# The Mobile Mock Operating Room: Bringing Team Training to the Point of Care

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## Abstract

**Objectives**: We examined the effectiveness of an innovative mobile mock operating room (MMOR) configuration to support realistic interdisciplinary operating room team training implemented at the point of care. **Methods**: The MMOR, created and used to support the System for Teamwork Effectiveness and Patient Safety (STEPS) training program, included a portable high-fidelity, computerized mannequin; an inanimate surgical procedure model; software for simulating mannequin responses; and a computer-based video recording system. Evaluation was based on direct experience with the MMOR and participants' responses to a questionnaire. **Results**: Participants perceived the MMOR as a realistic training environment. Feasibility and effectiveness were further supported by the research team experiences. **Conclusion**: The MMOR contributes to quality training at the point of care. Results suggest that our MMOR model may be useful for supporting simulation-based training in other high-risk settings where effective team functioning is particularly important (e.g., emergency room, intensive care unit).

## Introduction

The operating room (OR) is a dynamic work environment in which effective team interactions are critical to safe delivery of care. In this high-risk setting, lapses in teamwork can potentially lead to adverse patient outcomes. Promoting teamwork competencies characteristic of highly reliable teams is essential to ensure the proper and efficient coordination of OR team activities. They include open communication, adaptive response, and the use of a shared mental model.[1] Without such synchronization among members, care within the OR can become disjointed and haphazard.

Today, team interactions in the OR are characterized more by disruptive behaviors[2] than by the smooth delivery of care. The marked differences in the background of the various disciplines lead to misunderstandings.[3] The resultant lack of role clarity[4, 5, 6] and poor communication[7] can hinder effective teamwork. In addition, OR team members may not necessarily agree on their perceptions of rules and guidelines within an OR.[8] Team members often lack insight into their own strengths and weaknesses regarding teamwork abilities.[6, 9] Consequently, there is considerable variability among disciplines in OR teams regarding what constitutes high quality teamwork.[6, 9, 10, 11]

Improving teamwork in health care has become a national priority. The Institute of Medicine (IOM) has established the ability to work in interdisciplinary teams as one of its core competencies for health care professionals.[12] In addition, The Joint Commission has emphasized the importance of team training in its patient safety curriculum for institutions.[13] Finally, the Agency for Healthcare Research and Quality (AHRQ) has sponsored research aimed at defining the current relationship between medical teamwork, team training, and patient safety.[14] AHRQ has even collaborated with the Department of Defense to create TeamSTEPPS™—an evidence-based team-building program designed to promote teamwork skills in health care.[15]

High-fidelity simulation (HFS) can be used effectively to create immersive, realistic training environments that are ideal for practicing teamwork skills.[16, 17] In contrast to real life situations, HFS supports a low-risk teaching and learning environment conducive to reflective and deliberate practice with feedback, making it an ideal teaching tool.[18] Although crew-based training of particular disciplines within the OR is well established,[19, 20, 21, 22] the current literature has relatively few examples of true interdisciplinary training of entire OR teams.[23, 24, 25] To date, examples have been limited to single-site training at large academic centers that have affiliated tertiary hospitals.

Based on our prior experiences with HFS-based teaching and learning, we created in 2004 a Virtual Operating Room (VOR) model to support truly interdisciplinary teamwork training. Initial pilot testing of this approach for OR teamwork training occurred in August 2005. Participants' feedback revealed high receptivity and effectiveness for teaching, learning, and practicing interdisciplinary teamwork skills in the OR.[23] However, time away from the work setting and the need to travel to and from remote sites for training were obvious factors that could hinder full participation of an interdisciplinary team member in training.

Building on our initial center-based model, we adapted the VOR to facilitate taking training to OR teams, rather than requiring them to come to the learning center. We developed a mobile mock operating room (MMOR) configuration to support simulation-based training at the point of care in geographically diverse settings.

Our initial full scale use of the MMOR was in the System for Teamwork Effectiveness and Patient Safety (STEPS) program that was funded, in part, by AHRQ. This article describes the results of testing of the MMOR in two hospitals located 80 miles apart. We hypothesized that the MMOR could be used easily to support standardized implementation of the STEPS training sessions in actual ORs. As a result, participants would perceive the training sessions as realistic and effective learning environments for teaching, learning, and practicing teamwork skills.

## Methods

In this section, we describe the development and refinement of the MMOR and its component features. We also briefly describe how the MMOR was used to support the STEPS training sessions in actual ORs. Finally, we describe the evaluation methods used to examine the feasibility and effectiveness of the MMOR for implementing high quality simulation-based training at the point of care.

