Promoting Organizational Learning in Healthcare through Simulation: A Study in Serendipity

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In a case study of a simulation-based medical education program, we serendipitously discovered organizational learning as it emerged among expected patterns of individual learning. During simulation debriefings, radiologists-in-training ("residents") spontaneously engaged in organizational learning processes. They identified routines that hindered patient care for uncommon, but potentially fatal contrast media reactions. We provide exemplars illustrating how residents identified system-related patient safety threats. Residents learned directly from simulation, recollected clinical encounters, and constructed hypothetical histories (imagining what could have happened in their hospitals). We discuss implications for organizational learning from hypothetical histories and future research promoting organizational learning in healthcare through simulation.

Simulation in healthcare, designed primarily for educating individual clinicians, can also foster organizational learning processes. We describe the serendipity of discovering organizational learning as it emerged among the expected patterns of individual learning. Specifically, we present a case of a simulation-based medical educational program in which physicians training in radiology ("residents") and their radiology faculty ("attendings") spontaneously engage in organizational learning. Following March (Levitt & March, 1988; March, 1999), we define organizational learning as a process in which decision makers reflect on their past experience and decide whether to change routines that guide future behavior. When past experience is sparse, such as for low probability, high consequence events, decision makers

may construct and seek to learn from "hypothetical histories", "events that might have happened under certain unrealized but plausible conditions" (March, Sproull, & Tamuz, 1991, p. 4). During simulation sessions, residents reflected on clinical experience to identify organizational routines that hinder their ability to diagnose and treat patients who suffer adverse reactions to contrast media.

We present exemplars from the simulation to illustrate *how* radiologists identified these threats to patient safety and thus, engaged in organizational learning. We explore processes of organizational learning in healthcare through simulation and suggest directions for future simulation research. Before discussing the case in detail, we briefly introduce organizational learning in healthcare, simulation in healthcare, and contrast media reactions.

INTRODUCTION

Organizational Learning in Healthcare

Researchers increasingly focus on organizational learning in healthcare. Investigators have studied organizational learning from different levels of analysis (e.g., Edmondson, 2002) and conceptual frameworks (e.g., Argote & Miron-Spektor, 2011; Argyris, 1990). Some focus on learning processes (e.g., Levitt & March, 1988); others emphasize improving outcomes (e.g., Fiol & Lyles, 1985). Research on organizational learning in healthcare examines "deliberate learning" (Nembhard & Tucker, 2011) in which healthcare organizations implement best practices (e.g., Nembhard, Cherian, & Bradley, 2014; Tucker, Nembhard, & Edmondson, 2007) and new technologies (e.g., Edmondson, Bohmer, & Pisano, 2001). Other studies analyze how frontline employees participate in organizational learning (e.g., Tucker, 2007; Tucker, 2016; Tucker, Edmondson, & Spear, 2002).

Investigators also study how hospitals learn from formal analyses of events involving preventable patient harm. They note that Morbidity and Mortality (M&M) conferences, common hospital-based event analysis forums, draw conclusions from the shortcomings of clinicians and may also identify contributing system-based factors (Kravet, Howell, & Wright, 2006; Lipshitz & Popper, 2000; Orlander, Barber, & Fincke, 2002). However, few empirical studies examine how hospitals learn from these M&M conferences or from root cause analyses of sentinel events (Nicolini, Waring, & Mengis, 2011a; Nicolini, Waring, & Mengis, 2011b) and other instances of preventable patient harm (Ramanujam & Goodman, 2011). More research is needed on how healthcare organizations learn about low probability, high consequence events, in particular, before they result in harm, such as near misses and simulation. In this study, we explore how frontline employees (i.e., residents) engage in organizational learning through simulation of uncommon, potentially life-threatening medical conditions (i.e., patients' adverse reactions to contrast media).

Simulation in Healthcare

Learning clinical skills from simulation supplements the traditional medical model of clinical instruction known as "see one, do one, teach one". Simulation is a relatively new educational modality for healthcare providers. It is modeled after the established use of aviation simulators (Gaba, 2004) where pilots acquire and demonstrate proficiency in realistic simulated cockpits. Individual and teams of clinicians diagnose and treat simulated patients, such as high-fidelity mannequins, as they enact reality-based simulation scenarios (e.g., Levine, DeMaria, Schwartz, & Sim, 2013). Healthcare professionals, like pilots, also use simulation to practice teamwork skills, such as Crisis Resource Management, originally developed for aviation (Helmreich & Schaefer, 1994; Fanning, Goldhaber-Fiebert, Undani, & Gaba, 2013).

Post-scenario Debriefing

Learning tends to occur during post-scenario debriefings, as expert debriefers guide participants in discussing how they enacted the scenario. During debriefings, clinicians reflect on their experience during the scenario and debriefers prompt them to describe the "mental models" that framed their decision making (Rudolph, Simon, Dufresne, & Raemer, 2006). Participants may learn from their errors or

"performance gaps" (Rudolph, Simon, Raemer, & Eppich, 2008) in patient diagnosis and treatment as well as interprofessional communication. Simulation practitioners may choose from an array of debriefing methods (Motola, Devine, Chung, Sullivan, & Issenberg, 2013), but most techniques aim to offer clinicians constructive feedback under conditions of psychological safety (Edmondson, 1999) while precluding patient harm.

