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Research and Applications

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Designing and executing a functional exercise to test a novel informatics tool for mass casualty triage

Sara B. Donevant,[1] Erik R. Svendsen,[2] Jane V. Richter,[1] Abbas S. Tavakoli,[1] Jean B.r Craig,[3] Nicholas D. Boltin,[4] Homayoun Valafar,[4] Salvatore Robert DiNardi,[1] and Joan M. Culley[1]

[1]College of Nursing University of South Carolina, Columbia, South Carolina, USA, [2]Medical University of South Carolina, Charleston, South Carolina, USA, [3]Office of Biomedical Informatics Center Medical University of South Carolina, Charleston, South Carolina, USA, and [4]College of Engineering and Computing University of South Carolina, Columbia, South Carolina, USA

Corresponding Author: Sara Belle Donevant, PhD, RN, CCRN, College of Nursing University of South Carolina, William Bryce Building, Room 609, 1601 Greene Street, Columbia, SC 29208, USA (Donevant@email.sc.edu)

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ABSTRACT

Objective: The testing of informatics tools designed for use during mass casualty incidents presents a unique problem as there is no readily available population of victims or identical exposure setting. The purpose of this article is to describe the process of designing, planning, and executing a functional exercise to accomplish the research objective of validating an informatics tool specifically designed to identify and triage victims of irritant gas syndrome agents.

Materials and Methods: During a 3-year time frame, the research team and partners developed the Emergency Department Informatics Computational Tool and planned a functional exercise to test it using medical records data from 298 patients seen in 1 emergency department following a chlorine gas exposure in 2005.

Results: The research team learned valuable lessons throughout the planning process that will assist future researchers with developing a functional exercise to test informatics tools. Key considerations for a functional exercise include contributors, venue, and information technology needs (ie, hardware, software, and data collection methods).

Discussion: Due to the nature of mass casualty incidents, testing informatics tools and technology for these incidents is challenging. Previous studies have shown a functional exercise as a viable option to test informatics tools developed for use during mass casualty incidents.

Conclusion: Utilizing a functional exercise to test new mass casualty management technology and informatics tools involves a painstaking and complex planning process; however, it does allow researchers to address issues inherent in studying informatics tools for mas casualty incidents.

Key words: chlorine exposure, disaster, functional exercise, informatics, mass casualty incident

INTRODUCTION

Due to the nature of mass casualty incidents (MCIs), testing informatics tools and technology for MCIs can be difficult. First, there is no readily available victim population or identical setting for validation and usability testing and using untested informatic tools during a real-life MCI may potentially place patients' lives at risk.[1] Previous studies have shown the functional exercise (FE) as a viable option for 1) testing a wireless electronic health record,[2,3] 2) evaluating instruction and critical thinking,[4] 3) comparing human actors to high-fidelity simulators,[5] 4) testing equipment and tools in the field,[6–8] and 5) comparing triage systems.[9] Following the success of these studies, we decided to use the FE methodology to test the Emergency Department Informatics Computational Tool (EDICT), an informatics tool designed to efficiently and accurately triage patients exposed to chemicals.[10] The purpose of this article is to describe the process of designing, planning, and executing an FE to accomplish the research objective of validating the novel informatics tool, EDICT.

During any MCI, emergency departments (EDs) are overwhelmed by the sheer number of patients, the severity of injuries, and limited staff to triage and care for patients, all significant public health concerns.[11–13] MCIs involving chemicals greatly increase the complexity of triaging, treating, and managing patients exposed to an unknown chemical, which was the situation on January 6, 2005 in Graniteville, SC. A train derailment released chlorine into the surrounding area killing 9 people and sending hundreds to the local EDs with no forewarning of the incident or the chemical involved.[14,15] This lack of knowledge left ED providers without appropriate guidance for the chemical involved and evidence-based triage methods for the arriving victims. The Graniteville incident demonstrated the need for a chemical MCI triage method that harnesses the power of informatics to provide early detection of an MCI, to identify an Irritant Gas Syndrome Agent (IGSA), and to deliver accurate and efficient ED triage to improve patient outcomes and potentially save lives.[15,16] Informatics tools have the potential to improve these outcomes through the use of integrated informatics tools specifically designed for these ED purposes and capable of providing situational awareness to emergency responders.

