping an open mind will allow you to partner toward the best outcome.

Question
Is there a group that was not represented in the care of the patient or as a supporting role that would benefit the team going forward?

Patients/Family/Caregivers/Advocates The patient and family perspectives and experiences are vital components throughout the redesign process. To achieve the goal of providing all patients safe, high quality and equitable care a diverse set of patients should be engaged. In the example provided the patient and/or patient's caregivers could provide an end-user perspective based on their experiences with triage, emergency medical services and the interprofessional clinical teams. They can provide input on their (or their family's) needs and how aspects of the redesign could positively or negatively impact their lived experience.

Leadership The presence of managers and executive leadership is essential. Each level of administration will have differing degrees of engagement which must be taken into consideration when inviting them to participate. Overall, their participation or sponsorship will help generate buy-in. However, their participation should be weighed against the risk that their presence may affect the way the team interacts and performs during the simulations and debriefing activities.

Engaging Stakeholders and Subject Matter Experts

The described case involves the improvement of an existing clinical space that was primarily used for medical purposes to better serve patients with psychiatric or behavioral health emergencies. The complexity of this problem will require a large, diverse, and interprofessional group of individuals. Other projects may be less complex and may not require a large group. However, as a project evolves and the simulation scenarios become more detailed, additional issues may be identified, and additional individuals or groups may need to be recruited.

While the initial request in this case came from a hospital senior leader, requests for simulation activities may also come from other team members without leadership roles, internal organizational stakeholders such as legal, risk, patient safety, or external regulatory bodies. Engagement of SMEs and Stakeholders in the overall project and the simulation-based components will require a commitment by these individuals as well as their supervisors. In this case, the nurse manager leading the work will likely have a deep level of engagement and understanding of both the clinical environment and underlying objectives. However, to maximize the efficacy of the work, the project and simulations will require engagement of the front-line staff who may be less engaged. The project and simulation teams must work with senior leaders or executives to ensure that participants have protected time to participate in the simulations. This can be either through supporting coverage during a shift and/or offering overtime. If staff are pulled away from patient care without coverage that can be dangerous and lead to a lack of engagement during the simulation. Having an executive sponsor and a project charter with clear expectations in terms of the number of individuals needed as well as the purpose of each simulation session creates a shared expectation for the simulation team, the SMEs, and the stakeholders.

Participants who feel that they have been "voluntold" to participate may have negative feelings towards the project and little motivation to fully engage. The best incentive for participation is for the individual to see purpose to what they are doing and to understand the potential improvement simulation can have on the clinical environment. In conducting these simulations some participants may see this as a valuable method to improve care on their unit while others may not see this as an ineffective use of their time. Financial incentives, such as being paid for the hours spent on the sim-

ulation or being provided a gift card may enhance engagement. Participants could be recruited through creative approaches such as having simulations embedded in the work and/or other educational initiatives of the unit. For example, simulations could be conducted for behavioral restraint training and concurrently the simulation team and human factors specialists could evaluate the systems processes for potential redesign. In this example the simulation activity serves dual purposes—skill development and system redesign. Additionally, if the simulation team clearly links the system improvements made to the simulation exercise, this creative strategy may help convince stakeholders and SMEs of the value simulation can have beyond the purpose of education, enhancing buy-in for future simulation projects.

Setting expectations and clear ground rules for the simulation as well as debriefing is critical. When participants understand the purpose of the simulation as well as how the data acquired during the simulation and debriefing will be used to achieve that goal they are more likely to be engaged. Concurrently, it is critical to work with leaders to ensure that front line providers feel valued and supported. Communicating these expectations in written format to leadership, participants, and facilitators will support a shared understanding of expectations. When all participants have a shared mental model and are properly prepared, the simulation experience is maximized, producing the intended results of the exercise. As more people throughout the organization have positive experiences with simulation, word of mouth will help to increase engagement in future simulation projects.

During the simulation it is important to check in with SMEs and Stakeholders to make sure that the objectives of the exercises are being met. Obtaining feedback from your SMEs on a regular basis can help to continuously improve your simulations, whether you implement the feedback during this project or future simulation projects. Local SMEs can help distinguish the nuances of the specific environment which can play a role in increasing the fidelity and thus the efficacy of the simulation experience. Additionally, keeping Stakeholders abreast of your progress helps to maintain their support for the project and ensure the project remains a main priority for the organization as new demands strain resources.

Following the simulated experience, debriefing is essential to allow the project team to explore participants' experiences and perspectives on clinical processes (work as simulated as opposed to work as imagined). Understanding these responses is critical to developing a realistic and helpful assessment of the problem and guiding improvements. Debriefing provides an opportunity to ask qualitative questions of providers immediately after an "on demand" clinical experience. This information is valuable in the early phases of design and should be used throughout the iterative redesign process. There are a variety of frameworks for debriefing, which range from open ended "advocacy inquiry" to more closed ended questions that probe specific areas of interest. A challenge of open-ended debriefing in the design process is that the discussion may move on a tangent, away from the specific elements of interest for the design team. It takes skills to keep participants focused, while also making sure they feel heard.

Report Out/Outcomes

After each simulation and debriefing it is important to focus on the ultimate goal of gaining a deeper understanding of the problem and possible solutions to guide improvement. As work progresses it is imperative to provide participants with follow-up on how their input is used in the improvement process so that they see that their expertise and knowledge of local conditions is valued and to help support ongoing engagement. The project team and simulation team should work together to collect information about the improvement process, through qualitative frameworks or quantitative data collection forms or both depending upon the project. These findings need to be communicated to the Stakeholders and leaders who hold the decision making power to implement the results of simulation activities and make improvements to the clinical redesign process. Reporting these data in a clear and concise format will help to monitor what progress is being made and when objectives are met. Finally, participating SMEs and stakeholders should be recognized by providing feedback and appreciation to their supervisors and leaders.

Summary

Subject matter experts provide invaluable input into system improvement projects, such as the ED redesign we have discussed. SMEs may also be stakeholders, based on professional expertise and personal experiences, and vice versa. Depending on the nature of the project, involvement by individuals with expertise in clinical care, patient care experiences, medication management, architecture, supply chain, patient safety, human factors, regulations, administration or other diverse fields is important to conduct a thorough needs assessment. The needs assessment then informs simulation planning to maximize the engagement and learning potential for the team of SMEs, stakeholders, and simulationists. Periodically providing information on the synthesis of the quantitative and qualitative findings and how these data will inform the next phase of the improvement process will stimulate continued participation and learning. The success of a simulation-based component of the improvement process requires sustained engagement and enthusiasm from both the frontline clinicians and senior leaders.

Working with Experts from Non-clinical Fields

28

Yan Xiao, Mary Sesto, and Susan Coffey Zern

Introduction

Healthcare simulation programs work closely with experts from clinical fields to generate scenarios, conduct simulation sessions, and design programs to meet clinical training needs. To maximize the value of simulation, working with experts from other, non-clinical fields is a necessity. As in the case of aviation simulation, healthcare simulation is moving forward beyond providing a level of physical fidelity as task trainers. Simulation is increasingly used in device and facility design, in analysis of system safety in rare events, in identifying training needs, and in facilitating learning of cognitive and team skills and behaviors. As illustrated in the cases below (Examples 28.1, 28.2, and 28.3), experts ranging from game designers to human factors specialists can be productively engaged in simulation. Clinicians can benefit from working with non-clinician experts to understand concepts, methodologies, and theories useful or even vital for simulation to be effective. However, cross-disciplinary collaboration tends to be challenging due to differences in traditions, perspectives, and goals, and it takes time to build common ground. This chapter describes top non-clinical fields that can support simulation programs in innovative uses of simulation for a variety of objectives related to understanding and more effectively enhancing the sociotechnical work of healthcare and with education missions that meet not only clinical needs but enhance the participant's role within the system. We also provide practical suggestions in finding and forming collaborating relationships with experts from non-clinical fields.

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Collaborating Effectively with Experts from Non-clinical Fields

Healthcare simulation continues to advance beyond solely training healthcare providers. Simulation can be used to assess a process, evaluate a medical device, identify latent patient safety issues, perform a failure mode and effects analysis and understand the interaction between information technology and humans. Therefore, in order to maximize the benefit of simulation for healthcare, the expertise of many different disciplines has become necessary. These disciplines may be outside healthcare. The collaboration of clinical experts and experts from non-clinical fields can be somewhat challenging as the groups come from different professional backgrounds, may not speak a common language and have different priorities. Although this partnership can be challenging the outcome of such a team effort has enormous implications for the improvement and advancement of healthcare.

The first step in working with non-clinical experts is to develop the team. There are many models of effective teamwork. According to Mickan & Rodger [1], the six key characteristics of a successful team are a common purpose, measurable goals, an effective team leader, effective communication, rapport and cohesion, and mutual respect. Mutual respect is an important component with diverse teams, it allows for team members to embrace and encourage diversity of thought and opinion. Effort should be given to develop the team, as the upfront work in this process will pay dividends in the end. Once the team is established, the next step should be to develop a Project Charter with the team to define the problem, needs assessment, working objectives, roles and responsibilities, stakeholders, timelines and deliverables. This step will allow the team to be part of the

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process of developing their goals and understanding more fully how their work will contribute to the overall project. Examples 28.1 and 28.2 illustrate the process and approaches in collaborating with experts from non-clinical fields in simulation. Example 28.3 also provides lessons learned in working with non-clinical experts.

