

Prevention of Latent Safety Threats: A Quality Improvement Project to Mobilize a Portable CT

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Abstract

Introduction: Transporting critically ill patients to diagnostic imaging for needed studies can be challenging and even prohibitive. A portable computerized tomography (CT) scanner allows the patient to remain in the intensive care unit, but presents new positioning and team challenges. Before activation of a portable CT scanner in our pediatric intensive care unit and through the use of iterative simulation-based Plan-Do-Study-Act (PDSA) cycles in the clinical environment, a multidisciplinary team of bedside caregivers determined optimal patient positioning, equipment needs, and specific staffing and choreography to develop detailed portable CT guidelines. **Method:** Our team engaged stakeholders from radiology, critical care, respiratory therapy, environmental services, facilities operations, and the CT vendor to develop scenarios. Simulations included infant and pediatric patients who required critical invasive monitoring and treatment devices, such as ventilators, and high-risk intracardiac and intravascular lines. Scenario objectives centered on the safe positioning, transfer, and scanning of the patient. Trained simulation specialists from the hospital's simulation center facilitated simulation sessions. **Results:** Simulation-based PDSA testing identified 31 latent safety threats, including the need for a custom bed adapter due to pediatric patients' variable size. We paused portable CT activation pending the custom adapter's availability and remediation of other latent safety threats. Additional simulation-based PDSA cycles further refined the process once the custom adapter was available. **Conclusions:** Simulation identified unanticipated latent safety threats before the implementation of a portable CT scanner. (*Pediatr Qual Saf* 2021;6:e422; doi: 10.1097/pq9.000000000000422; Published online June 23, 2021.)

INTRODUCTION

Diagnostic imaging test results may be indispensable in guiding the management of critically ill patients. However, these tests typically require an intrahospital transfer of unstable patients with an increased

risk for complications.¹ Some series report more than a third of these patients suffer serious adverse outcomes, including death.²

In addition, intrafacility transport can require substantial staff resources and time.³ Portable computerized tomography (CT) scanners offer an appealing solution,⁴⁻⁹ but require careful, choreographed manipulation of critically ill patients connected to multiple life-sustaining modalities.

Despite providers' perceived safety advantages, introducing portable CT scanners into critical care units lacking prior experience with this technology can inadvertently introduce latent safety threats (LSTs). LSTs are defined as the system's flaws that allow accidents to happen and can be identified using simulation.¹⁰ Simulation recreates patient care scenarios for training and testing. Simulation-based system testing (SBST) has been used to identify LSTs before initiating new clinical processes or workflows.¹⁰ Within our institution, SBST has been used to evaluate new patient care spaces and complex processes such as extracorporeal cardiopulmonary resuscitation (E-CPR). Given these successes and our lack of experience with portable CT scanners, leaders in radiology and critical care identified SBST as a key component of safe implementation. Together with our simulation center, we aimed to use the Plan-Do-Study-Act

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(PDSA) methodology to conduct small tests of change scenarios to determine the safest procedure for obtaining a bedside head CT scan of a critically ill pediatric patient. Our objective was to create a safe and efficient process for the optimal use of the portable CT scanner for patients in one of our critical care units requiring noncontrast head CTs. Using iterative SBST, front-line providers and leaders determined and refined processes, including optimal room setup, patient positioning, equipment, staffing, and choreography, before activating a portable CT scanner in the intensive care unit (ICU).

METHODS

We aimed to use simulation for rapid cycle tests of process change to develop optimal choreography for varying patient scenarios. The team planned for a ½ day (4 hours) simulation or round 1 utilizing 2 different patient scenarios, to define the head CT process. Scenarios could be cycled multiple times as needed. We planned for 2 scenarios to meet our testing objectives, which included testing both the bed and the crib with varying size patients. Based on the participant's findings, we report on the evolving cycles in results. After round 1, we determined that a second round of testing was needed (round 2).