Identifying Latent System Issues through Simulation

Simulation ultimately seeks to improve patient care in healthcare systems (Dunn et al., 2013). To identify threats to patient safety or "latent errors" (Reason, 1990), medical researchers usually conduct "in situ" simulation (i.e., in the actual healthcare setting) (e.g., Blike, Christoffersen, Cravero, Andeweg, & Jensen, 2005; Rodriguez-Paz, et al., 2009). A notable exception is Geis and his colleagues who use laboratory-based simulation to identify actual latent errors (Burton, et al., 2011; Wetzel, Lang, Pendergrass, Taylor, & Geis, 2013). However, both in situ and laboratory-based simulation studies tend to focus on outcomes rather than processes of learning and change. Process research is needed on how clinicians learn about actual organizational routines through simulation.

Contrast Media Reactions

Iodinated contrast-enhanced computed tomography ("CT") scans are ubiquitous. In the U.S., about 85 million CT scans are performed annually (Brenner, 2012). Although aggregate data on the proportion of CT scans using intravenous contrast media are lacking, a health system-based, decade-long (2000-2010) study indicates that half of the patients who underwent thoracic, abdominal, and pelvic CT scans received intravenous contrast (McDonald, et al. 2014).

Some patients have life-threatening reactions to contrast media, although such serious acute reactions are rare (Morcos & Thomsen, 2001), "…with an historical rate of approximately four in 10,000 (0.04%)" (American College of Radiology (ACR), 2016). Most contrast media reactions ("contrast reactions") are mild and the overall reported incidence of such contrast reactions ranges from 0.18-0.70% (ACR, 2016). Lethal reactions to contrast media occur without warning and most begin during the first 20 minutes after contrast media administration (ACR, 2016). Therefore, timely diagnosis and treatment are critical in averting fatalities and preventing moderate reactions from developing into severe ones (Namasivayam, Kalra, Torres, & Small, 2006). Whereas the low rate of contrast reactions remains unchanged, the number of scans being performed is increasing and, in conjunction, the number of contrast reaction cases is also rising.

Radiologists should know how to recognize and effectively treat contrast reactions. Yet radiology residents lack clinical exposure (Issenberg & Scalese, 2008). They rarely have an opportunity to learn from experience about these uncommon, potentially life-threatening conditions. Simulation enables residents to practice applying evidence-based guidelines (ACR, 2016) for the diagnosis and management of contrast reactions. Investigators use simulation in evaluating (Tubbs, et al., 2009) and improving radiology residents' knowledge, perceived competency, and simulated clinical practice (Petscavage, et al., 2012). Contrast reaction simulations have proven effective in educating residents in time-critical diagnosis and treatment (Sarwani, Tappouni, & Flemming, 2012). However, few studies evaluate hospital readiness to respond to contrast reactions (Bartlett & Bynevelt, 2003; Favinger, Bastawrous, & Bhargava, 2013).

METHODS

Case Study

This retrospective case study (Yin, 2014) of a 2013 simulation-based educational program focuses on the debriefings in which individual learning usually occurs. We culled exemplars from the simulation sessions to illustrate how the resident and attending physicians learn about their actual healthcare organizations through simulation.

Simulation Design

Prompted by a few patients who unexpectedly experienced severe contrast reactions, Dr. Barry Kanzer, an attending physician in radiology, developed a simulation-based educational program based on research by Sarwani and his colleagues (Sarwani, et al., 2012).

Simulation-based Educational Program

During each of the six 4-hour simulation sessions, a resident individually engages in at least one of five different contrast reaction scenarios, while his/her colleagues simultaneously observe on a remote video monitor (See Figure 1). The first three scenarios focus on allergic-type reactions (mild, moderate, severe), the fourth presents a vasovagal patient response (i.e., a temporary fall in blood pressure or fainting), and in the fifth scenario a patient experiences bronchospasm (i.e., contraction of airway muscles leading to airway narrowing). Residents discuss the scenarios in three group debriefings, jointly led by at least two educators, a debriefing expert and one or two radiology attendings ("debriefers").