Example 28.1 New Space Design

Our hospital system is in the process of constructing a new Women's and Children's building. This building will be state of the art, allowing babies who require intensive care the opportunity to room with their mothers. Both patients will get the appropriate level of care that they require. Since this building and room set up is so new and unique, our simulation center was asked to assist in evaluating the proposed rooms and giving feedback to the Women's and Children's Service Line and the architect regarding the space design.

A number of experts from non-clinical fields assisted us with this project; the architect, a human factors expert and patient/family advisors. The simulation team and the human factors expert co-lead the project. As a first step, we met with all members of the team to determine our goals and objectives as well as the timeline for completion. We were given a preconstruction shell and the architect supplied the preliminary architectural drawings to create the space to scale. Using cardboard boxes, the simulation team built the space creating cabinets and counter tops with accurate dimensions, and adding appropriate equipment, i.e., hospital beds, chairs and monitors (Figs. 28.1 and 28.2). The simulation team and human factors expert then met with the Women's and Children's nurses and physicians to develop patient care scenarios for the session. We developed simulation scenarios to assess process flow during normal work and during emergencies for both the mother and the infant. We wanted to know if the rooms were configured in a way that would allow for simultaneous care for both the mother and the infant. Patient advisors gave feedback regarding how the new parents, grandparents and family would use the space, and feel most comfortable. This project involved many meetings to ensure that everyone was on the same page regarding our goals and objectives; we also discussed how we would observe the simulations. All members of the team, which included simulation experts, a human factors expert, architecture design and construction experts and patient family/advisors debriefed with the obstetrical and neonatal teams after each scenario to understand the clinical team's feedback and priorities for the space.

A final report was compiled by the simulation team and human factors expert, based on the outcomes of the simulation sessions. The report detailed the findings as well as suggested changes based on the perspectives of diverse stakeholders. This report was given to the Women and Children's service line as well as the architect and recommendations were incorporated into the design of the new building (Fig. 28.3).

Example 28.2 Equipment Selection

Our institution recently worked collaboratively with multiple non-clinical and clinical experts to determine which new defibrillators to purchase. The team consisted of simulation, clinical engineering, human factors and clinical experts. We met as a team to discuss the project and timeline, and developed a project charter that detailed our goal and objectives. The human factors expert and the simulation team worked together to plan specific tasks for clinical end users, including nurses, and attending and resident physicians, to perform on each device. The clinical end users participated in standardized skills tasks which gave both participants and observers information regarding training needs and device usability. Once the device was selected for purchase, the simulation team developed an educational curriculum based on the observed gaps in clinical end user's knowledge and skill identified during the simulations. Additionally, the simulation team's Advanced Cardiac Life Support (ACLS) coordinator worked with clinical engineering to program the devices. The team members met multiple times throughout the process to ensure a shared mental model, anticipate the needs of the team and discuss the next steps. Throughout this process, the different perspectives of clinical and non-clinical experts allowed us to identify and mitigate potential patient safety issues before the devices were deployed system-wide.

Often non-clinical experts are unfamiliar with clinical care pathways and processes in the healthcare system. They may require orientation to the process and culture before they can fully assist with the project. There are many ways to orient non-clinicians. Table 28.1 gives some examples of opportunities for orientation. The goal of orienting the non-clinician is to allow them to see the current state of patient care processes and to understand the problems or challenges faced by healthcare providers. This orientation process

Example 28.3 Developing a Serious Game

Our project team developed a role-play simulation game for nurses and physicians to gain insight into team communication practices. The team included nurses, physicians, curriculum experts and teamwork experts, and involved game developers from the start. It took nearly a year for the project members to understand each other's field. For example, initially non-game developers did not understand why gaming can be an effective learning strategy, or how many key steps are necessary to develop a game in a virtual environment that a learner can access anywhere at any time. The game developers demonstrated non-healthcare games to educate team members about what is possible. The clinical team members shared key requirements for deploying a game to busy clinicians. The teamwork experts prioritized the most important concepts for learners to master in a 1-hour game. Although the project was a success in deployingSerious game, developing the game in a study, the clinicians on the team were surprised to learn that the game was hardwired into a specific version of a virtual gaming platform. The limitation was obvious to game developers but was not communicated with other team members, who had assumed that that game could be easily updated.

should be tempered by not giving the non-clinical expert too much information and detail, as this may blunt the value of a fresh perspective. Conversely orientation of the clinical experts to the knowledge and skill of the non-clinician is just as important. It allows both groups to understand what each party brings to the table.

Simulation can be a valuable tool to orient non-clinical experts to the processes, settings and challenges in healthcare. A fully immersive simulation can be developed, in order to reveal the problem or process for the non-clinical expert to view. Simulation has the capacity to demonstrate the common interactions between the healthcare environment, providers and patients and their families.

Overview of Non-clinical Fields and Their Value to Simulation

The following section provides an overview of non-clinical fields that may play important roles in healthcare simulation projects. We list places where one may find experts and consultants within health care organizations as well as resources at universities and professional organizations. In addition,

Fig. 28.1 Simulation created to prepare for ChristianaCare's new Women and Children's building. Walls are temporary and cabinets are constructed from cardboard

Fig. 28.2 Finished Labor and Delivery Room after simulation sessions permitted the OB/GYN team, human factors expert and architect to test the space and confirm the optimal design of the room. Work station was lowered and moved at the suggestion of the nurses

universities may offer graduate student projects and undergraduate capstone projects as well as internships that may be useful for collaborative efforts. Please refer to Table 28.2 for a summary of these fields as well as information on finding experts.

Human Factors and Ergonomics

Human factors and ergonomics professionals are trained with knowledge of human abilities and limitations needed to design systems, organizations, tasks, tools, equipment and consumer and professional products for safe, efficient, and comfortable human use [2, 3]. Human factors and ergonomics professionals apply their expertise in understanding complex work systems to improve patient safety and health

Fig. 28.3 Comparison of full-scale simulation (left) with final construction (right) for ChristianaCare's new Women and Children's building

Table 28.1 Orientation to healthcare – specifically the organizational culture and process

Opportunities to orient non-clinicians to healthcare
Grand rounds
Morbidity and mortality conference
Hospital safety meetings
Relevant journal articles
Meetings with care providers/front line staff
Shadowing during clinical care
Webinars
National/state/regional conferences

outcomes. Human factors and ergonomics professionals may specialize in areas of human decision making, expertise development, team performance, performance under stress such as time pressure, vigilance, ergonomics of workplace layout, and human interfaces.

Health and Safety Professionals

Health and safety professionals develop procedures and design systems to protect people from illness and injury as well as property from damage. They often combine knowledge of engineering and health and safety to ensure that items, materials, and tasks in the work environment will not cause harm to people or damage to property as well as identifying what works well within an organization [4].

Quality Improvement

Quality improvement professionals use data and feedback to track and evaluate performance and to inform changes in processes to improve performance and outcomes [5]. Quality improvement specialists strive to create a high-value health care system and can provide expertise on using quality improvement methods and tools to improve patient, clinician and organizational outcomes in complex health care systems.

Health Informatics Specialists

Health informatics specialists have expertise in the design, implementation, application and use of IT-based innovations in healthcare services delivery, management and planning. This multidisciplinary approach includes experts from social science, computer science, information science and cognitive science and strives to optimize the acquisition, management, storage, retrieval, and use of voluminous amounts of health care data to improve health outcomes [6].

Game Developers

Game developers often have training and experience in art and animation as well as programming. They can create gaming technology that motivates and engages the end user

Table 28.2 Example of sources of expertise potentially found in hospital and university departments as well as professional organizations

Specialty	Hospital departments	University departments	Professional organizations
Human Factors, Ergonomics	Quality Improvement Patient Safety Risk Management Biomedical Engineering Occupational Health & Safety	Industrial Engineering Psychology Education	Human Factors and Ergonomics International Ergonomics Association
Health & Safety	Quality Improvement Facilities Risk Management Safety	Occupational Health and Safety Industrial/Occupational Hygiene Safety Management	American Society of Safety Engineers
Quality Improvement	Quality Improvement Facilities Safety	Business Quality Management Engineering Statistics	American Society for Quality National Association for Healthcare Quality
Health Informatics	Health or clinical informatics/technology Administration Quality Improvement	Computer Sciences Engineering Bioinformatics Statistics	American Medical Informatics Organization HealthCare Information and Management Systems Society
Game Developers	Health or Clinical Informatics/Technology Innovation	Computer Sciences Human-Computer interaction Media/Art Studies	International Game Developers Association Special Interest Group on Computer-Human Interaction
Sensor technology, automated video/image analysis	Biomedical Engineering Medical Education Video Production	Computer Science Engineering Human-Computer Interaction Kinesiology	Association for Computing Machinery
Biostatistics, Psychometrics	Health or Clinical Informatics Biostatistics or Bioinformatics Quality Improvement	Statistics Public or Population Health Epidemiology Bioinformatics	American College of Epidemiology American Statistical Association, Section on Statistics in Epidemiology

[7]. Examples of use of this technology in healthcare include clinician training and development of health-related apps that support behavior modification (e.g. exercise, meditation).

Experts in Sensor Technology, Automated Video/Image Analysis

The technology fields of sensors and automated video analysis are defined by their capabilities to capture and process data often needed in clinical simulations. Posture trackers, for example, can be used to quantify the impact of workplace and instrument design in reducing skeleto-muscular strains. Physiological sensors may be used to measure workload and stress. With the increasing power of video processing algorithms and ever more ways to capture video materials, metrics can be derived from video sources in clinical simulation aided by automated tools. For example, computer algorithms may support automated time-motion studies or identification of key video clips for manual analysis or archiving.