Prior to implementation, we obtained institutional review board (IRB) approval at an exempt status, as part of a larger research protocol targeting simulation-based training and assessment. While similar approval was not required by the hospital-based research and compliance officers, we initiated and maintained open and ongoing communications with these individuals to facilitate positive relationships and cooperation.

## Mobile Mock Operating Room Design

The MMOR is an adaptation of the previously described virtual operating room (VOR) concept that we established at the Isidore Cohn, Jr. MD Learning Center on the main campus of the Louisiana State University Health Sciences Center in New Orleans.[23] Key considerations in adapting the VOR to an MMOR configuration included easy and efficient transport, set up, use, breakdown, and storage. To create an authentic clinical environment for training sessions, major features of the MMOR included:

- A portable mannequin capable of simulating physiological responses.
- An appropriate anatomical model for performing a surgical procedure.
- A software interface for enhancing mannequin responses in clinical scenarios.
- A realistic patient scenario.
- A portable, compact, computer-based system to record training sessions and support easy playback of selected video segments in debriefing and teaching discussions with teams immediately after their scenario-based experiences.

**MMOR setting.** We designed the MMOR to fit within a typical OR and to create an authentic clinical environment for training at the actual point of care. Ideally, this space should be an actual operating room, but any available room of adequate size located near the OR department could be configured to simulate an OR (e.g., an endoscopy or minor procedure suite).

Easy transport and use of the MMOR was facilitated by the hospital providing all surgical and anesthetic equipment and supplies. This allowed participants to perform routine tasks associated with surgical patient care (e.g., prepare and drape the mannequin like a real patient). Additionally, the realism of the training environment was enhanced by participants' access to their own instruments, monitors, surgical towers, and other accessories for the scenario. Situated in an actual OR (or an adapted room nearby), participants already knew which additional items were available and where to access them as needed for managing patient care during training, just as they would in a real patient case.

To minimize expense and use of resources, we salvaged and re-used consumable materials whenever possible for multiple training sessions (e.g., we used the same patient drapes for multiple scenarios and recycled any disposable instruments throughout the training period). Depending on the focus of training, other case- or procedure-specific equipment and supplies might be needed. For this study, each of the four training scenarios we used involved a patient undergoing a laparoscopic cholecystectomy. Therefore, each hospital also provided a laparoscopic surgical tower with camera, light source, and insufflator, as well as a complete open cholecystectomy instrument set with selected laparoscopic instruments.

For the current study, we used actual operating rooms for all STEPS training sessions at both hospitals. Because the MMOR situates training in the actual patient-care environment, training sessions could be scheduled as actual patient cases. Thus, the MMOR was assigned to an OR, just as actual cases were assigned. For example, over a month-long period, the MMOR was assigned to several ORs in each hospital's department. Participants scheduled for training were then assigned to the OR where the MMOR was located, just as if they had been scheduled for an OR for managing patient cases on a particular day. In keeping with our STEPS training program, all training sessions were scheduled during regular daytime elective surgery hours to maximize convenience and opportunity for all OR staff, anesthesiology staff, and general surgery residents and staff participants.

**MMOR simulator equipment.** As shown in Figure 1, the MMOR for this study consisted of the actual OR setting and equipment mentioned previously, in addition to a portable computer operated mannequin and an inanimate cholecystectomy model to support the specific patient scenarios developed for the STEPS training sessions. Taken together, these simulators provided a

**Figure 1.** The two main components of the MMOR simulator equipment include a portable computerized mannequin combined with an inanimate cholecystectomy model. The mannequin rests on the OR table with the cholecystectomy model at the foot of the bed. The mannequin control box is placed underneath the OR table and is connected to the computer via an Ethernet cable (lower left) and an air compressor via tubing (middle right).

platform for the interface between the OR team and "patient" during a simulated surgical procedure and managed the unfolding scenario in which the full participation of each team member was necessary.

We placed the portable Medical Education Technologies, Inc. (METI, Sarasota, FL) Emergency Care Simulator® (ECS) mannequin on the OR table and connected it to the control box situated below the OR table. The control box was connected via an Ethernet cable to a laptop computer located in the corner of the OR. In addition, the ECS was attached via specialized tubing to an air compressor placed just outside the OR. The computer was also connected to another monitor placed at the head of the bed to display the mannequin's vital signs and serve as the anesthesia machine monitor during the scenario. We were careful to place the laptop computer in an unobtrusive location, but we made sure that the operator was still able to easily see and hear team performance throughout the training session. Because the compressor is noisy, placement just outside the OR was necessary to minimize sound interference.