Emergency department informatics computational tool

Due to the lack of IGSA informatics tools for MCIs,[16] the research team embarked on the development of EDICT, a native mobile application that incorporates an artificial intelligence (AI) algorithm to provide decision support in triaging and treating patients exposed to an IGSA. The development of EDICT occurred using a robust and systematic approach to produce a solid chain of evidence. First, the data for 298 patients from 1 local ED (ie, 198 exposed to chlorine and 100 not exposed for comparison) was abstracted using Research Electronic Data Capture (REDCap), a secure web-based research platform.[17,18] Next, 3 clusters of signs/symptoms (ie, respiratory, chest discomfort, eyes/nose/throat) were found to be statistically significant with a chlorine exposure ($p < .010$) and provided the basis for the algorithm to guide the development of EDICT.[17,19] The algorithm was tested using a computer simulation exercise with 26 experienced nurses and was found to be more precise (weighted Kappa-0.82, CI 0.78–0.85) and accurate (weighted Kappa-0.81, CI 0.77–0.85) than traditional triage methods (weighted Kappa-0.73, CI 0.69–0.77; 0.32 CI 0.26–0.37).[20] Once the research team's computer scientists incorporated the validated algorithm into EDICT, the team was ready to assess the accuracy and efficiency of EDICT using a FE.

EDICT is a mobile application designed to triage and manage patients during a chemical MCI using a client-server transaction model.[21] Users interacted with EDICT through unique modes, kiosk mode and nurse mode. Kiosk mode is designed for patient data entry while nurse mode utilizes the AI algorithm to provide decision support on exposure status and triage recommendations. Furthermore, EDICT's mobile interface allowed nurses to move about the ED while remaining connected to the decision support system for situational awareness information available through summary screens.

OBJECTIVE

Due to the limited patient population (ie, patients exposed to chlorine) and lack of access to real-time MCIs, the research team determined there was a need to conduct an FE for the testing and validation of EDICT. Therefore, the objective is to describe our methodological process of designing and implementing an FE to serve as a guide for other research involving informatics tools that lack a readily available population for testing. The 3-year EDICT planning and development process identified needs for designing and implementing an FE to meet the rigorous research requirements. We describe the 5 key components of the FE: 1) contributors, 2) venue, 3) hardware, 4) IT elements, and 5) data collection methods.

MATERIAL AND METHODS

The university Institutional Review Board and the local hospital reviewed and approved the study as exempt from the Protection of Human Subjects Regulations. The research team developed rigorous protocols to assure validity, reliability, and reproducibility of EDICT. This commitment to research integrity contributed to the complexity and considerations of the FE design and execution. For example, the research team used multiple data collection methods (ie, client-server model, REDCap, video, and paper surveys) to ensure a robust research data set.

The FE included a simulated ED area complete with patient kiosk stations and nurses' stations to triage patients. The simulated patients were given standardized information cards with the relevant victim details from the abstracted and de-identified clinical data. During the FE, as the patients arrived in the ED, they were quickly observed by a triage nurse to identify those patients in need of life-threatening intervention and immediate processing. Noncritical patients proceeded to the kiosk area where they entered data into EDICT via preprogrammed android tablets. Next, patients proceeded to an area where they were summoned for evaluation and triage by a nurse. Using EDICT, the nurse accessed the kiosk data in real-time and reviewed the AI recommendation for exposure status and triage recommendation. After the nurse confirmed or modified the decision support recommendation, the patient exited the ED. Figure 1 provides the layout of the simulated ED triage area.