Biostatisticians, Psychometricians

Biostatisticians collect, analyze and develop statistical conclusions based on data. They can use these methods for the design of research studies, data collection and analysis as well as to identify factors for risk stratification, diagnostic accuracy of tests and measures and effectiveness of medical interventions [8].

Summary: Multi-disciplinary Collaboration in Clinical Simulation Programs

Clinical simulation programs vary widely, often with core missions related to education. Collaboration with experts from non-clinical fields will allow expansion of such programs into research about simulation and research using simulation, as well as simulation to accomplish process improvement. We provide a broad overview of several fields of non-clinical sciences and some examples of how they can contribute to innovative uses of clinical simulation. Experts in many non-clinical fields have knowledge and skills that

can serve as important resources and add value to simulation programs. We have provided a broad perspective of different scientific fields and how they may enrich simulation programs, as well as a structure for addressing requirements for successful collaboration.

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Simulation and Safety Education for Healthcare

29

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Simulation to improve Safety can be integrated into healthcare education. How do we educate future clinicians and other allied specialists about using systems-based approach? How do we educate future human factors and other engineers about using simulation for clinical explorations?

Introduction

Healthcare providers have been vested with the responsibility to identify, diagnose and seek to heal sick systems as well as sick patients [1]. All healthcare workers, and the patients who receive care within those systems and from those workers, will benefit from an understanding of the role system design plays in framing processes of care, and ultimately, outcomes [2]. There is general agreement among those who study system design and its impact on the delivery of healthcare that flaws in system design are often unrecognized by most healthcare workers, and perhaps even more critically, by healthcare leadership. Although providers are the most likely to diagnose and seek to "heal sick systems", they are not alone in this responsibility. Any healthcare worker, including environmental services, sterile supply, financial, or other support service workers can possess the ability to recognize the role of systems in their organization, and recognize sick systems when encountered. Healthcare workers should be aware of interdependencies within the healthcare system, such as the need for adaptive behaviors because of changes in another area of the healthcare work system. Other examples include the need for substitutions by administrative, support or front-line decision-makers because of insurance or resource constraints, or equipment or medication shortages. Every adaptation may have implications for outcomes, risk and safety management. Systems science education can help healthcare workers understand and improve healthcare delivery systems. However, adding this topic to the sheer quantity of information that healthcare workers must assimilate is challenging, so novel approaches are necessary. Incorporating system learning into simulation-based education is one strategy that shows promise [3], and is the topic of this chapter.

Specific Learner Groups

Understanding the unique characteristics of each learner group, and the environmental context in which learners will operationalize their learning, are critical pre-requisites for developing effective educational programs [4]. Educational strategies are not universally applicable, despite the well-known tendency of institutional employee training programs to assume so. Education must be tailored to "personalize" content based on pre-existing knowledge, skills, and interests.

Education of clinical and pre-clinical learners in fundamentals of system science is in its infancy. Current efforts to educate physicians are sporadic and directed primarily at medical students and residents. The Accreditation Council for Graduate Medical Education (ACGME) has designated "Systems-Based Practice" as one of the 6 basic physician competencies that must be incorporated into residency training programs of all specialties [5]. It would be optimal for education in systems science to also be addressed to mid-level providers and nurses, as well as technicians and a wide variety of therapists.

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Undergraduate Medical Education

Several medical schools have already begun to integrate systems education into their curricula; at the University of Michigan a human factors content expert holds a full-time faculty appointment in the medical school [6]. Current efforts to instruct students in system science are incorporated into other content areas, often in the form of small group sessions such as problem based learning (PBL) or simulation scenarios. As a general rule, these efforts are still "one offs" and are heavily dependent on the specific interests and skills of the course designer and small group facilitators. It can be generally stated that a national effort to integrate systems science education into undergraduate medical education is still in the future.

Medical Resident Education

As noted above the ACGME specifically includes "systems based practice" as a competency to be integrated into residency training programs. The interpretation of what is meant by this term varies from learning how to cope with specific system requirements to education about strategies to recognize, diagnose, and "treat" system "illnesses." The latter strategy is typically incorporated into quality assurance and patient safety meetings; in most residencies these meetings have replaced traditional "Morbidity and Mortality" conferences, which historically focused on individual practitioner error. Despite more than a decade of progress and employment of numerous strategies, residency training programs still are challenged by the need to assure their trainees understand the fundamentals of systems science [7].

An ever-increasing focus on simulation-based education is now integrated into nearly all resident training programs. Simulation may be of many, or mixed, modalities, including patient manikins, task trainers, standardized patients, or even cadaveric material. The readers of this chapter are aware of the wide range of these educational strategies, which will not be reviewed here. An opportunity exists to address system-based factors within simulation-based education, which may involve introducing defects or recognizing existing defects in patient care delivery systems, as well as recognizing effective system components and addressing ways to mitigate or improve system processes. Specific examples will be discussed later in this chapter.

Continuing Medical Education

Simulation introduced into CME courses has generally been well received. A simulation course is given yearly at the Canadian Society of Otolaryngology's annual meeting using a video recording of a simulated perioperative crisis in which multiple errors pile up as the scenario develops. The video is halted periodically and the learners, all experienced physicians, discuss in small groups what has happened and how it might have been prevented or mitigated earlier in the scenario. In a similar manner a "worst case" scenario simulation course conducted yearly at the American Academy of Otolaryngology annual meeting also addresses system issues in the scripted debriefing. Nonetheless, at the present time simulation training efforts have predominantly been focused on provider performance, particularly teamwork and communication, not on systems science; or on opportunities for rescue and recovery from failure. The opportunity to leverage simulation education to do so however is clearly present and should be explored more widely.

Nursing Education

Introduction of human factors science, and particularly systems science, into nursing education is in its infancy. Building off of competencies outlined by the Institute of Medicine, the Quality and Safety Education for Nurses (QSEN) Institute specifies quality and safety competencies for nurses at prelicensure and graduate levels [8]. These competencies are intended to guide curriculum development in formal educational, transition to practice, and continuing education programs and specifically outline knowledge, skills, and attitude requirements for systems analysis and human factors related to system design. Several Schools of Nursing have integrated systems engineering and human factors into their curricula through appointment of full-time faculty with expertise in these areas. Further, new Doctor of Nursing Practice (DNP) programs focusing on leadership and systems innovation are requiring interdisciplinary courses in human factors engineering (HFE) in healthcare. For example, the new DNP program in Systems Leadership and Innovation at the University of Wisconsin-Madison requires a 3-credit graduate course in Human Factors Engineering in Healthcare Systems.

At the undergraduate level, one of the authors of this chapter (YX) of University of Texas at Arlington has introduced an online curriculum addressing human factors and system science into the undergraduate nursing education program, one of the largest in the United States. Dr. Xiao applied his experience working in an integrated healthcare delivery organization to develop a curriculum aimed at common and practical human factors principles that frontline clinicians and leaders can use. The curriculum was implemented with nearly 20 video segments to invite learners to explore common HF principles through guided reflections as well as to relate new human factor concepts in individualized ways to the learners' own experience in improving patient safety. The course delivery design was in part based on ideas from "Shadowbox" training approach [9], in which learners

engage with cases and are encouraged to actively participate in making judgments and decisions, which are then compared with experts' opinions. In this course learners can compare their reflections with those of the experts, based on the human factors principles targeted by the course.

The combination of watching videos and guided reflections is well liked by online students, most of whom so far are practicing nurses. Possibly in the future these educational products may be made publicly available online.

Education for Leaders of Healthcare Organizations

Healthcare organization leaders may represent the most critical – "holy grail" - learner group who would benefit from understanding the essential fundamentals of system science. Educating this group would have the largest impact on healing sick systems since ultimately these individuals make important resource allocation decisions for the systems through which healthcare is delivered. Simulations can be structured to be brief and conducted at the relative convenience of leaders. Tabletop simulations which involve complex trade-offs of personnel, equipment, and space resources may be the most relevant for this group. Educating leaders is challenging because they often have neither the time or inclination to observe actual clinical practice and their cognitive resources are often consumed by the nearly continuous need to react to external forces imposed by the mega-systems in which they must function. Their roles are frequently the embodiment of the expression, "it is difficult to drain the swamp when you are busy fighting off the alligators." Nonetheless, efforts to engage leaders in system learning may ultimately provide benefits at multiple organizational levels.

Leveraging Simulation-Based Investigation into Use Errors to Educate Participants

Investigating factors that impact device or other use errors is challenged by the infrequent reporting of such errors and the likelihood that many are intercepted by healthcare workers prior to impacting the patient. Notable examples of use errors in which design of the product led to adverse events, including death, are well known within the safety community. One classic example is the series of 6 deaths that occurred due to the software design of the Therac 25 linear accelerator. Keystroke errors by the radiation therapy technologist as the radiation delivery parameters were entered led to 100-fold overdoses even when the error was recognized and corrected immediately after backspacing. ("Immediately" in this case was less than 8 seconds) The device technology was unable to compensate for the backspacing, and retained the original (inaccurate) parameter which resulted in the overdoses. Moreover, the unit did not display the actual device configuration, so the effect of the corrected data entry error was opaque to the user. The response of the manufacturer – "remove the backspace key from the keyboard" – is legendary in patient safety circles and prompted dramatic changes in device testing [10, 11].