Setting

Our institution is a 969-bed freestanding quaternary care academic pediatric hospital, including a Level 1 trauma center with a full pediatric intensive care tower. Our ICU rooms are private, large spaces with booms in each room allowing for various life-sustaining therapies. We have a dedicated simulation center and staff with experience conducting SBST, including implementing new procedures. To improve the simulation scenarios' realism, we conducted the simulations and debriefings in actual pediatric ICU rooms. Our hospital steering team limited the use of the portable CT scanner to our critical care tower, which does not include our emergency center and neonatal intensive care units, which were therefore excluded from this project. Key stakeholders included representatives from the following departments: radiology, critical care, respiratory therapy, environmental services, facilities operations, and the portable CT scanner vendor. These individuals partnered with the simulation center to design the scenarios and participate in the SBST.

Participants and Observers

Within the 2 rounds of testing, there were 12 participants, including 6 nurses, 3 respiratory therapists, 2 CT technicians, and 2 electroencephalogram (EEG) technologists. Additional personnel included 18 observers (12 nurse leaders, 2 physicians, 1 advance practice provider, and 3 radiology leaders). Participants were instructed to immerse themselves into the scenario; to provide safe care for the simulated patient as they usually would. In contrast, observers were instructed not to provide care during

the simulation, but to observe, note potential LSTs, and participate in the participants' debriefing.

Departmental leadership selected participants based on experience and availability and specific expertise related to the portable CT. Before simulation, participants in the simulation received information and training about the proposed portable CT process, and were instructed that their feedback would further refine the process.

Scenario Development

Three scenarios were developed and refined over the course of 3 in-person meetings and via email. Scenarios were explicitly designed to give participants enough background about the patient but minimal direction regarding how to move the patient and the machinery around the room. The scenarios included both infant and pediatric patients, who required technological support including high-frequency oscillatory ventilation, intravenous lines, and monitoring including continuous EEG.

Scenarios included patients who would be considered by medical staff too unstable to move to the conventional CT scanner and thus candidates for portable CT.

Scenario A

A 3-year-old, 18 kg, male patient (Sim junior mannequin) was struck by a vehicle. He required high-frequency oscillatory ventilation, a cervical collar, continuous EEG monitoring, multiple pressure and intravenous lines, and an ICU bed.

Scenario B

A 9-month-old, 12 kg, male patient (Sim baby mannequin) admitted to the ICU after abusive head injury. He was conventionally ventilated, had a cervical collar, intracranial pressure monitor and drain in place, intravenous lines, and was positioned in an infant crib.

Both mannequins were attached to all pumps, monitors, ventilators, and equipment that would typically be present. Patients were positioned in actual ICU rooms in the usual manner for our institution, with flexible equipment and mobile booms used for monitoring and additional equipment surrounding the patient. Our aim was not to test the clinical decision-making process, so participants were informed that the patients were not stable for transport and would need a portable CT.

One round of testing using both scenarios was planned initially. However, based on LSTs identified during the first round, implementation was postponed. A custom bed adapter was manufactured before further SBSTs were performed.

Scenario C

An 18-month-old, 23 kg male/female patient (Sim baby mannequin) involved in an unrestrained motor vehicle collision. This patient required a crib, preventing attachment of the scanning board to the bed; otherwise, setup was the same as the first scenarios. This scenario was not

designed for patient deterioration in the scanner; however, participants requested such an event. Consequently, we adapted the scenario during the simulation for the patient to experience a bradycardic arrest while in the scanner, thus allowing the participants to move through the steps to safely begin resuscitation.

Debriefings and Data Collection

Immediately after each simulation cycle, the simulation team led a multidisciplinary debriefing using the modified PEARLS framework for systems integration,^{8,9} which includes prompting participants and observers to reflect on systems issues, identify LSTs, and provide solutions. Debriefings were held in the same clinical space as the simulations, facilitating team engagement around choreography during the debriefing. Debriefings were transcribed, and the findings were provided to all key stakeholders.

RESULTS

Round 1 (PDSA Cycles 1a, 1b, 2)

PDSA Cycle 1a: Scenario A

The proposed procedure contemplated rotation of the bed by 90 degrees to place the head of the bed in line with the door. During the debriefing, the staff voiced concerns with moving the patient 90 degrees, given the patient's condition and the need for increased staff. Thus, the team elected to repeat the simulation with newly proposed positioning.