Contributors to the FE methodology

External advisory committee

The research team selected an External Advisory Committee (EAC), which included 19 individuals representing organizations within the community as well as national experts to assist in the design of EDICT and the FE planning and execution. Experts from nursing ($n = 7$, 35%), medicine ($n = 1$, 5%), toxicology ($n = 1$, 5%), military ($n = 1$, 5%), emergency response ($n = 4$, 20%), policy/community ($n = 4$, 20%), and law enforcement/health and safety ($n = 2$, 10%) were involved. Beginning in 2015, the EAC assisted the research team in assessing the needs (ie, venue, participants, IT, data collection) to successfully plan and execute the FE.

FE participants

Key FE coordinators and facilitators. Key personnel involved in the FE execution met monthly before the exercise to plan the logistics and data collection methods. Early in the design process, it was crucial to identify and define the essential roles. Based upon the needs assessment, the team identified 7 key positions: 1) exercise research

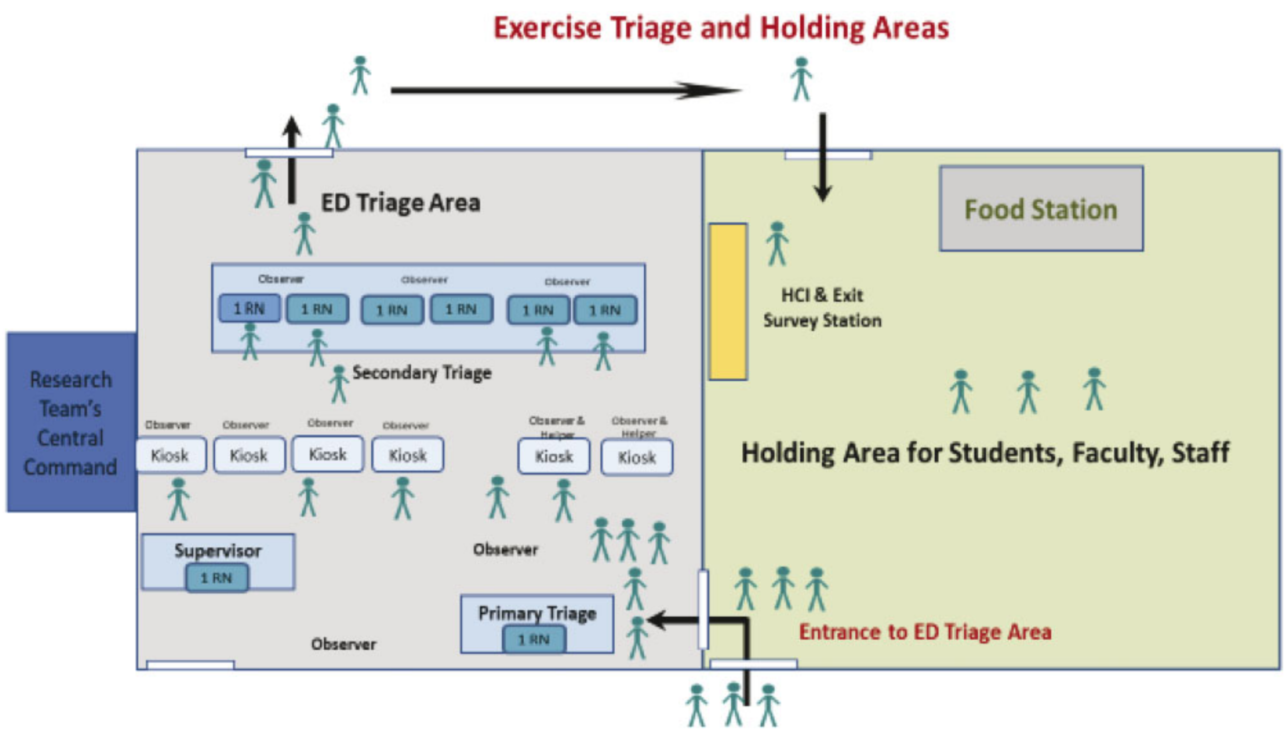


Figure 1. Simulated ED for the testing of EDICT.

director, 2) safety officer, 3) exercise controller, 4) information technology (IT) coordinator, 5) student coordinator, 6) exercise observer supervisor, and 7) registration in/out coordinator. Job action sheets (JAS) were developed which described the role, duties, and chain of command for each position, as well as the information presented in the Just-In-Time (JIT) training the morning of the FE. The responsibilities for the 7 Key FE roles are described in Supplementary Appendix A.