FIGURE 1
CONTRAST MEDIA REACTION SIMULATION DESIGN AND PROCESS

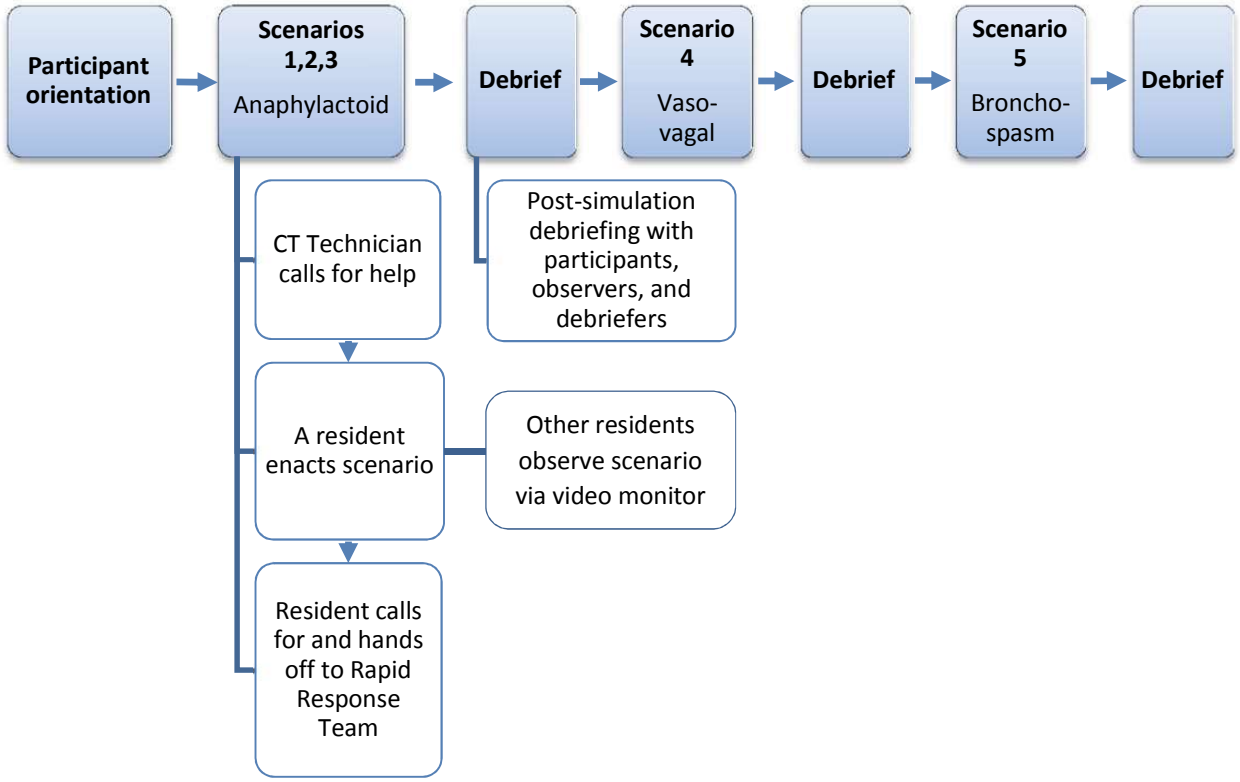

Figure 1. Contrast media reaction simulation design and process. Horizontally, the figure depicts the order and content of the five scenarios and three post-scenario debriefings. Vertically, it illustrates how each scenario and debriefing unfolds during simulation. The Rapid Response Team is represented by senior resident(s).

Debriefing

Applying "debriefing with good judgment" methods (Rudolph, et al., 2006), debriefers elicit residents' perspectives on and knowledge of contrast reactions. They also ask residents open-ended questions to generalize the simulation experience, prompting them to think about the scenarios in the context of their clinical work (Rudolph, et al., 2008). These questions aim to assist clinicians in applying the lessons learned in simulation to their actual clinical practice.

Participants

Participants are residents in an accredited radiology residency program in the U.S. who work in two tertiary care hospitals as well as outpatient imaging centers. In 2013, all the residents (residency years 1-4) participated in the mandatory contrast reaction simulation-based educational program. Of 39 total residents, 28 participated directly in the simulation scenarios and the remaining 11 senior residents acted as Rapid Response Teams. The seniors remotely observed the scenarios until their junior colleague called for assistance.

Data Collection

A research assistant watched the video-recordings of 18 debriefings from the six simulation sessions (n = 6 x 3 debriefings). Blinded to the study purpose, the research assistant did not observe the simulation in real time. We instructed the assistant to exclude specific clinical discussions (e.g., the physiologic effects of epinephrine) and identify dialogue in which residents mentioned system-related issues or discussed their experience during the scenario or in an actual healthcare setting. A second research assistant transcribed and reliability-checked the debriefing excerpts.[1] A research team of two research assistants and an investigator chose the exemplars. A radiologist who did not participate in the research team served as a "peer reviewer" (Lincoln & Guba, 1985), reviewing the excerpts from the debriefings and challenging the choice of exemplars.

RESULTS

Of the 37 eligible residents, 36 consented to participate in the study. Two residents were ineligible because they are co-investigators. We did not find examples of participants who considered organizational implications of their simulation experience in the first session nor the fifth one (guided by a substitute debriefer).