PDSA Cycle 1b: Scenario A

It was repeated by moving the patient using an alternate method. The patient and the bed were first moved down to the footwall, leaving space at the headwall for the portable CT scanner. This decreased the need to turn the patient and equipment, leaving enough space to position the scanner. The team found this acceptable, prompting them to move onto the next step of the simulation phase.

Once the bed was in an optimal position, the patient was moved onto the universal bed adapter. The universal bed adapter is designed (Fig. 1A) for patients of all sizes who are not on adapter-ready beds.

PDSA Cycle 2: Scenario B

This cycle was designed to simulate the use of the neonatal scanning platform (NSP) for patients in cribs (Fig. 2A). Once the patient was on the NSP, the staff determined the patient was not secure. We discovered that the NSP was designed to hold infants only up to 7.5 kg; larger patients in the crib could not be supported by the NSP.

LSTs Identified during Round 1

We identified 23 LSTs during round 1 (PDSA 1a, 1b, and 2) of simulation testing (Tables 1 and 2). Most notable was the universal bed adapter, a considerable portion of the patient, and mattress had to be moved to position the patient's head in the scanner (Fig. 1B). Additionally, we discovered that

A



B



Fig. 1. Universal bed adaptor and how it was used during the simulation that led to the identification of latent safety threats. A, Universal bed adaptor (PDSA1) round 1. B, LST identified with the Universal bed adapter.

the universal bed adapter did not attach securely to our beds, leading to a risk of patient falls and potential staff injury. This finding led key stakeholders to pause portable CT scanner implementation until a custom bed adapter and silhouette board could be manufactured (Fig. 3).

After reviewing LSTs from round 1, clinical leadership made 2 significant decisions. First, we asked the manufacturer to create a custom silhouette board and total care adapter that would bolt onto the ICU beds. Second, the hospital would acquire a pediatric scanning platform (Fig. 3B) to hold patients over 7.5 kg who were still in cribs.

Round 2 (PDSA Cycles 3 and 4): Utilizing the Custom Bed Adapter and the Silhouette Board

PDSA Cycle 3: Scenario A

This simulation included the new custom bed adapter and the silhouette board that would adapt to 2 ICU specialty beds. Once the bed and equipment (booms, lines,



Fig. 2. Custom-made board and adaptor that was made in response to the latent safety threats identified. A, NSP for patients less than 7 kg. B, Pediatric scanning platform for patients 7–40 kg.

cables, and wires) were positioned, the total care adapter was attached to the bed, and the custom-made silhouette board was put in place. The patient was moved onto the silhouette board and positioned into the scanner.

PDSA Cycle 4

Pediatric scan platform testing in a crib: PDSA 4 was designed to test the newly constructed pediatric scan platform (Fig. 2B). This was different than the neonatal scan platform from round 1, with the ability to hold larger pediatric patients (greater than 7.5 kg). Scenario C was explicitly developed with this platform in mind (Fig. 4).

LSTs Identified during Round 2

We identified 8 LSTs during PDSA 3 (Table 1). Most critically, the space between the mattress and the head holder on the silhouette board made it difficult to maintain cervical spine immobilization. The team recommended a foam pad be placed between the gap in the bed and mattress to make sliding the patient into the scanner safer. Also, the lack of straps to secure and immobilize the patient was identified as a risk. Smaller patients were able to be swaddled for security. There were no new LSTs identified during PDSA cycle 4.

DISCUSSION

Summary of Key Findings

We successfully utilized SBST PDSA cycles to refine the process and test the safety of using a portable CT scanner in the pediatric ICU. Despite extensive planning before SBST, we identified 23 additional LSTs in the first round of testing and another 8 during the second round. Notable outcomes from SBST included determining the optimal positioning of patients with all life-supporting equipment, identifying the need for a new pediatric scanning platform, and the customization of a bed adapter. Although the content experts from radiology were aware of the weight limit of the NSP before the simulation, it had not been discussed with the clinical experts that children larger than 7 kg could still be in a crib, thus requiring the NSP platform. The NSP simulation affirmed that it is problematic to try to modify a device beyond its designated limitations. Additionally, even though this was not initially planned as part of the simulation, the participants could plan how to respond to deteriorating patients during repositioning and imaging.