Roles for patients, ED nurses, and support staff. Over 390 individuals participated in the FE. Junior and senior nursing students ($n = 298$, 76%), faculty ($n = 41$, 10%), and staff ($n = 15$, 4%) from 2 universities participated as patients, ED nurses, and support staff. Additional nurses and individuals from the community ($n = 29$, 7%) were recruited to assist in various roles as well as the Reserve Officers' Training Corps ($n = 10$, 3%) who assisted with logistics. Before the FE, students completed online emergency preparedness training modules in Blackboard Learn (Washington, DC).

The students portrayed the 298 patients (referenced as patients throughout this article). Before the FE, each student was randomly assigned a number that correlated with a patient ID and a time to enter the ED in groups modeled to replicate a surge associated with an MCI (ie, starting with a slow and steady stream and increasing to create a surge).

The morning of the FE, all participants received a packet at registration that contained essential information including JAS and schedule. Each student participant also received a patient ID sticker and patient card with de-identified patient data. The patient card included fictitious name, address, and date of birth; patient ID, bar code of patient ID, chief complaint, and description of how to play the assigned patient (ie, coughing, leaning forward to breathe, etc.). Before the start of the FE, JIT training and a safety briefing were provided to all participants specific to their role.

Faculty served as kiosk helpers ($n = 4$, 10%), primary triage nurses ($n = 2$, 5%), supervisor nurses ($n = 2$, 5%), secondary triage nurses ($n = 10$, 24%), observers ($n = 19$, 46%), and ED expeditors ($n = 4$, 10%). Additional ancillary staff assisted with a variety of supporting roles such as directing students, food distribution, registration, communications, information technology, and clean-up.

Key IT methodology components of the FE

Venue

When selecting the venue, the needs of the FE dictated that sufficient space was essential to accommodate a large number of participants including parking and adequate facilities (ie, restrooms, audio-video equipment, kitchen, and holding area). The research team decided on an indoor venue to accommodate any weather condition and was allowed access to the university football stadium and its 11 000 square foot banquet facility for the FE (Figure 1) as well as 6 classrooms for JIT training. Throughout the planning process, the research team visited the venue to plan the layout and logistics of the FE. Other FE needs included the location of restrooms, electrical outlets, tables/chairs, and audio-visual equipment.

Hardware/software architecture and standards

EDICT's user interface is a mobile application running on an android operating system (OS). Android OS was selected because of the flexibility of open source development, the ability to customize the user interface, and ease of adoption. Android OS accounts for nearly 65% of mobile devices and tablet market share, meaning users would most likely have previous experience using android applications.[22] EDICT was developed using the Android Studio integrated development environment (IDE) architecture running on Linux Ubuntu 16.04.3 LTS. Bitbucket was integrated as the software version control, and GIT was used for local and remote repository access.

The Samsung Galaxy Tab A, model SM-T550 with Android Marshmallow 6.0.1, was selected for the FE. Based upon the need assessment for the FE, the research team's computer engineers found Samsung's larger 10-inch screen allowed for favorable human-computer interaction (HCI) elements, such as larger text and buttons, and provided 12 hours of use on a single charge. However, the research team assured redundancy by having additional tablets and charging capabilities. The Galaxy's 16 GB with 2 GB of RAM provided sufficient data storage, backup, and expanded memory for quicker access to patient information via the real-time client-server communication. Also, the research team purchased protective cases to safeguard the integrity of the tablets in the event of dropping or falling. Another need was barcode scanning, which is a commonly used feature within healthcare facilities. The Samsung Galaxy tablet included a camera for barcode scanning.