Investigations of design factors impacting medical product use errors that employ simulation have been performed by a number of investigators. One of these investigators, an author of this chapter, (JE) has employed simulation as the test bed to investigate use errors in a number of devices and products. These studies have been performed using actual healthcare workers who are likely to use the product in their daily occupational activities.

One of her early studies was performed in response to a near miss in which an intravenous (IV) bag of a diluted lidocaine infusion was inadvertently placed in the same location in an anesthesia cart as hydroxyethyl starch (i.e., Hespan™ a volume expander); both are clear liquids. The volume expander is utilized in cases of hypotension due to blood loss, hence is infused rapidly. Lidocaine is utilized to reduce cardiac electrical conduction in cases of increased irritability in order to block irregular beats and prevent ventricular tachycardia or other potentially deadly rhythm. It must be titrated carefully as to not overdose the heart, which can result in asystole, cardiogenic shock, and death.

She hypothesized that the small, cluttered text on the labels of the IV bags may have impacted the probability of selecting the wrong bag of fluid. To this end, a randomized trial of two different label formats was used in a realistic, high-stress simulation scenario incorporated into an existing anesthesia crisis management course. Ninety anesthesia trainees participated in the study at the University of Pittsburgh Simulation Center (WISER). Participants were "set up to fail" by improperly stocking the IV lidocaine in the same bin as the Hespan™ solution, and by generating the high stress of massive blood loss in a young man with a religious prohibition against receiving blood products. The scenario design led to 60% of one group of participants selecting and preparing to infuse the wrong IV solution (i.e., lidocaine). Simulated patients who inadvertently received lidocaine at high flow rates during the intraoperative simulated crisis "died" and could not be resuscitated. Label redesign, the impact of which was the goal of the study, reduced the risk of incorrect selection by about 50% [12].

Despite having been "set up" to commit a fatal error during the simulation, the participants voiced appreciation for the experience during the debriefing that followed the simulations. Specifically, several commented that they would "never again" hang a bag of IV fluid without rechecking the contents on the label. It was also clear to them that mistakes

in IV bag stocking can "set up" healthcare workers to fail. Sadly, at about the same time the investigation at VA Pittsburgh was being performed, a similar event occurred in Connecticut, resulting in the death of a patient during routine surgery at an ambulatory surgery center. The wrongful death case was settled out of court in October 2018 [13].

Another study investigating the potential for use errors in setting up electro-surgical units (ESUs; e.g., "Bovie machines") for surgical procedures demonstrated similar educational impact on the operating room (OR) nurses serving as study participants. A variety of ESU consoles were used in the study, with complex scenarios designed to generate stress, which was further increased by paid actors playing the roles of surgeon and scrub technician [14]. Prior to their participation, the majority of the participants were unaware that device design of the ESU consoles facilitated errors in set up which could lead to harm. In casual conversation with OR nurses following their participation in the study one of the authors of this chapter (DE) was struck by the number of nurses who commented that they had not realized prior to the study that human error could be so easily precipitated by device design. Subsequent simulation-based investigations have resulted in similar informal feed-back from study participants (unpublished anecdotal information).

An unanticipated, but gratifying benefit of these and other device use studies was the educational impact on the study participants. Not only did participation in the study potentially lead to awareness of the potential risk of use errors and changes in practice to mitigate that risk, but more significantly a new awareness of how system design can lead to this increased risk of use error.

Introduction of System Defects into Simulation-Based Training

The examples above noting the unexpected benefits of learner participation in use-error research suggest an ideal strategy that can be leveraged to teach how system design impacts human performance. Some educators have integrated system "flaws" into their simulation scenarios to demonstrate the significance of environment design as well as increase awareness of the learners. A wide range of system flaws could potentially be introduced (Table 29.1).

Introduction of system defects into training scenarios, such as stocking an IV solution in the wrong bin, has the potential to dramatically "imprint" learners with an understanding of this fundamental and critical fact: system design impacts patient safety. Essentially all healthcare workers have, at some time, experienced a patient-related adverse event due to error, and that adverse event impacted their practices for the rest of their career. Simulation allows healthcare workers to experience the impact of an error both on a patient and on themselves, without the consequences of direct harm for real patients. The science of learning informs us that an emotional response to error helps strengthen strong memory-based learning. The value of generating heightened arousal to enhance retention of learning has been studied [15], and the use of fear in this regard has been coined "The Terror of Error" by Itiel Dror (personal communication). The impact of this fear on the learner is titrated by the pre-briefing which sets the expectations, and the debriefing which helps solidify the learning in a positive manner. System flaws must be introduced with caution, as too many may detract from the overarching goal of the simulation scenario. As in other simulation education, the specific objectives of the scenario and the skills of the debriefing faculty are key in achieving this goal.

Just as medical disease scenarios are designed to help teach medical management, introducing system diseases can help teach systems science. Hopefully this learning will generate enthusiasm for re-designing systems less likely to adversely affect patient care. Since the learners are already engaged in the simulation, adding one or more system defects in a judicious manner can stimulate this learning. The debriefing following the scenario provides an ideal opportunity to discuss and propose solutions to these system failures.

Table 29.1 Possible system "flaws" that can be introduced into simulation training scenarios, and discussed during debriefing

(a) Poor device design
(b) Poor device or medication labeling
(c) Dysfunctional teams (confederates)
(d) Fatigued team member (confederate)
(e) Interruptions
(f) Poor facility design such as insufficient room to bring in a portable x-ray machine
(g) Poorly designed workflow – need to stop scenario to access the EHR for example
(h) Forced work-arounds – opportunity for discussion during debriefing
(i) Unworkable policies
(j) "Swiss Cheese" effect – multiple factors in same scenario – example might be no laryngoscope for intubation, when it arrives it has the wrong blade. The correct blade has a burned-out bulb, etc.
(k) Domino effect – one problem precipitates another, starting a "chain" of events
(l) Production pressures, which could encourage drift into failure, probably with confederate

Faculty Training

As in all simulation education, training of faculty is critical to assure safe and effective learning. It can probably be assumed that the majority of the learners have not previously been exposed to system science, hence it is particularly critical that the faculty be able to direct the discussion during the debriefing. For example, learners may respond in anger to what they

perceive is being "tricked" or "set up" when in fact the situations represented, although rare, are in fact realistic. It is critical that during the debriefing the faculty be prepared to defuse the anger and point out that although it is likely they will never encounter the specific system defect that they be aware that it has happened, and that an awareness of the possibility is an important learning goal. Providing sufficient time for the debriefing discussion to examine inter-dependencies and dissect the "chain of error" is also critical.

Summary

Simulation training provides an ideal opportunity to teach learner groups about the nature and impact of defective systems that can result in harm to patients. Introducing system defects into training scenarios is an ideal strategy useful for increasing awareness and teaching the fundamentals of systems science to a wide range of learners. Judicious use of system defects and skillful debriefing can enhance learner's appreciation for system science.

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Part IV

Future Directions

Leadership Engagement in Support of Simulation

30

Andrew Johnson, Lennox Huang, and Michael Shepherd

What do leaders need or want to enable them to advocate for the simulation program and provide financial and other resources?

Introduction

There is no perfect recipe for engaging leadership and making a case for any new initiative, and simulation is not different.

> *You are a newly appointed lead of a small simulation program in a large healthcare organization. Your clinical background combined with your work in developing unique inter-professional training programs has given you insight into what simulation could do across the organization. Demand for simulation has increased over the past year and you have easily outstripped your modest physical space, human resources and budget. It seems obvious to you that the organization should invest in simulation but your efforts to secure this investment have been rebuffed over time.*

Programs often develop through a combination of serendipity and persistence together with a well-honed and planned approach. In this chapter we offer a framework with some practical elements that will increase the chance of success when opportunity arises.

How Health Systems Operate

> *You've worked in your organization for over a decade and understand how care is delivered to patients and clients. After a few conversations with your mentors you realize that the patient care interface is just one part of the organization and you're not clear what the other parts of the organization are, let alone how they work.*

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Linear and Hierarchical Versus Complex and Adaptive

We have all seen organization charts. When asked to draw their organization, approximately 90% of workshop participants draw a version of a hierarchical organization chart. They vary, but they almost always represent a linear relationship from the middle management or worker level, to the Board Chair. The well-established concept is that strategy is set at the Board, operationalised through the Chief Executive and their "C-Suite", and enacted through middle management to worker level. This is true in theory at least.

The evolving paradigm for how administrative and organizational work actually occurs is somewhat different. Health services are the most complex of human endeavours. There are multiple components of the work system that must come together to make things happen: the patients; the healthcare workers; the infrastructure (physical and organizational); the finances and overhead costs; the external players (regulatory, investors, suppliers etc). The inter-connectedness and interrelatedness of these components is what sets healthcare apart from other industries as there are formal and informal networks. The formal network, seen in an "organizational chart" is a representation of the hierarchical structure as seen from a management or levels of responsibility perspective (Fig. 30.1). The linear hierarchy is the mechanism by which resources are allocated, defining the investment that the Board and Executive see as important. There are also informal networks of which Fig. 30.2 is one representation of the reality of these relationships. These informal networks are present in most work settings and can be described as what actually "makes things go". Some people within the informal network have been described as "Connectors", that is they are the informal backbone of the organizations, they maintain good understanding of how the work gets done, bring people together, solve problems, mediate and manage behind the scenes [2]. Connectors however may not be, and often are not in formal linear leadership and management roles.