Table 1. Latent Safety Threats from Combined PDSA Cycles

LSTs from PDSA cycles 1a, 1b, 2			
23 Total LSTs Identified			
Facility Issues (Facility or space setup concerns that are not conducive to effective, efficient, and safe patient care)	Equipment Issues (specifically related to equipment whether missing, malfunctioning or unable to use)	Clinical Performance Issues (related to cognitive skills, technical skills, or institutional process knowledge of clinical personnel that can be a focus for future simulation-based training)	Resource Issues (Issues related to personnel, or medication, whether missing, malfunctioning, or unable to use due to lack of provider familiarity with the device)
None identified	7 = 30%	5 = 22%	11 = 48%
LSTs from PDSA 3			
8 Total LSTs Identified			
Facility Issues (Facility or space set up concerns that are not conducive to effective, efficient, and safe patient care)	Equipment Issues (specifically related to equipment whether missing, malfunctioning or unable to use)	Clinical Performance Issues (related to cognitive skills, technical skills, or institutional process knowledge of clinical personnel that can be a focus for future simulation-based training)	Resource Issues (Issues related to personnel, or medication, whether missing, malfunctioning, or unable to use due to lack of provider familiarity with the device)
None identified	4 = 50%	4 = 50%	Nonidentified
LSTs identified from PDSA 4			
0 Total LSTs Identified			

The first round of testing resulted in identifying a critical threat related to the universal slide board, which we concluded was a substantial enough threat for the institution to delay implementation until a custom adaptor could be built and tested. With the introduction of new equipment, 8 LSTs found in the second round of testing were mitigated before the scanner was used for patient care.

Simulation highlighted the importance of considering the full range of patient sizes, ages, and development when implementing new processes in pediatric hospital settings. This has significant bearing on how portable CT imaging is implemented. Patient weight and size greatly influences organization and choreography for moving the patient, transferring the patient to various platforms, and the way patients are secured to different platforms.

Our project is the first example of SBST PDSA testing before implementation of a portable CT scanner. Other studies have reported using portable CT once implemented,^{1,2,4,6,7} but have not reported on systematic testing before implementation. Although these reports highlight the potential benefits of portable CT, they also report on potential harms. Some reported decreased workload⁴; however, our team learned that the number of staff needed to safely position the patient for portable CT was

similar when compared to that required for transport to a nonportable CT scanner. Additional staff was needed for portable CT, to reposition the patient, mechanical booms, and other equipment. Our experience was that the time for a patient to obtain CT imaging was similar using the portable versus nonportable CT scanner. One could argue that there is a learning curve with any implementation of new clinical hardware and procedures. Both lower labor needs and time reduction can be achieved as staff become more proficient and the techniques refined.

Nevertheless, at the end of the simulation, we confirmed that one distinct benefit to portable CT imaging is the elimination of the need to transport critically ill patients out of the intensive care unit. Allowing critically ill patients to remain in the ICU while undergoing imaging lowers the risk to these vulnerable patients because the likelihood of surviving cardiac arrest outside of the ICU is lower than inside the ICU.¹⁰⁻¹³ Monitoring in the ICU is more extensive and reliable than during transport, allowing for clinical deterioration detection sooner, before full cardiopulmonary collapse. Furthermore, should resuscitative measures be needed, there is more staff support immediately available inside the ICU. Furthermore, potential disruption of therapies, disconnection of power supplies, exposure risk, and movement logistics in hallways and elevators are also

Table 2. Detailed Breakdown of LSTs from PDSA 1a and 1b

Examples of LST Identified in Round 1	
PDSA 1a and 1b	
Equipment—Universal bed adapter	<ul style="list-style-type: none"> • Mattress would have to move into scanner with patient on it. Not all beds had mobile mattresses • The universal bed adapter required a strap to fasten the board to the bed. The concern was raised that the strap might not fit all sizes of beds
Resources	<ul style="list-style-type: none"> • Concerns were raised regarding the need to log-roll the patient onto the board • Resources were limited initially, staff noted the increased need for personnel to help move patient and all equipment • 5–6 staff needed to safely position the patient and equipment. • The patient was difficult to monitor during the scan, and a staff member would need to stay in the room to monitor
Clinical practice	<ul style="list-style-type: none"> • Patient positioning was a concern initially; however, the changed positioning in PDSA 1b was improved • Staff education about positioning would be critical • Discussion about family members in the room and where they would be moved during the CT • There were concerns regarding the scatter radiation of the portable CT scanner • The need for staff shielding with lead was discussed



Fig. 3. Hill-Rom care assist ES bed and low air loss bed with total care adapter and custom silhouette board (round 2: PDSA 4). A, NSP. B, Pedi scanning platform.