The on-site server allowed for real-time bidirectional communication with EDICT to receive patient data from the kiosk stations and, based upon the tested AI algorithm discussed above, provided AI decision support to the nurse stations.[21] The server used the patients' symptoms (ie, type and number) and vitals (ie, heart rate, respiratory rate, oxygen saturation) along with the patients' geographical locations to provide the secondary triage nurse with a recommended exposure status (ie, exposed, potentially exposed, not exposed) and triage category (ie, exit, monitor, urgent, immediate). The interoperability allowed for data integrity in the event of a hardware failure. The stadium's bandwidth allowed for real-time and secure data collection/transmission as well as storage to accommodate EDICT data and research desktop computers.

Data collection methods

EDICT data collection. A critical data collection need was the discrete data entered directly into EDICT by the patients and nurses. User data was collected in real-time and stored on a Linux Apache server Ver. 2.4.18 using a MySQL Ver. 14.14 relational database. The database schema is shown in Figure 2.

Observer data collection. The research team determined the need to observe the following locations: 1) kiosk stations (ie, where patients entered data into EDICT), 2) Nurse stations (ie, primary triage, secondary triage, and supervisor), and 3) entire simulated ED. When designing the observer data collection tools, the research team was driven by the need to capture information electronically in a quick, easy-to-use method. REDCap was chosen as the data collection tool due to its ease of use and ability to function in an offline mode when the internet is not available.[18] The user interface requires a web browser for the online mode and the REDCap Mobile App[23] with the data collection tool downloaded and configured for the offline mode to enhance interoperability.

When developing the data collection tools, the research team identified a list of necessary features and data elements for capture, which guided the data collection design in REDCap. Supplementary Appendix B lists the data collected with these tools.

Patients wore a readily visible ID number which allowed the observers to view and record the number when documenting observations without interacting with the participants (ie, patients, nurses) or interfering with FE activities. Similarly, Kiosk and Secondary Triage stations were labeled with unique letters corresponding to the EDICT tablets. Figure 3 is a representation of a Kiosk Observer Tool. The observers were instructed to interface only with the Exercise Observer Coordinator or the Exercise Controller when needing assistance. Prior to the FE, the Exercise Observer Coordinator installed the REDCap mobile app on 15 Apple iPads which were configured so no login was required and had the ability to be used in the event of no or poor internet availability.

Participant data collection. All participants were asked to complete paper surveys at the end of the FE that included a combination of 5-point Likert questions and open-ended questions. This process provided feedback on the participants' perception of their role in the FE. Data collected on this survey is listed in Supplementary Appendix C.

HCI data collection. An HCI expert developed paper surveys for the participants to record their perception of EDICT's usability. We utilized the widely used and validated System Usability Scale (SUS) with a 5-point Likert rating scale as well as 3 yes/no questions, and 1 open-ended question (see Supplementary Appendix D).[24]

Video data collection. The research team opted to use videos to collect additional data. A videographer was hired to record the entire FE using multiple cameras focused on different areas of the simulated ED. In addition, students and nurses were randomly assigned to wear a GoPro to provide visualization of the students' and nurses' activities.

RESULTS

Planning a large-scale FE required substantial time and attention to details as the research team only had this 1 opportunity to complete the aims of the research using the FE. The prior 3 years of planning and EDICT development culminated in the careful execution of this FE. The research team learned several lessons throughout the planning and execution process, which are shared below to assist future researchers with developing an FE to test informatics tools.

Contributors to the FE methodology

External advisory committee

The EAC was essential to the development and successful implementation of the FE. The EAC met biannually throughout the 3-year planning process and helped with assessing the needs for the FE. The 19 members provided diverse perspectives to produce a robust FE. Several EAC members attended the FE to observe the testing process.

FE participants

Roles for patients, ED nurses, and support staff. The student nurses, faculty, and community nurse volunteers filled the crucial roles of patients and ED nurses as the end-users of EDICT. The participants' JASs, FE schedule, and JIT training ensured they successfully performed their assigned tasks.