In the following, we present three exemplars describing how the residents identified patient safety threats related to 1) locating equipment and medications, 2) administering epinephrine (a critical, fast-acting medication), and 3) transporting contrast reaction patients. Following each exemplar, we note how the attendings responded to issues raised by the residents. In some debriefings, an attending-debriefer immediately confirmed that the residents had identified a patient safety threat. Alternatively, the attendings prioritized safety issues when they met informally after the simulation session. The results section concludes by describing the development of the attending's role in fostering organizational learning over the six sessions.

Exemplar 1: Locating Essential Medications and Equipment

Organizational Learning from a Successful Simulation Experience that Prompted Hypothetical History Construction

A resident, who demonstrated effective clinical performance during the scenario, expressed frustration when he compared the simulation to actual conditions. During the scenario, the resident promptly and accurately diagnosed and treated a simulated patient's contrast reaction. In the debriefing, he demonstrated his thorough knowledge of the evidence-based guidelines. Yet, in an exasperated tone, he spontaneously said:

> Here [in simulation], it's nice. You know that you have anything that you may need on a table for you…. And now, especially being in two different [hospitals], I don't know…where things are, and I feel like that… would be a big problem in real life.

The resident reflected on his simulation experience and considered it in the context of his current healthcare setting, where he works in two different hospitals. He did not draw conclusions directly from what happened in the simulation scenario, where the appropriate medicine and equipment were arrayed on a table. But the simulation prompted him to construct a hypothetical history: What would have happened in "real life" if the scenario had occurred at one of the hospitals? Assessing the resident's comments, the attendings focused on the difficulty of finding medications and equipment in an emergency and sought to standardize the location of essential medication and equipment.

Organizational Learning from Recollection of Actual Experience

During the same debriefing, another resident recalled his experience responding to an actual contrast reaction:

> The MR[I] techs at [Hospital A] …, last time I was called there… [for a] contrast reaction, didn't actually know where anything was and we finally found the box… There was no Benadryl in the box and I was like, hm, interesting.

The resident reported having difficulty locating the Contrast Reaction Box ("Box") during an emergency and finding that the Box did not contain an essential medication. The resident recalled an actual experience during the discussion, suggesting that debriefings may provide opportunities for organizational learning from prior clinical encounters in addition to learning directly from the scenario itself. The attendings noted that the resident's experience not only highlighted the difficulty in finding medications and equipment, but also the lack of standard content in a Box.

Organizational Learning from a Hypothetical History

The radiology faculty designed the scenarios so residents could recognize and treat contrast reactions by applying the evidence-based guidelines delineated in the "contrast manual," routinely updated by a radiology professional association (ACR, 2013). During a debriefing, two residents imagined how they would apply these guidelines to diagnosis an actual patient. They did not challenge the guidelines' content, but rather the feasibility of following them in an actual healthcare setting.

> Debriefer: The goal here is for you guys to leave well-equipped with knowledge of how to handle these [scenarios]…These scenarios were based on the use of [the ACR] contrast manual. …. we chose … our own standard. So that's where a lot of the information can be found.
>
> Resident 4: It's almost impossible to know what to do with these [guidelines]. We don't have monitors on any of the patients that are getting scanned. We don't have blood pressures and we don't know if they're hypotensive [low blood pressure] and brady [bradycardic, slow heart rate] and not responsive.
>
> Resident 5: Yeah… why can't we have just have one of those portables [monitors]?
>
> Debriefer: Yeah, let me talk about that [with the radiology department].

The residents imagine how they could follow the evidence-based guidelines in an actual hospital context, thereby constructing a hypothetical history. Although they only refer to a hypothetical situation, the residents identify an actual routine requiring change (i.e., placing monitors in CT scanning suites) and suggest a solution (i.e., providing portable vital sign monitors). This example illustrates how an attending-debriefer recognizes that the residents identified an organizational routine that hinders their clinical work.

Exemplar 2: Administering an Epinephrine Auto-injector

Organizational Learning from a Mishap during a Simulation Scenario

When Resident 1 administered epinephrine to a simulated patient, he mistakenly held the EpiPen®, an epinephrine auto-injector, upside down. Had he used an actual EpiPen® (instead of a needleless

trainer), the needle (and medication) would have entered the resident's thumb and consequently, may have delayed urgently-needed patient treatment. In the debriefing, Resident 1 stated: "I've never even seen an EpiPen®, let alone used one." The resident first encountered an EpiPen® during simulation, unaware that they had recently been stocked in Boxes at outpatient centers, as reflected in a conversation among Resident 1 and his colleagues:

Resident 1: But the truth is, even in the hospital setting as an intern, I would never have seen an EpiPen®.

Resident 2: It's an outpatient thing. And then if it's IV it's during a code and a nurse is giving one.

Resident 1: I mean, not that…obviously that's horrible and someone [a patient] won't respond if I give it to myself …

Resident 3: Are there EpiPens® on the code cart?

Resident 2: Yeah. Definitely in the ones at [an outpatient imaging center] and I know the ones here are supposed to have them, too.