The computer-driven software that accompanies the ECS allows it to mimic physiologic responses to team interventions, medication administration, and treatments. In addition, the air compressor enables it to open and shut its eyes, breathe, alter airway size, and maintain palpable pulses. The ECS can support several procedural interventions: endotracheal tube intubation, chest tube placement, intravenous line placement, and urinary catheter placement. Such capabilities make it ideal for simulating different types of patients.

We enhanced the responsiveness of the ECS to various clinical scenarios using the Clinical Model, a proprietary (patent pending) software interface designed by Drs. Kozmenko and Hilton. This software enhances the extent to which the mannequin, as a patient, responds preoperatively to OR team members and perioperatively with appropriate and spontaneous physiologic reactions to actions taken by the team during the surgical procedure. The software interface enhances the realistic progression of patient scenarios during training sessions, contributing to the psychological fidelity of training (i.e., it enhances suspended disbelief).

Because the cholecystectomy model could not be optimally placed in or on top of the mannequin's abdomen, we chose to remove the mannequin's legs and place the model at the foot of the OR bed. This strategy enhanced overall placement, and the altered state of the mannequin did not seem to interfere significantly with the realism of the MMOR configuration. In this location, the scrubbed OR team members could assemble around the OR table to operate, just as they would in a real life case. The arrangement of the mannequin and procedure model allowed the major steps of a gallbladder removal to be performed: accessing the abdomen, identifying and dividing the cystic artery and duct, and removing the gallbladder from the liver bed.

Of note, two separate inanimate trainers were used for this study. At the first hospital, we used the Minimal Access Therapy Technique (MATT) Trainer® (Limbs & Things, Bristol, UK) that housed a gallbladder replica. When we were ready to implement the MMOR for STEPS training at the second hospital, the MATT trainer was no longer available, so we substituted for it with the Simulab Torso Trainer® (STT) (Simulab Corporation, Seattle, WA) containing a laparoscopic cholecystectomy model. The STT has a replaceable outer skin through which laparoscopic ports can be placed. The inner cholecystectomy model of the STT consists of a mold depicting the upper abdomen with a detachable gallbladder representation in the liver bed. This disposable gallbladder replica contains both a cystic artery and biliary drainage system. The cystic artery and duct can be dissected free from surrounding tissues, clipped, and divided during the course of the scenario. The gallbladder itself can then be removed off the liver bed and extracted. Figure 2, shows the MMOR configuration being used in a STEPS training session that included the ECS and SST in an actual OR.

**Figure 2.** A mobile mock operating room scenario in progress. The surgeon (second from right) looks at the monitor as she explores the abdomen with a laparoscope with the scrub technologist (left foreground) assisting her. The nurse anesthetist (right) observes from the head of the bed as the circulating nurse (left background) works. The draped mannequin's vital signs are displayed on the monitor at the head of the bed.

**MMOR scenarios.** The Clinical Model software interface uses preprogrammed algorithms in patient scenarios that cause the mannequin to respond appropriately and spontaneously to the decisions and actions of the OR team.[23] In this manner, the team's decisions and actions directly influence the mannequin's outcome and minimize outside operator intervention that sometimes interrupts participants' suspended disbelief during training. Figure 3 shows a simple example of a Clinical Model algorithm for a particular scenario.

As mentioned previously, four authentic patient scenarios involving a laparoscopic cholecystectomy were created and used for training sessions in this study. Each scenario involved one of the following intraoperative critical events to act as a catalyst for team interaction and response: onset of malignant hyperthermia, unstable cardiac arrhythmias, anaphylactic shock, or septic shock. All four scenarios also contained specific opportunities for team interaction that occurred regardless of the team decisionmaking. For example, the mannequin experienced bradycardia in response to initial establishment of pneumoperitoneum in each scenario. Two scenarios were selected for use in each STEPS training session. Their selection was based on minimizing participants' exposure to repeating scenarios.