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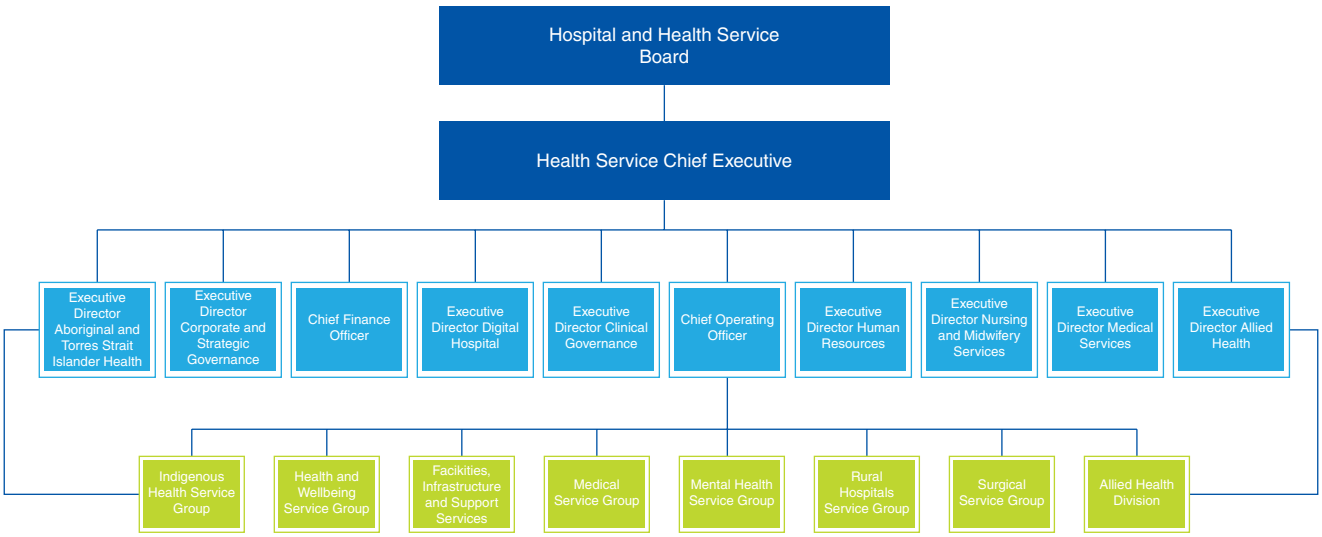

Fig. 30.1 A traditional organization chart

One of the first steps in developing your strategy for leadership engagement is to research both aspects of the organization. The linear paradigm and the complex-adaptive paradigms actually live in parallel, are not mutually exclusive and it is important to navigate both.

Leaders, both formal and informal, within the organization come in many forms and at every level. Informal leaders are commonly the "Connectors", sometimes called "Mavens" who navigate, translate and influence rather than control within the system and represent a complementary and/or at times competing source of power to the formal leadership roles in the organizational hierarchy. In Fig. 30.2, which maps the problem-solving networks in an Australian Emergency Department, the informal leaders are represented by the large dots and their relationships to each of the other individuals. Of note, most of these leaders are not in formal leadership roles. If you want to find influence, look for the people who do the connecting. They may not always be easy to see at first glance, to find them you may want to ask some questions. For example, try asking people at the coalface or in frontline formal leadership roles "if you have a problem in your area/or with getting what you need from another area of the facility—who would you talk with or call who you know could get it done?"

Whilst the internal organization is important to understand, external influences can also be critical. Your organization lives within a societal context. It is usually only one part of a broader health system and will have synergies with external bodies and providers or may be in competition with them. There are a set of common forces that are driving healthcare organizations globally and Individual organizations may be at different stages in experiencing and managing these pressures. Consumerization of healthcare, increasing costs, demographic shifts, evolving use of technology combined with workforce, changes in the physical environment, data driven management, personalized health care are all examples of the forces driving healthcare organizations. You can start to gain an understanding of how an organization has positioned itself with respect to these pressures by examining the mission, vision, values, institutional scorecards and the most recent multi-year strategic plan. The degree to which an individual organization focuses on any one of these pressures will depend on leadership, community/social pressures, political pressures, and resourcing.

Resourcing Simulation: Finding the Funding

> *Your organization's annual operating expenditure (Opex) is around $2 billion dollars. You are seeking investment in simulation of $1 million per year, 0.05% of annual Opex, which you know will provide significant benefits to healthcare delivery. Despite this seemingly small request, you have not been successful with previous attempts to secure funding.*

Whilst most healthcare leaders and managers will emphasise an organizational focus on patients and clinical outcomes, this must be balanced with fiscal responsibility. Financial performance is easily measured and will almost always be a key performance indicator for senior leaders. Healthcare structure and function, and particularly the ability to change, is often related to funding streams and incentives. To achieve substantive change in the form of a sustainably funded simulation program one must understand not only how an organization is funded, but also what expenditure incentives and pressures are at play and who has power over and who has influence related to expenditures.

In most healthcare systems, organizations have very little discretionary spending and executive leaders often have even

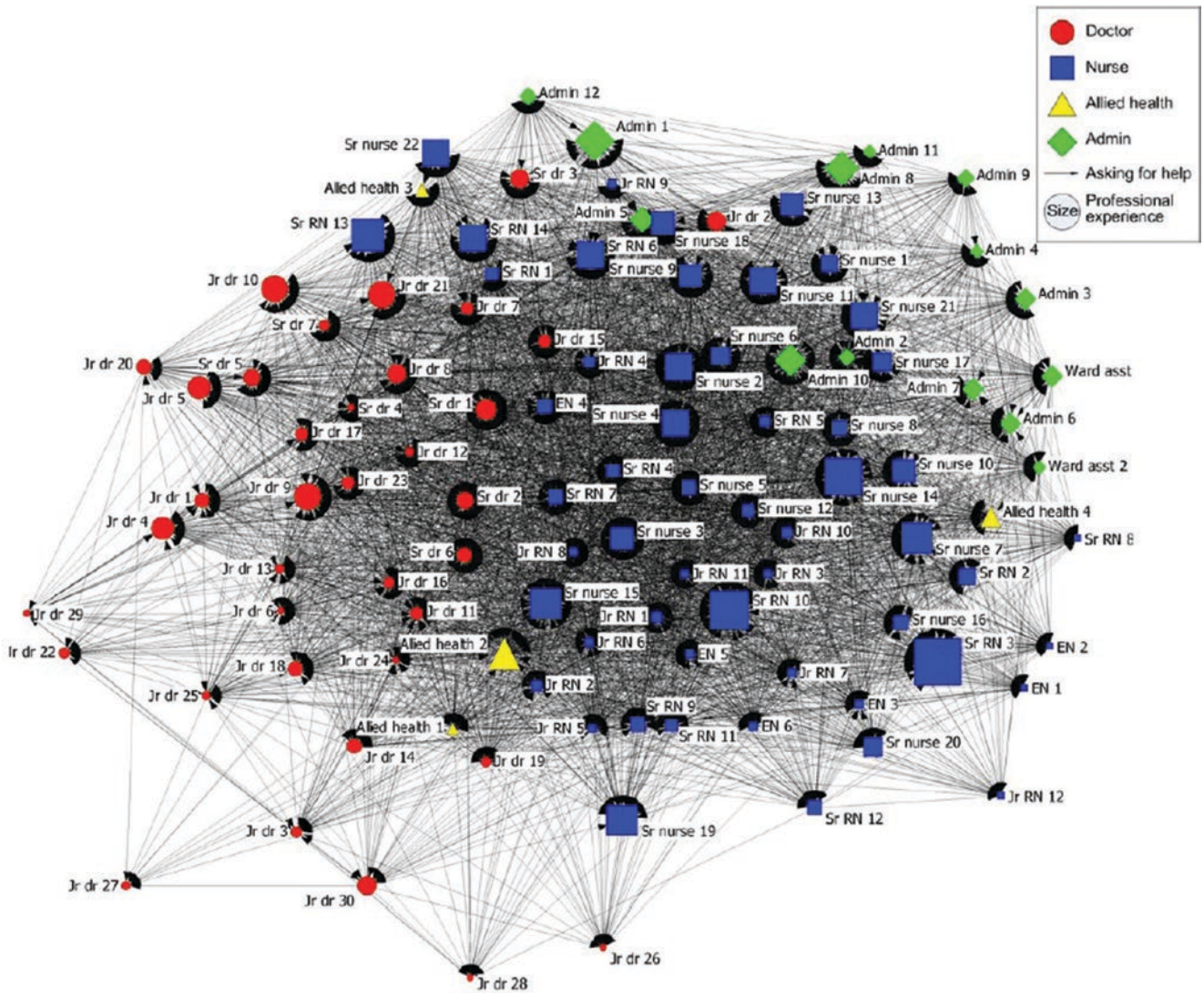

Fig. 30.2 Problem solving network in an Australian ED [1]

less. Revenue is usually directly linked to specific clinical activity and this activity will often have very little or no organizational profit. An increase in activity will usually require an increase in cost; consumables, bed days and activity based payments to clinicians. Opportunity cost is important to consider when seeking funding, with healthcare leaders often left with difficult decisions between essential services. The opportunity cost of funding your simulation programme may be an inability to increase staffing in an important clinical area.

Another important contributor to funding difficulty is that healthcare costs generally continue to rise rapidly and funding will typically lag behind cost growth, leaving organization leaders struggling to deliver a balanced budget. If profit is generated, and discretionary spending is available, it will often be in the control of a specific clinical service rather than the wider organization.