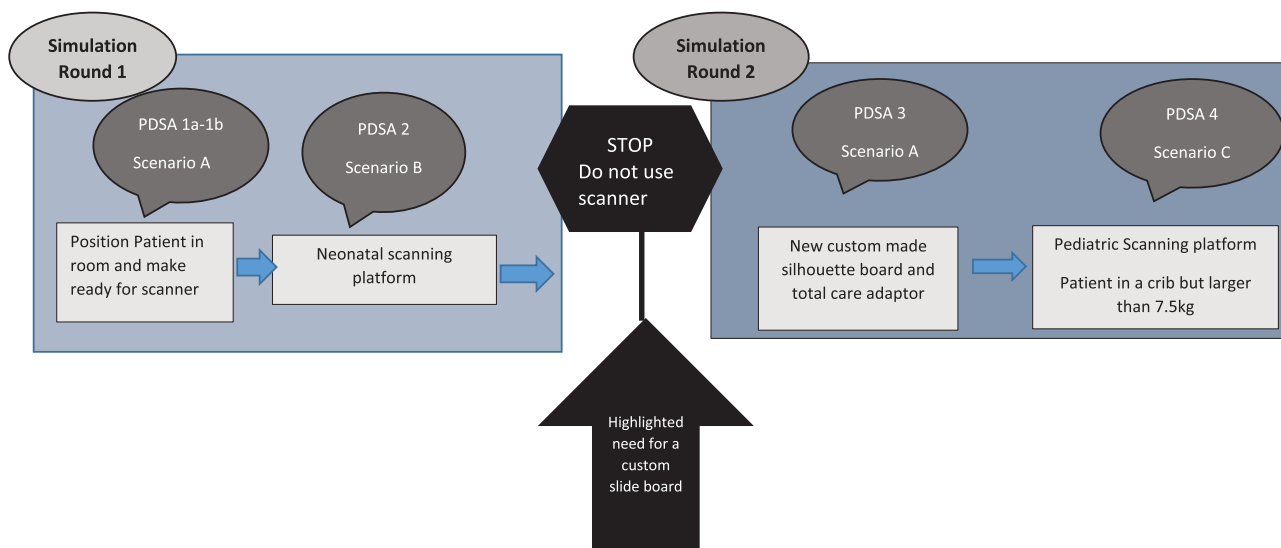


Fig. 4. Outline of PDSAs with LSTs.

essential considerations. Last, portable CT images are rapidly available to clinical staff for decision making.

Limitations

Simulation supplied an excellent tool for testing portable CT use before actual patient care; however, our teams noted some limitations. Simulation mannequins are much stiffer than actual sedated patients, and the teams recognized this made them easier to move without

dislodging wires or tubes. The team noted that for actual sedated patients, they might need to restrain the patient to secure tubes, wires, and the patients’ extremities in place while in the portable CT scanner. Future simulation should consider floppier, more flexible mannequins. In addition, the participants speculated that positioning for adult-size pediatric patients would be challenging because the patient’s shoulders could hang off the side of the board and potentially hit the portable CT walls.

This would prevent the patient's head from full insertion into the bore for scanning. Future studies should evaluate larger patient size.

CONCLUSIONS

SBST PDSA cycles allowed our team to rapidly test a new process, find critical LSTs that justified delays in implementation until solutions were found, and let the team practice seamless use of the portable CT scanner before implementation. SBST PDSA cycles should be considered before implementation of modern technologies, especially in high-risk areas with critical patients. Due to the project's scope as outlined by the leadership steering team and limited access to the portable CT scanner, other hospital units were not tested. In the event these areas become in scope for portable CT, we would recommend this same type of SBST PDSA.

DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

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