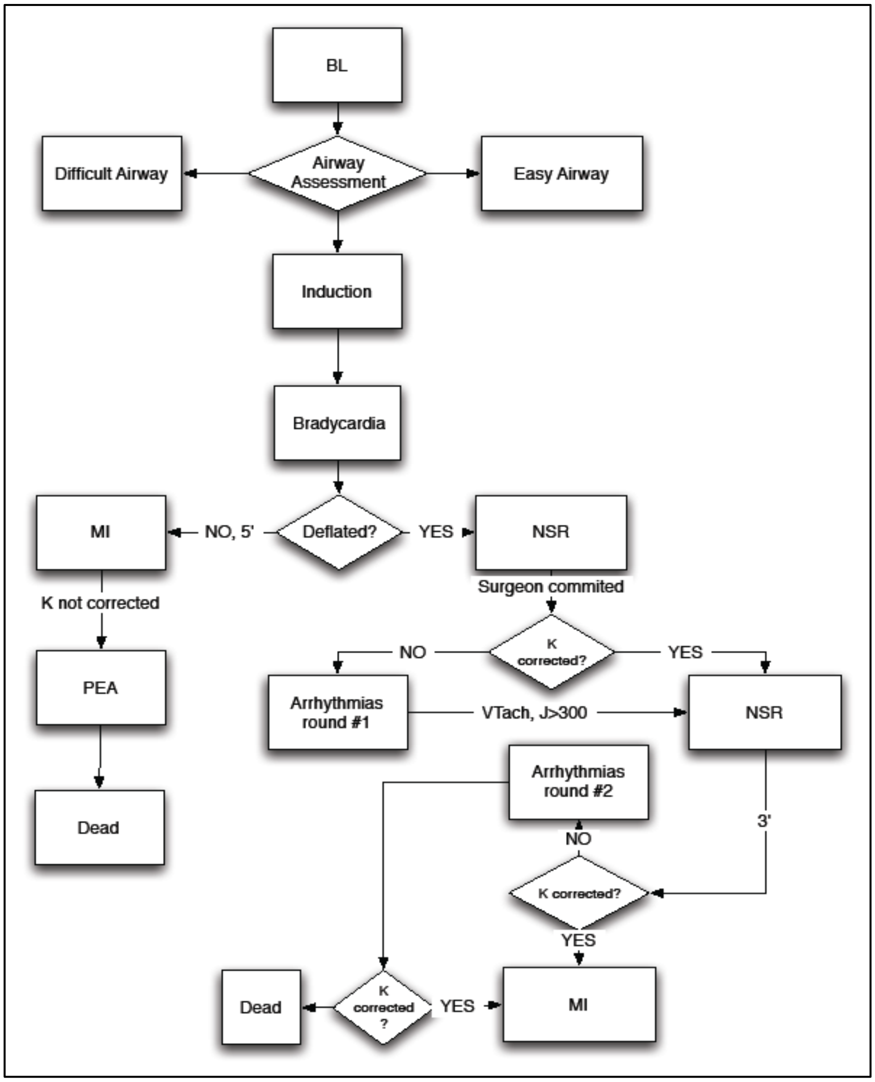


**Figure 3.** Example of a scenario algorithm used for an MMOR session. The patented software interface supports the development of physiologically complex scenarios involving the mannequin. BL = baseline; MI = myocardial infarction; PEA = pulseless electrical activity; NSR = normal sinus rhythm; K = potassium; Vtach = ventricular tachycardia; J = Joules. Copyright pending. Source: Paige J, Kozmenko V, Morgan B, et al. J Surg Educ 2007; 64(6): 369-377. Used with permission.

**MMOR recording and playback system.** We designed a compact, streamlined video recording and playback system to chronicle each scenario. Our experiences quickly taught us that, not only was space at a premium in the OR, but it was a critical logistical factor for both transportation and storage of the MMOR. Our system included a computer-based video camera with a built-in microphone, the iSight® (Apple, Inc., Cupertino, CA) that provided very good quality video and audio recording. Consequently, individual microphones for each participant were not necessary, which simplified the preparation and saved valuable time and storage space. A magnetic base on the camera allowed us to attach it to an intravenous pole located in the corner of the operating room next to the computer.

Video recording and playback was accomplished using Wirecast© computer-based video recording software (Vara Software, Poole, UK), an easy-to-use and inexpensive solution that included several features that were important for achieving an effective MMOR configuration. For example, Wirecast can be used to record several data inputs simultaneously (e.g., a room view of the OR team and a view of the vital signs monitor). As soon as the video is recorded, Wirecast formats these data to support a split screen video display, making multiple video views available immediately after a training scenario for use in a debriefing discussion.

In addition, the software includes a bookmarking feature that is quick and easy to use for identifying specific segments that one might choose to highlight in a debriefing discussion. A split screen playback of the two views can then be used in the debriefing discussion to examine team actions and "patient" reactions (and vice versa) during the after-action debriefing and teaching session. Compared with other solutions, our system was very compact, inexpensive, unobtrusive, and easy to use. We found it to be highly reliable in terms of function and quality of video and audio recording and playback across the various ORs in which it was used.

## Training Design

As mentioned previously, the MMOR configuration was a major factor in our ability to implement STEPS training sessions that were designed to conduct interdisciplinary OR team training in unique OR departments of geographically diverse hospitals. Half-day training sessions were embedded within the everyday work environment of two busy OR departments that varied physically, organizationally, and culturally in many ways. True interdisciplinary OR teams that work together on a regular basis participated in STEPS training in their own ORs.