While successful simulation programs can result in significant savings [3–5], this is a difficult sell to hospital leaders. These proposed savings are often medium to long term and related to reduced complications, reduced error or gradual efficiency gains. The absence of discretionary spending makes investing in opportunities for longer term saving very difficult. Additionally, constraints around external funding arrangements that are often present (i.e. contractual relationships between a hospital and a medical school) make investing in clinical improvement more difficult, but not impossible.

To realistically identify funding for your simulation program you must therefore identify where pockets of discretionary spending might exist within your organization, convince leaders that potential savings are 'real'; and/or identify and engage philanthropic sources of funding.

Identifying expenditure that the organization makes to external suppliers or contractors is likely to be more successful, as savings in this area are more readily quantified and will immediately improve budget positions. The most common example of this is the reduction in insurance premiums that has accompanied some surgical simulation training programs in North America. You may need to make contact with your business manager or Chief Financial Officer to help in this regard. You will often find them to be flattered and impressed to be approached by clinicians interested in their area of responsibility, looking to make a positive impact.

Another important potential source of discretionary spending is donations or a healthcare organization's associated charitable foundation. While this might not always provide sustainable program funding it can be very useful to develop an activity and demonstrate hard savings for hospital leadership. Simulation activity and equipment typically provides excellent 'collateral' for potential donors, being readily accessible and suitable for media coverage opportunities. Again, partnering with a business manager may help you navigate this approach.

There may be opportunities to negotiate with providers of simulation equipment to make your requests more affordable through donations or discounts. This approach needs to fit within your organisations procurement processes and will require declaration as a potential conflict of interest in the future. Other opportunities may emerge where you can look for external grant progams, these often look to see that the organization they are supporting has "skin in the game" and working with your business and finance colleagues, you may be able to identify suitable potential grants.

Connecting with and Influencing the Influencers

You've now figured out how your organization is structured, what some of the organizational goals are and who the formal and informal leaders are. All this knowledge is for nought without an appreciation for the people you will approach and an understanding of how to engage in discussions that may further your case for your simulation proposal.

Working with the connectors or mavens that you identified earlier will help get your project off the ground, or at least remove obstacles. Prior work with these influential people, working with them to create your solutions, will help prepare your proposals for success. Successful proposals take time and persistence, engaging thought leaders and resource holders, shaping your thoughts to create value for the organization.

Building the Case

You have now gathered a much better understanding of how your health system is designed and influenced, you understand the relevant funding opportunities in your organization and you have a strategic approach to influencing important stakeholders. You are now considering writing a business case to present to the leaders and influencers you have identified.

When you have a well-formulated proposal, you need also the opportunity. A solid business case ready to go means that when the next funding opportunity comes around, you can be ready to put the final touches on your case, ensuring that it meets the intent of the funding, and you are way ahead of competing bids.

Business cases often fail to deliver organizational development and at their worst become a way of delaying or avoiding decisions. This is because they are often developed and written from the perspective of the person who wants to lead, or is championing, the change.

To successfully progress with a simulation service, you will need to pay attention to several key considerations, critical to the negotiation.

Develop the Case with Leaders and Influencers

Successful business cases are usually a partnership between potential funders and providers. It is critical that leaders understand the proposal but it is even more likely to be successful if they feel ownership of the proposal.

Seeking other impending organizational change to partner with, or add value to, is also a potentially successful strategy. For example, an organization may be moving to roll out a new electronic prescribing and dispensing system following a series of sentinel events. The development of a simulation program to, amongst other things, ensure safe roll out, may be a relatively minor additional cost and would likely be strongly supported by the prescribing and dispensing project team.

Have a Compelling Rationale for Simulation

While simulation is an important and effective education tool, many organizations regard staff education as somewhat of a luxury and additional investment in staff education is often difficult to justify.

Successful cases for investment in simulation will usually identify a wide range of benefits and generally the closer these benefits are to patient outcomes or cost savings the bet-

ter. A simulation case that is integrated with the organizations quality and safety structure is more likely to be successful.

Examples include: improving important clinical Key Performance Indicators (KPI), e.g. decreasing the CLABSI rate; Improving efficiency, e.g. decreasing theatre turnaround times; testing and refining systems, e.g. post adverse event review; reducing risk, e.g. human factors training; reducing cost, e.g. insurer incentives; assisting with the development of facilities; reduction in staff orientation time, and recruitment and retention of staff [5].

Solve Other People's Problems

Noting the possible simulation benefits above, it is worth testing out these potential benefits with key influencers and leaders and prioritising accordingly. Emphasising the likely improvement in your bosses KPIs improves the chances of success.

Be Realistic

Whilst a fully self-sustained simulation program might be an ideal outcome, consider how you can make a start with less. Often incremental growth is easier to achieve than a single large development. It is also helpful to try to identify some simulation related income, e.g. courses, that may be able to supplement your program.

Be Opportunistic

Be ready to respond to opportunities within your organization. Potential opportunities may be leadership turnover, physical space becoming vacant or potentially complementary organizational change.

Taking it to the Top

Getting the attention of formal leaders may be a challenge. The first step is to understand the language they speak and the key drivers for their attention. You may be in a position to speak to them yourself, or perhaps talk with the Connectors and get the "low-down", the real story, from them. They will have worked it out and may be prepared to share their insights. Framing an initial simulation discussion in terms improving education for staff will not go far if the organization is under tremendous financial strain. In most organizations formal leaders will have personal KPIs that are aligned with the institutional KPIs, and top of the list is finance.

A Little About Negotiation

Negotiation is the means by which we influence others to achieve objectives. This occurs in our daily lives, commonly at a basic transactional level with little thought and need for flexibility. At other times, working as a healthcare practitioner, or seeking to influence within an organization, this can be a much more complex undertaking requiring an agile approach.

The key to successful negotiation is the concept of creating value, moving from defending "positions" to integrating "interests". That is, rather than fighting for your piece of the pie – Distributive Bargaining, you shift your thinking to alignment of interests and increasing the size of the pie – Integrative Bargaining. This requires us to think about our interests and the interests of the other party(ies), which in turn allows us to find the common ground and to explore the remaining areas where we may need to find solutions to different priorities. The degree to which we place importance on outcomes of negotiation and the relationships with our negotiating partners can define the style of negotiation employed. This is commonly described as a "dual concerns" approach. It is important to be flexible as each of the five ethical styles described by Lewicki, Hiam and Olander [6, 7] has a place. This is shown diagrammatically in an variant of the dual concerns model which has informed their work, at Fig. 30.3.

We all have default styles of negotiation but need to recognise when to flex into another style when the situation demands. The Collaborator values both the relationship and the outcome, looking for the "win-win solution". They give more than they take, they engage and they commonly feel constrained by rules and redefine them to create solutions. The collaborator is the most likely to create value. The Competitor does not hold value in the relationship and prosecutes the outcome, often with a "win at all costs" approach. They engage, follow the rules, and take more than they give. The Accommodator "loses to win", "takes one for the team", valuing the relationship over the outcome. They give, engage and accept the rules. The Avoider / Withdrawer is in the unfortunate position of advancing neither relationship nor outcome. They give, redefine rules and withdraw rather than engage. The Compromiser is keen to cut a deal, splitting the difference. They do create value. Compromisers withdraw more than they engage, take more than they give, and do follow rules. They can be very effective negotiators.

There can also be two unethical styles characterised as "Rob" and "Con". Both redefine the rules to suit themselves, both take more than they give, but you don't see the robber coming, they withdraw, while the Con is in your face while they take what they want.

The critical thing about negotiating to advocate for your proposal is to understand the interests of other parties and

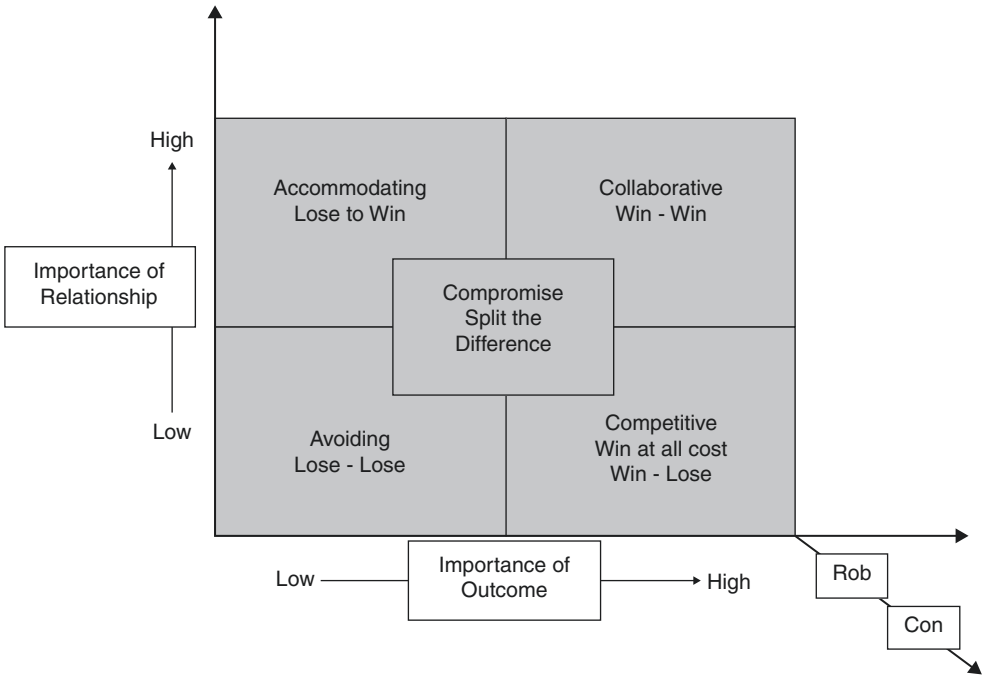

Fig. 30.3 Dual concerns approach to negotiation

align wherever possible. Understand your own negotiating style. If you can, try to move into a "collaborate" mode. For those not accustomed to this it can be frustrating, but if you want to be successful in creating value, it's what you need to do. Take yourself into a space where you place importance on the relationship and the outcome, and work with others to get them into that space also offers the best chance of a sustainable solution.