Resident 1: Also, I think when I hear EpiPen®, I think like, 'Oh how hard can this be to administer?'

This is an example of learning directly from a simulation experience. It also illustrates how individual learning may lead to organizational learning. One resident's mishap during simulation called attention to the lack of formal instruction in EpiPen® usage for all residents.

Organizational Learning from a Hypothetical History

During the same conversation, another resident imagined preparing to administer epinephrine in a syringe:

> At [an outpatient imaging center]…, even then the dilution is not 1:10,000, it's 1:1,000 and then you have to draw it up in a syringe…you give 0.1cc of the epi[nephrine] so it gets confusing and you're panicking and you're not going to sit there and titrate.

The resident described how difficult it would be to draw a tiny, precise amount of epinephrine from a larger vial in order to administer it to a patient. This example of learning from a hypothetical situation suggests that the recently-implemented organizational routines of distributing EpiPens® in outpatient imaging centers should be continued.

Exemplar 3: Processes for Transporting Patients

Organizational Learning from Recollection of Actual Experience

A resident described actually diagnosing and treating a patient for a mild contrast reaction. Because a mild contrast reaction could quickly develop into a severe, life-threatening one (ACR, 2016), patients require monitoring after initial treatment. The resident asked about monitoring during transport:

> What about sending the patients back? Like I had this issue, where I had a patient that I gave Benadryl…She had a contrast reaction, there was a rash and we gave Benadryl, 25 IV, and then I didn't know what to do with her….She was an inpatient…I didn't know when it was safe to send her upstairs with the transport. I really didn't know if she needed to be… accompanied by a nurse or a doctor.

This illustrates how a resident identified a patient safety threat by recollecting his actual clinical experience during a debriefing. The resident's experience highlighted the lack of an established organizational routine for monitoring contrast reaction patients during in-hospital transport.

Organizational Learning from a Hypothetical History

During the same debriefing, the lack of an established process for transporting a patient emerged in a different context. A resident did not know how to move a patient out of an enclosed MRI scanner in order to administer epinephrine:

> You can't take the patient out of the [MRI] scanner, that's the problem. For giving epinephrine, you can't get them out…If you're alone, how are you supposed to get them?...Where do you put them?

The resident did not describe a scenario nor recollect his actual clinical experience. He appears to be thinking hypothetically about how he would administer epinephrine to a patient during MRI imaging. In imagining a hypothetical situation, the resident identified the lack of standard procedures for single-handedly moving a patient.

In both examples in which a resident identified the lack of a procedure for transporting contrast reaction patients, the attendings did not prioritize resolving these issues. Therefore, these organizational learning processes, whether from actual or hypothetical experience, did not result in recognizing the need to change organizational routines.

Roles of Attending Physicians in Organizational Learning

The two attending physicians, who were involved in the design and implementation of the simulation-based educational program, also took an active role in organizational learning. One of them usually served as a debriefer, facilitating the post-simulation discussion; the second took the lead in initiating changes. The attendings prioritized issues that the residents recognized during debriefings, considered possible solutions, and worked with their colleagues on implementing changes in actual healthcare settings.

Over the six simulation sessions, the attendings increased their engagement in organization learning. First, while planning the program, they implemented organizational changes, choosing among alternative evidence-based guidelines, as an attending explained:

> In talking with some of my colleagues, we felt as an initial response, the IM [intramuscular] EpiPen® …would be preferable. We're actually creating an initiative to get EpiPens® everywhere, that way you don't have to be concerned with pulling up the wrong dose or drawing up something in the middle of a significant event.

Prior to the first simulation session, the attendings decided that radiologists would use EpiPen® auto-injectors to administer epinephrine intramuscularly (IM), rather than administer a more diluted dose intravenously (IV). Although evidence-based guidelines (ACR, 2013) approved both IM and IV medication administration routes, the attendings concluded that auto-injectors were less prone to dosage error and therefore, would benefit patient safety.

Second, drawing on the residents' initial simulation debriefings, the attendings recognized that residents found it difficult to gain immediate access to diagnostic equipment (e.g., stethoscopes) and medications for treatment. Learning from the residents' simulation experience, the attendings chose a solution proposed by their professional association (ACR, 2013), and decided to construct a Box. An attending explained while debriefing:

> We have put together a contrast reaction box. It's an orange, fishing tackle box… and they're at CT, they're at MR[I], they're at fluoroscopy, at the outpatient centers, at [Hospital A], at [Hospital Z] and it's going to go system-wide.

The attendings shepherded the decision through all of the hospital requirements, including hospital pharmacy approval, and by the final simulation session, Boxes had been distributed throughout the inpatient and outpatient imaging suites (i.e., CT, MRI, and fluoroscopy).

Third, at the conclusion of the third simulation session debriefings, an attending-debriefer actively solicited residents' questions and encouraged them to identify needed improvements.

> That's one of the values of this exercise too, not just for you, but for the hospitals, for the patients, and for us, identifying performance gaps and how we can fix them.…Your experience here and your contrasting it with what real life is and the difference, is very, very valuable.