In January 2007, pilot testing was carried out at a 179-bed public hospital affiliated with an academic health center. It targeted MMOR portability and technical function, while also testing the STEPS training scenarios and teaching methods. Although the hospital was within walking distance of our center-based simulation programs, issues related to technical function, transportation, set-up, and breakdown logistics were essentially the same as if the hospital had been located 100 miles away.

Full-scale implementation of the MMOR was achieved in March 2007, at a 157-bed public hospital, also affiliated with an academic health center located 80 miles away from our center. This academic health center was the targeted training site for the first year of the STEPS program, which was funded in part by AHRQ. Within 1 month, half-day training sessions were completed to accommodate every member of the OR and anesthesia departments, as well as the general surgery attending staff and all of the general surgery residents rotating at the hospital that month. Few refinements were necessary after pilot testing, so the MMOR configuration, training content and format, measures, and participant composition were very similar at the two hospitals.

**Training format.** Prior to implementing the training sessions, a general orientation to the simulation equipment, STEPS program, and scenario ground rules was conducted with all participants in a general session. Individuals had an opportunity to interact briefly with the simulator and to learn about its capabilities (and limitations).
For full-scale implementation at the second hospital, orientation was accomplished with a department-wide general session and informal opportunities to "meet" the simulator and ask

questions about the project activities. Each half-day training session began with a brief introduction that revisited simulator function and ground rules for scenarios (e.g., behavioral expectations, confidentiality of training experiences, and security for content of training scenarios). Each training session lasted up to 3 hours and included two simulation-based scenarios, each followed by an after-action debriefing discussion.

Within the training session, each scenario was introduced and initiated by giving the team the patient chart and instructing them to proceed as they would with a real patient. During debriefing discussions, the facilitator used video playback as needed to facilitate reflection on critical events and behaviors as they related to key teamwork competencies and strategies for improvement. While the MMOR could be managed by just two people, we found that a three-member training team worked best. The team included the following roles: a programming expert/mannequin operator, a training (scenario and debriefing) facilitator, and an observer and data collection manager.

**Training participants.** For the pilot training sessions, teams were volunteer OR and surgical staff, residents, fellows, and students. If a particular discipline was not available, a substitute from another discipline was used (e.g., surgical technologists played the circulating nurse role on two occasions). For full-scale implementation of the STEPS program at the second hospital, the entire OR, general surgical, and anesthesiology staff members and general surgery residents participated in the training. At each session, a representative from each profession was present. A typical team included a general surgery resident, circulating nurse, nurse anesthetist, and surgical technologist. When one of the three general surgery attending staff participated, he/she was paired with a lower level resident [i.e., postgraduate year (PGY) 1 or 2]. Anesthesiologists were available on call into the room during every session, as was typical of their role in everyday practice in the OR department at this hospital.

**Evaluation methods.** Participants voluntarily completed confidential pre- and post-session questionnaires related to a variety of training features and self-efficacy for teamwork competencies. Individuals were given instructions to generate a record identification code that was used only to match pre- and post-session questionnaires. For the study addressed in this article, only one scale comprising seven items on the post-session questionnaire was related to participants' perceptions of the MMOR configuration for supporting realistic and effective training.

Training participants responded to each item using a 6-point Likert-type response scale (1 = Definitely no to 6 = Definitely yes). Responses were compiled and analyzed after completion of the training sessions at a hospital. Item frequency counts, item mean scores, and standard deviations were calculated. Participants' perceptions were compared for each hospital training site based on a t-test of item means. Evaluation of the feasibility and effectiveness of the MMOR configuration was also accomplished through reflection on experiences and direct observations of actually transporting and using the MMOR to support the STEPS training sessions at the two hospitals.

## Results

Data were available for analysis from the last three of five pilot sessions conducted at the first hospital (17 respondents) and all 11 sessions conducted as part of the STEPS program at the second hospital (38 respondents). Disciplines represented in the pilot sessions included upper level general surgical trainees (i.e., PGY level 4 and above), nurse anesthetist staff and students, circulating nurses, and surgical technologists. At the second hospital, all members of the OR and anesthesiology departments and all general surgery attending staff and residents participated in the STEPS training sessions and completed questionnaires.