The Decision Is Made, What Next?

The case for investing in simulation may appear obvious in isolation, but in the real-world investment is a competition sport. Your case needs to be clear, compelling, collaborative, aligned to organizational goals and priorities. Simulation needs to solve your bosses' problems, not add to them. Take the time to explore the interests of key influencers, invest in relationships and prepare for the long game. Nothing worth having comes easily.

Persistence is critical. Don't be discouraged should the first proposal not be accepted on first presentation. Seek feedback should this occur and use it to build a stronger revised proposal. Meet again with those who helped you draft the first proposal to discuss revisions and strategize on revisions and approach. Do not give up on a good idea, its time will come, you may need to be patient.

Influence is achieved through **negotiation**, particularly in the absence of formal institutional power. Work with the powerful formal and informal leadership, don't compete with them.

And remember, luck is found at the crossroads of opportunity and prior preparation.

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The Future of Simulation in Healthcare Safety and System Improvement

31

Joseph R. Keebler and Mary E. Mancini

Introduction

This volume has demonstrated how simulation has an integral role to play in maximizing healthcare delivery today as well as developing and enhancing future healthcare systems. The role of simulation can span a variety of contexts from education and training of healthcare providers to re-designing tools, technologies, and even entire hospitals. The purpose of this chapter is to look forward to the role simulation may play in future systems. This chapter discusses how simulation can facilitate solving some of the largest challenges being faced in modern day healthcare including minimizing harm and enhancing healthcare outcomes, cybersecurity, telemedicine, and in-home health. We will end with a discussion of what the future may hold for healthcare simulation.

Human Factors for System Improvement

The science of human factors (HF) can enhance the development and implementation of both simulation and healthcare delivery systems. Just like any system, all technologies integrated into healthcare systems need to be considerate of how humans act and learn to best fit with organizational goals. The science of HF is interdisciplinary and brings together psychology, industrial engineering, design, and safety to best understand how humans are situated in their systems. It has been defined by the International Ergonomics Association as "*the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and other methods to design in order to optimize human well-being and overall system performance*" [1]. HF is often referred to as "human-centered design" due to its focus on ensuring that machines and technologies fit the demands of human cognition and behavior, and not the other way around.

Types of Simulation

Commonly in health care, simulation is thought of as mainly existing within the context of a learning or academic environment. However, simulation can also help with assessment and modeling to ascertain how certain tools or processes function, what the best flow for a task should be, or even how a hospital room or floor should be designed to ensure safety for patients and providers. Using simulation to help healthcare providers and others understand how HF principles impact healthcare design and processes can have a powerful synergistic effect on patient safety [2, 3]. Simulation will continue to expand to new learning technologies such as augmented reality or digital learning boards, and to complex computer simulations that allow the modeling of complicated procedures and processes. One path forward is to integrate simulation deeply into the center of future healthcare systems, integrated beyond education and training into daily system function. One guideline for such an integration is the Systems Engineering in Patient Safety (SEIPS) model [4] which provides a framework for thinking in terms of HF at a systems level.

Introduction of the SEIPS 2.0 Model

The SEIPS model is useful for understanding the intricacies of healthcare in an integrated systematic way. This model separates the system into inputs, processes, and outputs associated with healthcare delivery work and patient care. It considers all aspects of an organization and is therefore related

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to the idea of high reliability organizations [4] in the sense that it provides a thorough view of the multiple levels and causal chains that exist in healthcare settings. The SEIPS model can help us understand the constraints and downstream effects of simulation-informed initiatives and the potentially positive effect they will have on relevant provider, patient, and organizational outcomes. This model provides an important conceptual framework for understanding the complex systems in health care. In the context of this chapter we will focus on how simulation can be used to specifically affect the work system.

What Is the SEIPS 2.0 Model's Uses and Utility in Healthcare Settings?

The SEIPS 2.0 model is a conceptual framework that helps organizations understand how the individual components of an organization function together through various processes to lead to determinable outcomes. When applied to healthcare, the model is useful because it identifies the various components of the work system where simulation can be integrated. The goal of integrating simulation is to increase the effectiveness of processes to lead to desirable outcomes for patients, providers, and the organization as a whole.

How Can SEIPS Optimize the Impact of Simulation on Healthcare?

Looking towards the future, a systematic approach to acquisition and use of simulation is absolutely necessary for appropriate integration into hospital systems. Hospitals have limited resources so they need to be careful about where they apply those resources. Therefore, utilizing a model like SEIPS can provide guidance on what a specific part of a healthcare system can do or which aspect should receive focus, and what potential downstream effects changes can have on this part and the systems it interfaces with, which may include in-home care, regulatory agencies, nursing homes, pharmacies, durable medical equipment, and so on.

Using Simulation to Understand Failure and Success in Human Machine Coupling

In recent years the philosophy of HF has been adopted into medicine, including the concept that errors aren't based in the fallibility of humans, but instead are a normal aspect of complex systems where humans are coupled to a work system through technology. In other words, an error emerges when the constraints of the system and the constraints of the human lead to unexpected outcomes. Medical technology, training, and procedures are ever-changing so utmost care has to be given to the design, integration, and education on emergent devices and techniques.

Simulation plays a vital role in this evolution in healthcare. For instance, simulation's applications can range from error testing devices to demonstrating common failures in a specific technique or procedure. Simulation could allow preemptively evaluating systems that self-measure failures in human machine coupling and provide multi-level feedback to maintain system improvement. This can be tied directly to simulation-based training, which has been shown to be an excellent tool for recognition, avoidance and bounding of errors before they propagate [5]. Successes include team training, which has been linked to a 15% reduction in adverse patient outcomes [6].

Modern Methods

The simulation community is energetic and creative, and constantly seeks to expand its expertise and impact. Collaborations between simulationists, HF and clinical subject matter experts can improve healthcare delivery. The examples that follow describe activities that have been initiated in some organizations but may not yet be widespread.

Simulation for Usability Testing

Simulation will continue to be effectively used to test devices and technology in iterative design processes. Simulation could be used in a variety of ways for assessing digital health tools – from providing mockups and wire frames of potential tools to inserting tools into a simulated task to investigate how to best integrate the tool into a specific system or unit. Examples of this type of simulation have been around for quite some time, although it's not clear whether they have been effectively adopted into modern healthcare systems. As an example of simulation for tool integration, the "Bloodhound Project" [7] uncovered usability issues in web technologies through simulation. This software basically simulated traffic and flow on websites and gave success probabilities across a variety of end-user tasks. A similar process could be utilized to provide simulated testing before acquisition of equipment, such as medication infusion pumps, or new smartphone applications. Future work in simulation could also examine the use of Augmented Intelligence to facilitate end user-testing, and aid healthcare organizations in understanding the functionality of various electronic tools they are either purchasing or creating.

Simulation-Based Training for Enhancing Provider Performance

Novel simulation technologies for training tasks include virtual and augmented reality systems. Both Virtual reality (VR) and augmented reality (AR) involve interactions with computer generated graphics [8]. Although experimentation with AR for healthcare purposes has been around for decades [9], decreased costs and increased availability of wearable AR technologies have contributed to recent advances. AR seems especially useful when relevant task-related visual information, including both images and text, can be overlaid onto a work surface. For instance, AR software on iPad-like device can utilize the camera to automatically illustrate and label anatomical features of a cadaver or model. This has important implications for teaching anatomy, but AR could also be used in live settings to facilitate recognition of organ systems and aid with decision making [10].

Simulations Using Escape Rooms and Gamified Learning

Escape rooms have become popular tools for training a variety of healthcare tasks, usually through utilization of gamification principles that force individuals to work cooperatively as a team [11]. Although the majority of this work is focused on studying and enhancing teamwork, escape rooms provide a glimpse of a more basic application of gamification to training systems in the medical setting. Essentially an escape room is a team puzzle, usually utilizing a series of clues and locks to give the team access to a final key to "escape the room" within a set amount of time [12, 13]. The puzzles are normally designed in a way that forces the individuals to be interdependent [11–13], pushing them towards having to work as a team to succeed.

There are a multitude of considerations when attempting to implement an escape room in a healthcare setting. One of the most difficult is establishing a series of puzzles that are at the right level of difficulty given the time frame of the escape room. Those using escape rooms in this capacity must be mindful of calibrating the complexity and involvement of each puzzle in the room with learning objectives. Other design considerations include considering how much time teams have, how many hints to give teams that are struggling, and how long it takes to reset the room after use. Normally the types of puzzles must be mundane enough that they can be solved by anyone, but within the constraints of using an escape room as a healthcare training system the puzzles may use healthcare scenarios and equipment to provide face validity. Some escape rooms have now become virtual [14], leading to an entire new area for research and deployment of gamified team-based training.