Key FE coordinators and facilitators. The key FE coordinators and facilitators were under enormous pressure to successfully execute the exercise for the testing and validation of EDICT. However, the needs assessment identified the essential coordinators and facilitators early in the process, allowing the research team ample time to clearly delineate the responsibilities for each role and assign capable individuals to execute the responsibilities. The creation of JASs ensured that all tasks were assigned to a role and unique to each role to avoid

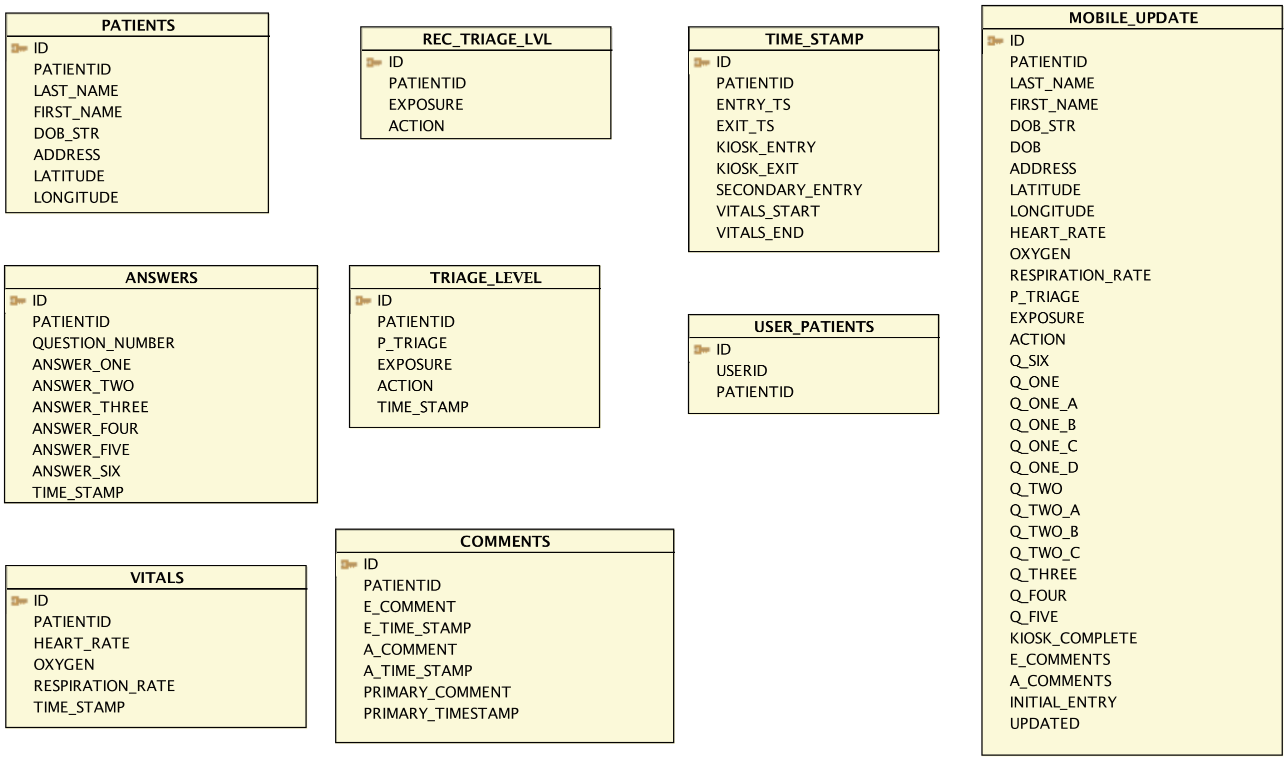


Figure 2. Relational database schema used to store user data collected from EDICT.

redundancy of tasks, which reduced confusion. The day of the FE, coordinators and facilitators successfully performed their tasks.