Table 1 shows each of the seven item statements and summarizes descriptive statistics and results of t-test comparisons. All but one of the item mean scores were >5.0 on a 6-point Likert-type scale. Results obtained during pilot testing at Hospital 1 revealed that item means ranged from 5.00 (Item 5) to 5.56 (Items 2, 6, and 7). For Hospital 2, where STEPS was fully implemented using the MMOR configuration, item means ranged from 4.89 (Item 4) to 5.76 (Items 6 and 7). Only one item mean score was <5.00 (Item 4, mean = 4.89). It was obtained at the second hospital and was related to the extent to which participants experienced the phenomenon of "suspended disbelief" during training scenarios. A review of the individual item statements and corresponding results revealed that participants perceived the training sessions to be realistic, valuable, and effective for examining and enhancing teamwork and patient safety practices.

### Table 1. Participants' feedback on authenticity of the simulation training model

| Item statement | Mean[a] (± SD) Hospital 1 (n = 17) | Mean[a] (± SD) Hospital 2 (n = 38) | *P* value[b] |
|---|---|---|---|
| 1. The physical setting of the training was realistic | 5.44 (0.63) | 5.39 (0.72) | 0.84 |
| 2. Patient scenarios reflected realistic situations that teams might face in OR | 5.56 (0.51) | 5.50 (0.76) | 0.77 |
| 3. Scenarios were effective for examining teamwork and patient safety practices | 5.44 (0.63) | 5.68 (0.47) | 0.12 |
| 4. During scenarios, I momentarily forgot about simulation and acted as if the situation were real | 5.13 (0.96) | 4.89 (0.92) | 0.41 |
| 5. The composition of the OR team reflected what I experienced in the real life setting | 5.00 (1.10) | 5.45 (0.76) | 0.09 |
| 6. Overall, the program was valuable experience | 5.56 (0.63) | 5.76 (0.49) | 0.21 |
| 7. I would encourage colleagues to enroll in this training program | 5.56 (0.63) | 5.76 (0.43) | 0.18 |

[a] Based on 6-point Likert-type scale: Definitely no = 1; Definitely yes = 6
[b] t-test

Based on our first-hand experiences, the MMOR configuration was easily handled by two people and transported using a mid-sized sports utility vehicle, negating the burden or additional expense that would be associated with leasing or renting specialized vehicles. The MMOR was also easily transported from the vehicle to a hospital OR by two people. Set-up in the OR and functional testing was easily completed within 20 to 30 minutes. We were generally pleased with the MMOR interface with hospital equipment from the outset. With some minor refinements following pilot testing at the first hospital, accurate and reliable technologic interface (e.g., anesthetic equipment) was achieved.

The compact nature of the MMOR facilitated our ability to position equipment and ourselves unobtrusively within the ORs where we conducted training. This was particularly noteworthy, since the ORs typically were small and—in some aspects—dated (e.g., limited storage and space for movement outside the sterile field area, limited electrical outlets beyond those needed for the MMOR to effectively create realistic clinical settings for the STEPS training without compromising any aspect of the actual OR functionality).

Breakdown of the MMOR was easy and quick and, with some practice, achieved in 15 to 20 minutes. As a result, the amount of OR time needed to support training sessions was minimized. We were able to enter and exit the OR department with the MMOR with a minimum of disruption, even when the OR corridors were crowded and busy. Secure, overnight storage in the OR department was an initial concern when faced with conducting multiple days of STEPS training sessions within a given week at a hospital located 80 miles (one way) from our center. However, despite the OR department being woefully in need of storage space for their own day-to-day operations, the MMOR was sufficiently compact that we were able to find secure storage space in a janitor's closet that was no longer being used, a significant factor in enhancing management of MMOR logistics.

Finally, the video recording and playback solution for the MMOR was a major achievement. From the outset, we were concerned that high visibility of video recording equipment might intimidate or substantially influence participants' involvement in training scenarios. Yet, video recording was important for both supporting after-action debriefing and research purposes. The small scale of the computer-based video recording playback equipment and the ease of use afforded by the Wirecast© software produced very good quality video, and participants did not seem to notice the recording equipment at all. Larger scale equipment typical of other types of video recording and playback solutions and the need to place microphones on each participant prior to training would have required considerably more preparation time and taken a much more visible role in the training sessions.

## Discussion

Reports in the literature demonstrate that teamwork in the modern OR is plagued by role confusion,[4, 5, 6] poor communication,[7] and tense interactions.[26] Furthermore, the hierarchical structure of the OR team is less than ideal for effective coordination among the disciplines.[4, 6] Such dysfunctional team dynamics can negatively impact patient safety, especially during complex procedures.[27] In addition, they can result in inter-professional conflicts,[28] OR inefficiency or delays,[7] and episodes of disruptive behavior characterized by yelling, abusive language, insults, patronizing tone, and a disrespectful attitude.[2]

Clearly, the need for training to improve teamwork is evident. Although large, group-based, interactive sessions are feasible and have been used successfully for such training,[29, 30] high-fidelity, simulation-based methods offer several key advantages. First, they create a realistic, immersive learning environment for learning and practicing actual team skills.[16, 17] Second, they require teams to manage the consequences of their actions in real time, but without risk of harm to the patient.[16] Finally, such training can be used to learn and practice specific team responses that are either difficult or impossible to do in real life (e.g., preparing for rare clinical scenarios that could occur in actual practice).[16] Authentic, simulation-based training can facilitate the use of deliberate and focused feedback and practice to improve critical aspects of communication and coordination that relate to teamwork effectiveness and patient safety.