Note that the attending spontaneously encouraged residents to consider their simulation experience in the context of their actual clinical experience in the hospitals and outpatient imaging centers.

In the sixth and final simulation session, the same attending continued to encourage the participants to ask questions and identify patient safety issues:

> One of the benefits we have derived from conducting these simulations is identifying all of these actual performance gaps in our real life that we're trying to …increase patient safety. So these are great questions that are coming up.

Here he emphasizes a process of organizational learning, from "actual performance gaps" identified by residents during simulation so that the attendings can seek to close them.

DISCUSSION

Creating a Forum for Organizational Learning

In the three exemplars, residents identified threats to patient safety resulting from organizational routines. They drew conclusions from simulated and actual clinical experience as well as by constructing hypothetical histories(See Table 1.) These exemplars suggest that debriefing discussions may enable participants to identify organizational routines that hinder (or support) the clinical processes of diagnosis and treatment.The debriefings, designed to foster individual learning, may also promote issue identification, initiating a process of organizational learning.

TABLE 1
REFLECTING ON VARIOUS EXPERIENCES TO IDENTIFY PATIENT SAFETY ISSUES

Time	Experience	Implications for Organizational Learning
Recent	**Simulated** Simulation scenario experience	**Adding data points:** Simulated experience enhances actual history. Did simulation artifacts affect the experience?
Prior history	**Actual** Clinical experience	**Comparing your experience with others' experience:** Are the underlying causes rooted in organizational conditions and routines?
Hypothetical history	**Hypothetical** Imagining if a simulation scenario would have occurred in actual healthcare setting	**Comparing simulation to actual healthcare sites:** Are underlying causes embedded in actual organizational conditions and routines?

Organizational Learning from Simulated Experience

We were surprised to discover that a successful simulation experience prompted a resident to construct a hypothetical history. As documented in Exemplar 1, the ready access to medications and equipment during simulation provoked a resident to negatively compare his simulation experience to what might occur in the hospital. This prompted radiology decision makers to reflect on and assess the routines for the distribution and location of essential equipment.

Participants also learned directly from the simulation scenario, as may be expected. Consider Exemplar 2, in which a resident simulated jabbing his thumb with a needle, thereby withholding critical medication from a simulated patient. From this experience, the individual resident learned how to administer an EpiPen® correctly.

The radiology department, an organizational unit, also learned from the resident's mishap during simulation. Specifically, they concluded that the lack of standard resident education was an organizational issue that led to an individual error during simulation and consequently, decided to educate all the residents in EpiPen® usage. Radiology decision makers had sparse experience from which to learn about

residents' EpiPen® proficiency, in part, because the department had just recently begun stocking EpiPens® in the imaging suites.

Organizational Learning from Recollected Prior Clinical Experience

When a resident recollected and reflected on his prior clinical experience, discussing the event during a debriefing enabled the participants to recognize organizational routines that may be hindering diagnosis and treatment processes. The residents, guided by the debriefers, compared previous clinical episodes among themselves and identified specific organizational conditions under which they found it difficult to recognize or treat contrast reactions. (See Table 1.) Consider Exemplar 3 in which a resident recalled his confusion about a lack of organizational routines for transporting hospitalized contrast reaction patients.

Organizational Learning from Hypothetical Histories

Imagining if a simulation scenario had occurred in an actual healthcare setting may trigger organizational learning processes. For example, residents relied solely on a hypothetical situation to identify the accessibility of vital signs monitors as a threat to patient safety, as described in Exemplar 2. For uncommon, potentially fatal events, such as contrast reactions, generating hypothetical histories enables participants to imagine a more varied array of contrast reaction cases than residents actually experience during their 4 years of radiology training or can be simulated within the 4-hour timeframe of an educational program.

Variations in Organizational Learning

Residents initiated organizational learning processes by reflecting on different kinds of experience (See Table 1). They reflected on their recent experience in a simulation scenario, recollected prior clinical experience, and/or constructed a hypothetical history by imagining what could have occurred in an actual healthcare organization. By examining one of these episodes in depth or comparing among them, clinicians recognized organizational conditions that influence their capacity to take care of patients.

Following each simulation session, a team of attendings and residents, supported by the debriefing expert, reviewed the patient safety threats identified by the residents. The team prioritized the issues by perceived importance and ease of remediation. They did not differentiate among the sources of the residents' experience, whether it was based on simulation, prior clinical experience, or on a resident's description of a hypothetical situation.

The attendings continued the process of organizational learning by initiating and monitoring remediation efforts, often in collaboration with radiology department colleagues. In some cases, they decided to retain existing organizational routines (i.e., using epinephrine auto-injectors). In others, they recognized an urgent need for change. For example, they immediately decided to instruct residents in EpiPen® usage. In yet others, they deferred decisions to modify routines, pending further investigation of patient safety threats, such as when the team documented the location of Boxes in various inpatient and outpatient settings. They engaged in organizational learning by reflecting on the experiences identified by the residents, and deciding whether or not to change existing organizational routines (March, 1999).