Simulation for Designing Hospital Rooms and At-Home Care

Simulation can be leveraged to design or re-design hospital, clinic, and at-home health environments. Hospital physical spaces may include patient rooms, surgical suites, and entire buildings. Non-hospital environments such as rehabilitation or clinic areas as well as in-home care settings can also benefit from the use of simulation-based design. Utilizing simulation in this capacity can allow mindful design to ensure safety. For instance, simulation can capture where an MRI is situated and disallow the placement of equipment or rooms that contain potential hazards when located near an MRI. Further, simulation can catch potential issues in rooms that might not be salient to architects or designers. Simulation has been used to provide better insight into wayfinding and signage [15], or to facilitate estimates of emergency room capacity [16].

Simulation in Medical Cybersecurity

Cyber security has already shown itself to be a key safety issue in healthcare systems. Given the severity of events, such as the National Health Service attack in the UK in 2017, there is a clear cybersecurity threat in modern healthcare systems. Cyber-attacks can lead to system-wide failures and potential harm to patients [17]. It has been argued that cybersecurity is in the hands of every worker in a system [18], and therefore, will need to be a focus of training systems and simulation in the contemporary healthcare setting.

Simulation could facilitate preparing individuals, teams, and entire organizations to deal with failures from cyber-attacks. This includes training novices and professionals to recognize and appropriately respond to various email based threats, training individuals to deal with equipment failures resulting from attacks, and facilitating changes in organizational policy to deal with the rapidly evolving cyber-threat space.

Future work will also need to examine the cybersecurity issues surrounding medical devices. The idea that a device such as a pacemaker could be affected by a cybersecurity attack is unfortunately a reality. HF experts can provide guidance on the review of medical devices to ensure they are resistant to attacks and that user tasks don't lead to situations where the device becomes vulnerable to cyber threats without the user being aware.

Simulation for In-Home Health

In the US, an aging population, changes in healthcare technologies, and challenges associated with pandemics such as COVID-19 have increased focus on providing healthcare in the home setting. Although being treated at home can lead to a plethora of benefits for patients and their families, it can also lead to a plethora of new challenges and issues.

While many hospitals incorporate videos and checklists into their discharge instructions, organizations such as the Institute for Healthcare Improvement (IHI) and the National Patient Safety Foundation (NPSF) encourage acute care facilities to leverage simulation technology and the science of HF to prepare patients, their families and caregivers to safely transition to home [19]. Transitions of care must include a robust portfolio of realistic scenarios where individuals can come up with home-based solutions and work arounds for care. In addition, opportunities to practice for rare but significant events (e. g. blocked tracheostomy tube) must be provided before discharge with reinforcement in the home environment through screen-based or hands-on simulation with feedback from professionals. In this manner, patients, families and caregivers will become confident and competent in situations that can impact them in the home… not as an afterthought but as an intentional, essential part of discharge planning.

Holden, et al. [20] noted that health-related activities are embedded in and shaped by levels of social, physical and organizational context. Drawing from this work which combined findings from three studies to specify 17 contextual or macro-ergonomic factors in home- and community-based work systems of chronically ill patients, it becomes clear that healthcare in the future will require an understanding of HF and applications beyond those directed to the healthcare professional and the acute care setting.

The National Research Council Committee on the Role of Human Factors in Home Health Care [16] noted the direct relationship between health and the physical environment of homes. Transition from an acute care facility to home often receives less attention than necessary. The focus is rarely on the environmental aspects of the home care setting. Models of patient homes can be utilized to understand where equipment will fit, how patients can or will move around their home after surgery, or where potential problems are in the house for a patient with a specific disability. With advances in software, we can envision a day when having a computer mockup of a patient's home would be a routine part of discharge planning.

Future of Simulation in Health Care

There are numerous sources describing how simulation has responded to novel needs [21, 22], patient safety [23] and system improvement [24]. Necessity as well as cutting-edge research will continue to push the boundaries of what simulation can do to enhance the quality and efficiency of healthcare services.

The Society for Simulation in Healthcare (SSH) maintains a directory of healthcare simulation centers across the globe [25]. Many of these centers are focused on the utilization of simulation as an educational tool. A lesson learned from the COVID-19 crisis in 2020 is the absolute necessity of having a robust infrastructure in place to efficiently provide just-in-time training as regards new information as well as assure competency in critical techniques (e.g. isolation) to the world's health care professionals. Screen-based simulation, as a pedagogy for health professions education, combined with simulation tools such as VR and AR can provide the basis for such an infrastructure. The time is now to bring together the world's experts in simulation, health profession education, and instructional design to prepare a system to meet these needs before the next emergency presents itself.

The future holds opportunities to expand the use of simulation beyond the confines of clinical care. The authors of *Bridging the Gap between Work-as-Imagined and Work-as-Done* [26], challenge those in healthcare to think of simulation as the bridge between healthcare work as we see it in its ideal state and the reality of this work as it is actually done. Given the constantly evolving, complex adaptive system that is healthcare, complete understanding of clinical as well as administrative processes is "an unattainable ideal." Simulation, however, when fully embraced and integrated by the highest levels of healthcare organizations can be leveraged to assess and improve functions (e.g., policies and practices) outside of clinical care. For example, how do those in the Billing Department respond to questions? Or, how does an organization decide which ultrasound machine to purchase? What are the implications to the individuals using this specific ultrasound machine in real-time based on decisions made in purchasing regarding new equipment? Simulation can be used to answer these questions and to bring to life the commitment to Continuous Process Improvement and acknowledgement of trade-offs and associated risk.

Another area that can and should be addressed in the future, is how not to squander lessons learned. All too often, issues or lessons surface during simulation sessions that are not directly related to the educational objective of the simulation. As such, they stay in the simulation center. These les-

sons often relate to latent safety threats or opportunities for improvement. However, these lessons learned or serendipitously identified in the running of a simulation need to be fully brought to light and used to improve patient outcomes and reduce patient risk. To achieve this goal will require that leaders clearly articulate the high value they place on lessons learned during simulation and intentionally establish structured systems to identify and report them so the system can learn from them.

Beyond the need for a more robust global infrastructure for healthcare simulation is the need to address how simulation centers can safely provide simulation-based education and assessments in a post-COVID world. This is particularly true in larger healthcare systems where a combination of center-based and *in-situ* simulation experiences occur. The protection of learners and educators requires us to re-conceptualize how we do what we do in simulation where contact is frequent and often in confined spaces. Advocacy for the learners and educators requires a collaborative response from our communities of interest.

The placement and organization of simulation activities within future medical systems will also need to be examined. With acceptance of the basic tenets of this volume, it is clear that the responsibility for simulations within hospitals and health systems needs to expand from the perspective of being part of human resource development to being part of patient safety offices and resilience engineering departments. Simulations need to be leveraged across a variety of contexts, from facilitating decision making to intentionally seeking to understand latent threats and errors in the system that lead to adverse events.

In this future state, every individual involved in health care – provider, administrator, architect, equipment developer and others – will have a deep understanding of the complex nature of systems, of SEIPS, and of simulation. How will we achieve this goal? One action step is to introduce the study of HF and its implications for enhancing patient safety into every health profession school, not as an elective but as a required course. With this as common background, system improvement will become an integral part of day-to-day operations in every health care facility. As an example of how this will alter "business as usual", all renovations or new construction and every new purchase would be required to have an assessment with simulation prior to final decisions being made.

To prepare individuals to be proactive and empower them to achieve these goals, healthcare professionals need to embrace a new, explicit core competency for all healthcare providers. This competency is the ability to debrief and to be debriefed. Currently, given the professional education associated with being in healthcare, it is *assumed* that doctors, nurses, therapists, hospital administrators and others are proficient in discussing situations and learning from them. This is simply not true. Being an effective communicator and learning from experience is, for most, a skill that must be learned. Debriefing has been defined as a "dialogue between two or more people; its goals are to discuss the actions and thought processes involved in a particular situation, encourage reflections on these actions and thought processes, and incorporate improvement into future performance" [27]. Simulation-ists have embraced debriefing as a core concept and it routinely has been inculcated into simulation activities [28]. The ability to debrief and be debriefed should not be limited to the simulation center but applied in all clinical and administrative activities as well. This competency is the glue that holds the healthcare team together and allows it to collaboratively consider how individuals, teams and systems can be improved. A mechanism for achieving general consensus that this specific competency is essential in healthcare providers is to leverage work groups already associated with interprofessional education such as the Interprofessional Education Collaborative (IPEC) [29].

Conclusion

As we look towards the future, it is clear that healthcare simulation must move from being viewed by healthcare systems as primarily an educational tool for individuals and teams, functioning quietly at the periphery. Simulation for system improvement requires central integration of simulation as an ongoing activity, like departmental meetings and quarterly billing audits, for multi-faceted testing and assessment of the system to inform design and development as well as identify developing risks and need for system adaptations. This will also require a change in stance by healthcare systems to a broader view of the interactions and inter-dependencies influencing care for the sick which occurs in a myriad of settings, many non-traditional. *One foundation for this future state of use of simulation by healthcare systems must include the discipline of HF and partnering with its experts.* As each new technology, technique, and profession grows and changes, HF/E will provide the guidance necessary to understand how these changes can be integrated best into the systems in which medicine takes place.

To truly live the oft stated commitment to 'being patient centered, focused on excellence, and embracing continuous improvement', the future of healthcare requires new method and approaches of which simulation for system improvement should be a mandate. Nothing less will do.

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Index

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