Key IT methodology components of the FE

Venue

Several weeks prior to the FE, key personnel met weekly to walk through the venue and plan the logistics specific to the needs assessment: 1) signage to mark directions and venue information, 2) participants' colored identification bracelets, 3) colored vests for key personnel, 4) location of registration, equipment, and supplies; 5) participant flow patterns; 6) location of all ED triage area components including kiosk stations, triage stations, observer stools, electrical outlets, placement of video equipment for recording of FE, Media Area for interviews and photo opportunities, and Research Team Central Command area for overview of research activities; 7) holding area for presentations, food station, seating, prep area for patients entering the ED triage area, and exit survey station; 8) audio-visual equipment in the 6 classrooms for JIT training; 9) testing of all equipment, tablets, Wi-Fi, bandwidth capabilities, walky-talky communication devices; and 10) Safety Officer area.

Patient flow between each station (ie, primary triage area, kiosk station, nurse station) was an essential consideration to reduce confusion and congestion. The day before the FE, the team set up the simulated ED per the designed layout. The preplanning reduced confusion and provided cohesion of the coordinators and facilitators during the FE set-up. The stadium banquet facility's collapsible partitions allowed the area to be adapted and changed throughout the day to accommodate the needs of the FE.

The stadium provided sufficient room and facilities for the FE, and the indoor venue ensured the FE proceeded regardless of inclement weather. The Wi-Fi bandwidth successfully met the FE requirements with no outages or delayed responses. This ensured the integrity of the data and reduced process delays. Interoperability across all systems and on-site servers provided sufficient data storage and backup.

Hardware/software architecture and standards

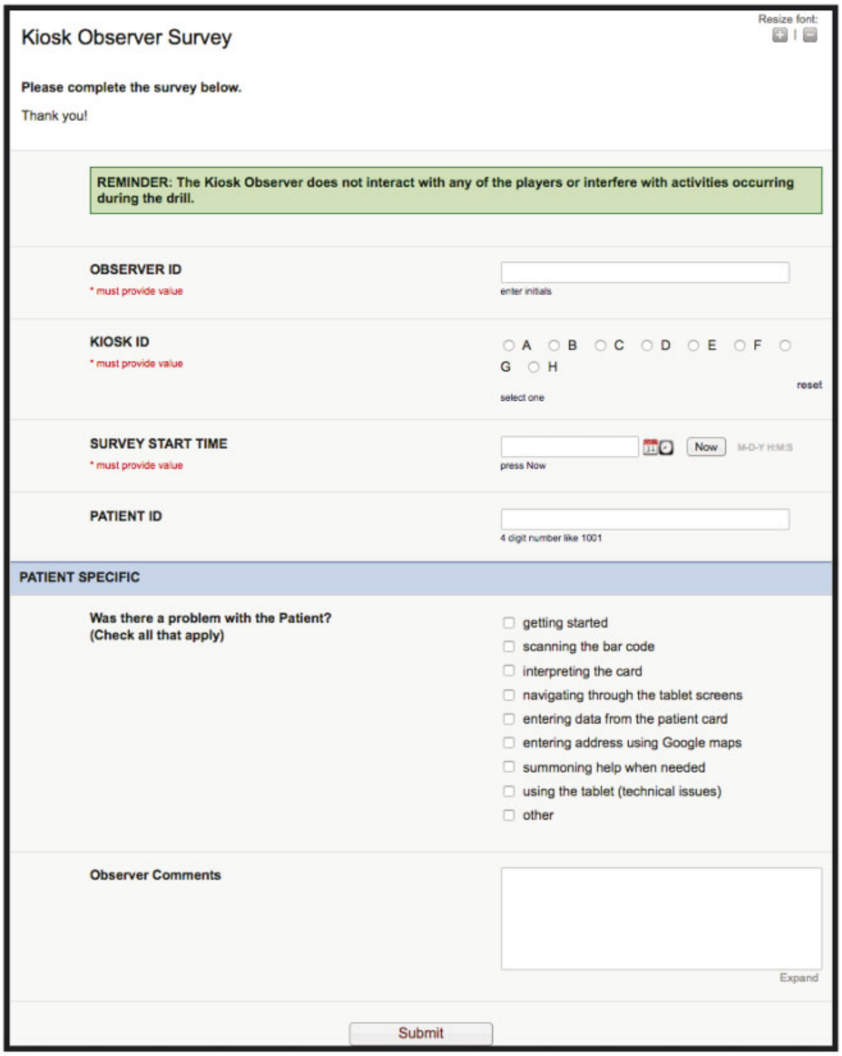
The Samsung Galaxy Tab A, model SM-T550 met the needs of the FE with minimal issues. Problems occurred with the camera functioning as a bar code scanner. In these occurrences, participants were instructed to manually enter the assigned patient ID. The additional tablets and charging capabilities enabled the FE to continue without interruption.