Power of Imagination

During debriefings, residents constructed hypothetical histories regarding the organizational routines that undergird their clinical work. They spontaneously imagined hypothetical situations and, in later sessions, debriefers also prompted them to think of the scenario in the context of an actual hospital setting. The residents identified valid patient safety threats as they considered hypothetical events. We speculate that when thinking about how he would recognize if a patient was reacting adversely to contrast media, a resident would imagine an actual CT suite and notice organizational conditions (e.g., lack of vital signs monitor) that hinder his clinical decision making.

The thought process of visualizing how to diagnose a patient in the hospital is related to "mental practice", a term that refers "specifically to a training technique in which the procedure required to perform a task is mentally rehearsed in the absence of actual physical movement" (Driskell, Copper &

Moran, 1994, p. 481.) Athletes and musicians engage in mental practice when they cognitively rehearse their actions, whether visualizing a figure-skating routine or audiating the phrasing of a sonata. In medicine, it has proved an effective supplement to actual practice sessions, especially when the tasks require intense cognitive skills as well as manual dexterity, such as simulated laparoscopic surgery (e.g., Immenroth et al., 2007). Engaging in mental practice also significantly affected the teamwork behavior of resident dyads as they responded to a simulated trauma scenario (Lorello et al., 2016). Consider the construction of hypothetical histories in the context of mental practice in medicine. It suggests that imagining medical practice in a specific clinical environment may prove to be an effective method to identify threats to patient safety, especially for low probability, high consequence events, when the stakes are high, clinical experience is scant, and in situ simulation may be impractical.

Generating Hypotheses for Future Simulation Design Studies

The case study also has practical applications for designing simulations to promote organizational learning. Building on the case study results and research on mental practice in medicine, we propose that for laboratory-based simulation, debriefings may expand opportunities for learning about the healthcare organizational routines that support (or hinder) the clinical practice. We hypothesize that under certain conditions, debriefings may foster the identification of patient safety issues, initiating first steps in a process of organizational learning.

Specifically, features of the "debriefing with good judgment" model (Rudolph, et al., 2006; Rudolph, et al., 2008), developed to foster individual learning, may also promote organizational learning (See Table 2). To illustrate, the debriefing is conducted under conditions of "psychological safety" (Edmondson, 1999) designed to make participants feel comfortable learning from their experience during the simulation scenario. In a safe educational environment, participants may also be willing to speak up and identify threats to patient safety. Giving participants time to "reflect rigorously" on their experience is another key design feature. Rudolph and her colleagues describe rigorous reflection as a process that "brings to the surface and helps resolve the clinical and behavioral" (Rudolph, et al., 2006, p. 49) issues that emerge during simulation. Debriefers further augment individual reflection and provide a fresh perspective by calling attention to a participant's specific behaviors during the scenario and inquiring about the "mental model" underlying their actions. We posit that these conditions are necessary, albeit, insufficient to foster organizational learning.

TABLE 2
DEBRIEFING PRACTICES THAT PROMOTE ORGANIZATIONAL LEARNING

Debriefing Design	Practice	Implications for Organizational Learning
Debriefing with Good Judgment Practices	Psychological safety	In a confidential, non-punitive debriefing, participants may feel comfortable identifying threats to patient safety and making suggestions for improvement.
	Time for rigorous reflection	Debriefings are designed to provide time for reflection on individual's behavior and mental models, as well as team interactions.
	Provide feedback on behavior	Debriefers observe a participant during a scenario and provide a fresh perspective by calling attention to specific participant behaviors during the debriefing.

Common Debriefing Practices	Compare clinical experience to simulation	Participants may compare their actual clinical experiences with colleagues.
	Compare healthcare setting to simulation	Participants may imagine simulated diagnosis and/or treatment processes as they might occur under actual conditions.

In addition to these three fundamental debriefing design features, we propose that debriefers may also apply common debriefing practices to promote organizational learning. When debriefers ask participants to compare the simulation to their actual prior clinical experience, it may prompt the clinicians to recollect actual events in which organizational factors supported (or hindered) their clinical work. Another debriefing practice is to ask "normalization" questions (DeVoe & Kerner, 2014) in which a debriefer asks a participant what if the simulation scenario had occurred back at the hospital. We reason that asking participants to imagine if a simulation scenario had occurred at an actual healthcare site might prompt them to construct hypothetical histories. Therefore, we propose that organizational learning will increase by systematically asking debriefing participants to compare the simulation scenario: 1) to their previous clinical experience and 2) to a current healthcare setting. (See Table 2).

Building on the attendings' increasing enthusiasm and engagement throughout the simulation sessions, we also propose adding debriefing questions regarding recommendations for improvement. We posit that a debriefer expresses psychological safety when he explicitly requests and encourages residents to offer their suggestions for improvement. Of course, the debriefer's encouragement to propose improvements does not indicate whether participants actually feel psychologically safe to speak up about them during debriefings.