Involving the entire team in behavioral skills training is essential for achieving highly reliable team functioning in actual practice.[31] To date, true interdisciplinary team training for OR personnel has been limited to specialized simulation suites located at or near academic health centers and targeted hospitals.[23, 24, 25, 32, 33] The MMOR model significantly expands the portability of high-fidelity, simulation-based interdisciplinary OR training by taking it to the point of care. In this study, training was conducted successfully at two hospitals located 80 miles apart, demonstrating both the feasibility and effectiveness of the MMOR and its potential for expanding both the geographic and demographic reach of interdisciplinary team training to improve teamwork and patient care.

Fidelity in simulation-based training requires the use of true-to-life equipment in a realistic training environment and the psychological buy-in of participants.[16, 18] The MMOR configuration allowed us to take the STEPS program “on the road” and retain these essential characteristics. The ability to assemble a realistic OR team composition for training was possible because the MMOR facilitated taking the STEPS program to the point of care, where real teams already existed, and participation in training was convenient. Even when we had to rely on volunteer participants in the pilot testing, we encountered only two sessions in which we needed surgical technologists to play the role of circulating nurses because none were available at the time. The consistency of high item mean scores for the two hospital training sites and the nonsignificant results of t-test analyses were particularly encouraging and demonstrated the effectiveness of the MMOR for reproducing the STEPS training sessions with different OR personnel working in two OR departments that reflected different physical, organizational, and cultural work environments. These results build upon prior studies of simulation-based OR team training conducted near the point of care.[25, 32]

Given the increasing demands that OR personnel frequently face (e.g., time pressures, short staffing, increasing productivity expectations) and the increasing costs and hassle of travel, individuals are becoming less interested and willing to leave their work settings to attend training elsewhere. Taking the training to health care professionals and conducting it in their own work settings appeared to enhance receptivity and psychological buy-in for simulation-based training. Based on evaluation results, the effectiveness of the MMOR for supporting simulation-based training at the point of care suggests the following design principles:

- Portability increases individual and organizational access to training.
- Adaptability of training to real life OR settings facilitates implementation and minimizes cancellations due to unexpected events (e.g., training is embedded within the everyday routine, making it easy to move a session to an alternate OR when an emergency case arises and alters the training schedule).
- Technologic features of the simulators and their compatible interface with real life settings support use of authentic scenarios.
- Situating simulation in real life settings facilitates standardized training that can offer practical benefits.
- Training in real world environments promotes incorporation of systems-based practice.

Related to systems-based practice, the MMOR configuration facilitates the integrated use of simulated and real elements in training (i.e., a mixed reality environment). Mixed reality methods offer opportunities to examine latent individual and organizational features that either facilitate or interfere with OR team function and the transfer of new knowledge and skills to everyday practice. Paying attention to such features can enhance the potential for long-lasting improvements. For example, new OR staff participating in the STEPS training learned where specific equipment was located before a real life crisis occurred that would have required its use. In addition, team members were made aware of a specialized malignant hyperthermia kit that the anesthesiology staff had created. While these were not objectives-related outcomes of the STEPS training, they did represent intentions for participants to gain such insights as a result of using a mixed reality environment afforded by the MMOR configuration.

Despite the very positive and encouraging results, we identified several noteworthy challenges that include the following:

- Cost.
- Logistics (e.g., transportation).
- Technologic limitations of portable simulators.
- Human capital needed to sustain an MMOR and associated training program.
- Individual, departmental, and institutional commitment or buy-in for training.

First, investing in portable simulation-based training requires substantial commitment of time, people, technology, and finances. Even though we were able to streamline the MMOR components and incorporate some very cost-effective features (e.g., Wirecast© video recording software), acquiring and maintaining an ECS alone can run into the tens of thousands of dollars. Despite substantial experience with METI simulators and simulation-based training, creating and supporting rich, authentic training scenarios requires considerable expertise and efforts.