In summary, based on this case study, we propose designing simulation debriefings to foster organizational learning. Psychological safety and time for rigorous reflection, two of the same simulation design features that support learning on the individual and team levels, may also directly support organizational learning. Moreover, we propose systematically incorporating three open-ended questions during debriefings that ask participants to: 1) compare their actual clinical experience with the simulation; 2) imagine if the simulation scenario had occurred in their actual healthcare setting; and 3) identify system issues that hinder (or support) their clinical practice and offer suggestions for improvement. We posit that adding these debriefing questions will encourage participants to reflect on their experience in the simulation, recollect relevant prior experience, and imagine hypothetical histories.

We hypothesize that by reflecting on a variety of simulated, recollected, and hypothetical experience, participants will identify organizational routines that hinder (or support) their capacity to diagnose and treat patients. This is especially important for cases of treating patients with uncommon, but potentially fatal conditions, where residents lack clinical exposure and thus, have limited opportunities to learn directly from experience. Currently, the primary objective of laboratory-based simulation in healthcare is for clinicians to apply what they learn in simulation to their actual clinical practice. We suggest expanding that aim to enable clinicians also to consider how to improve the organizational conditions that influence their clinical practice.

Limitations

In Exemplar 2, decision makers learned directly from a simulation scenario. However, in general, organizational learning from simulation may be limited. It remains uncertain whether a mishap during a scenario is an artifact of the simulation or would be replicated in an actual healthcare setting. First,

participants might behave differently in a simulation than they would under actual conditions, in part, because they know they are being observed. Second, the faculty and simulation staff may be unaware of how the lack of verisimilitude in the simulation (e.g., in the scenario or physical setting) influences participants' actual clinical behavior (McGarry, Cashin, & Fowler, 2014). The second factor is one of the limitations of identifying patient safety threats in a simulation laboratory. However, this case study suggests that the decisions makers may focus less on determining whether the simulation represents reality, and instead, concentrate on deciding whether the participants identify valid threats to patient safety. Because the debriefing prompts participants to recollect prior experience or think of hypothetical histories, it may be less critical to replicate the clinical setting accurately in the laboratory. Therefore, creating debriefings session that are conducive to organizational learning may overcome some of the limitations of laboratory-based simulation. Of course, in situ simulation may reveal previously unknown organizational issues, but at the expense of participants having less time for rigorous reflection and problem solving.

Practical Lessons Learned

The simulation proved an effective forum for the identification of threats to patient safety. Working with colleagues in the radiology department, the attendings succeeded in improving patient safety by changing organizational routines, in particular, those related to medications and equipment. For example, they distributed Boxes in two tertiary care hospitals and the outpatient imaging centers; two community hospitals in the health system also adopted Boxes. The radiologists also changed routines that guide physicians' behavior. For instance, they identified optimal outpatient emergency procedures and implemented an EpiPen® educational program.

Organizational learning processes began in the debriefing discussions where residents raised safety issues. However, the implementation of critical changes resulted from the efforts and perseverance of a small group of radiology attendings. An effective simulation-based educational program design must not only enable participants to identify threats to patient safety, but also foster decision making processes in which senior clinicians decide what changes, if any, are necessary and follow up to assure change implementation.

CONCLUSION

In this case study, we examine a simulation-based educational program designed to teach individual radiology residents how to recognize and treat contrast media reactions. Through serendipity, we noticed that the participating residents spontaneously used the simulations to identify threats to patient safety. In debriefings, they called attention to the organizational routines, particularly regarding medications and equipment, which hindered their ability to diagnose and treat contrast reactions. They not only drew these conclusions directly from the simulation scenarios, but they also recollected prior clinical experience and constructed hypothetical histories by imagining what could happen in actual healthcare settings.

Of course, one cannot generalize from a single case study. However, this study offers conceptual insights to expand the understanding of organizational learning in healthcare, especially from hypothetical histories. The study results also suggest directions for future simulation design research in an effort to replicate the conditions that fostered organizational learning, but occurred by chance during this case. This case study suggests how clinicians may use simulation to promote organizational learning in healthcare, in particular, to improve the care of patients who suffer contrast reactions, and other uncommon, but potentially fatal medical conditions.

ENDNOTES

1. Please note that to de-identify the participants, we use male pronouns and removed information that would identify the resident (i.e., year of residency) or the health system (e.g., hospital name). Deletions of one or a few words are noted by 3 dots …, 4 dots indicate removal of a sentence, and any comments and clarifications appear in [brackets]. For clarity and brevity, we deleted some common speech fillers, such as repetitions of words, "like" and "you know

ACKNOWLEDGEMENTS

We gratefully acknowledge the contributions of Erin McLaughlin, MD; John Perrone; and our research assistants Joshua L. Brenner, Jia Gao, Michelle A. Kikel, and Brian P. Scanlon.

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