Scheduling our own time to develop the MMOR and implement STEPS activities (e.g., planning, training, assessment, followup, refinement) while holding multiple and competing responsibilities has been a significant challenge. Clearly, one alternative would be to create a core team or set of teams with appropriate expertise that could devote full-time efforts to support ongoing development and enhancements and to provide training to a region, network of hospitals, or statewide initiative. Such an arrangement could produce synergy and afford a realistic solution to managing costs and logistics effectively, enhancing efficacy, and maximizing assets to achieve optimal benefits to health care providers and ultimately to patients.

We selected the METI ECS as our portable mannequin component of the MMOR. Even with enhancements made possible through our patented Clinical Model software interface, the mannequin itself has certain limitations that continue to challenge achieving optimal levels of authenticity. For example, the ECS cannot interpret the amount and type of "medication" administered because it lacks the bar code reading system that is available on the nonportable mannequin (METI HPS) we use in our center-based simulation suite. As a result, participants must verbalize the type and amount of medication they are administering to the "patient" during scenarios in order to have this information entered into the mannequin software. Once entered, the mannequin gives the appropriate physiologic response to the drug and dose given. However, such verbal drug administration is not representative of what occurs in an actual OR case. Typically, a nurse anesthetist or anesthesiologist is able to and often does give medications without telling other team members. This dynamic is different than in our MMOR. Clearly, a bar code system allowing the nonverbal administration of medication for the ECS would be preferable. Even so, our evaluation results suggest that this technical deficiency did not substantially detract from realistic features of training.

Finally, we recognized that the use of the OR space and personnel who participated in training resulted in reduced hospital revenue that could not be avoided. Such costs and increasing demands for productivity and accountability make it imperative to obtain convincing evidence that the benefits of such training outweigh the real and perceived costs. Results from this study provide only initial evidence of receptivity and satisfaction. Our continuing research efforts are targeting evaluation of learning, behavior change, and ultimately, evidence of impact on outcomes.

Visible support from key leaders is essential to achieving and sustaining buy-in for any type of training, particularly when innovative and performance-based approaches—such as simulation training at the point of care—is proposed.[25] In this study, the OR nurse managers at both participating hospitals were essential in the successful use of the MMOR to support the STEPS training. Without their enthusiastic support and assistance, we would not have been able to gain entry to the OR department and access equipment and supplies, much less implement training sessions with interdisciplinary OR teams. At the second hospital where the STEPS program was fully implemented, the hospital medical director, a general surgeon, seized opportunities from the beginning to demonstrate his enthusiasm and support to key hospital leaders. In addition, he participated in a STEPS training session with other OR team members. His actions contributed to developing enthusiasm and support at other levels of the OR department and the hospital, affording us an important opportunity to introduce the STEPS training to staff in the OR, anesthesiology, and general surgery departments. We observed that if individuals were willing to consider such training at the point of care, the MMOR configuration was usually sufficiently captivating to facilitate all or most principals' buy-in for participating in the STEPS training. With buy-in and participation in training, anticipated improvements in teamwork, for example, can then be recognized and rewarded, and followup strategies can be used to promote long-lasting change.

Our experiences with the MMOR configuration and feedback from STEPS training participants have provided encouraging support for implementing standardized training to meet institutional and regional needs for interdisciplinary OR team training. The outcomes of this study also suggest that the conceptual design of the MMOR and STEPS training could be adapted to expand the availability of team-based training using mixed reality methods to create authentic learning environments for enhancing performance of other types of teams in a variety of settings, (e.g., interdisciplinary teams working in intensive care units, emergency rooms, and even interdisciplinary/interagency first responder teams, which ultimately interact with hospitals, particularly when large scale emergencies and disasters occur). Individuals interested in creating highly authentic and replicable training programs might benefit from adopting or adapting our MMOR configuration and its associated design principles for support of team training initiatives.

## Conclusion

Taking high-fidelity, simulation-based training to the point of care requires innovative support structures to achieve realistic, sustainable, and value added training. Our MMOR configuration supports interdisciplinary team training in the actual OR setting. Completion of the STEPS training sessions at two hospitals located 80 miles apart and participants' very high ratings of effectiveness provide evidence that the MMOR has clear potential for increasing geographic- and demographic-based access to authentic simulation-based OR team training via a standardized, reproducible, regional-based team training program. Such a regional approach to training at the point of care would facilitate integrating simulation into actual health care delivery systems and strengthening collaborative partnerships between academia and community practice.

As we continue our refinements of the MMOR and implementation of the STEPS program, we are examining the impact of such simulation-based training on actual transfer of learning and skill development to everyday practice and to the overall culture of teamwork and patient safety in the OR setting. We are also exploring how the MMOR design and implementation principles can be used to support other types of mixed reality training experiences.

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