Data collection methods

EDICT. Data collection from EDICT was successful and each component of the database schema was gathered and transmitted to the secure server for later analysis. A key component of EDICT was the ability to scale the data collection and triage processes to meet the expanding or contracting needs of an MCI. During the FE, tablets were adapted to switch functions between nurse mode and kiosk mode to meet the needs of the patient surge. This provided a very efficient methodology to quickly process patients through the ED and reduce the triage time. Overall, the triage process progressed faster than anticipated and allowed the testing to be completed ahead of schedule.[21] This was due, in part, to the flexibility of EDICT to meet the demand.

Observer data. The observers were strategically placed to document potential issues or problems during the FE yet not interfere with the process. The data collected by the observers can be associated with a specific patient and nurse. REDCap functioned well as a data collection method and allowed flexibility while collecting the necessary data.

Video data. The videographer collected over 8 hours of video. The use of different views allowed a comprehensive overview of the



Kiosk Observer Survey

Resize font:

Please complete the survey below.

Thank you!

REMINDER: The Kiosk Observer does not interact with any of the players or interfere with activities occurring during the drill.

OBSERVER ID
* must provide value
enter initials

KIOSK ID
* must provide value
A B C D E F G H
reset
select one

SURVEY START TIME
* must provide value
Now M-D-Y H:M:S
press Now

PATIENT ID
4 digit number like 1001

PATIENT SPECIFIC

Was there a problem with the Patient? (Check all that apply)
- getting started
- scanning the bar code
- interpreting the card
- navigating through the tablet screens
- entering data from the patient card
- entering address using Google maps
- summoning help when needed
- using the tablet (technical issues)
- other

Observer Comments
Expand

Submit

Figure 3. Example of Kiosk Observer Collection Tool.

Figure 4. Secondary triage nurses' station with patients, observers, and IT staff.

FE and provided a robust review process. These videos can assist in resolving potential data problems (eg, missing patient ID, etc.). In addition, the GoPro added a unique perspective of the FE flow and process.

Participant data. Surveys provided feedback on participants' perspective of the FE and EDICT. This analysis provides important insights into the EDICT validation and the FE success, including the educational experience for the students and faculty.

Figure 5. Student with GoPro™ at kiosk station.

HCI data. The SUS surveys were completed by nurses, helpers, and students (see Supplementary Material Appendix D).[24] These surveys focused on EDICT's HCI elements and provided specific guidelines for future revisions to improve the user interface of EDICT. EDICT's mean SUS score was 72.93 (SD 16.49), which is considered above average.[25] In addition, the open-ended question provided details for improvements and revisions.

Secondary Triage Nurses' Station with Patients, Observers, and IT Staff

DISCUSSION

Testing and validating informatics tools for MCIs present a unique problem since a readily available population is not accessible. Furthermore, testing a new informatics tool during a real-life MCI may put victims' lives at risk. Based upon these key issues, other alternatives for testing and validation of information tools for MCIs were necessary. Our research team selected an FE to safely and effectively test our novel informatics tool, EDICT, for triaging patients during an MCI involving an IGSA.

This study was a large MCI FE with almost 400 participants and demonstrates that such an FE can effectively test informatics. However, an FE of this scale is complex and requires extensive planning and a highly skilled and diverse team of individuals. These findings add to the existing body of evidence to support the use of an FE to test informatics tools for MCIs particularly when a specific population is not available (ie, patients exposed to chlorine).

The inclusion of nursing students provided an appropriate pool of participants. The collaboration between the research team and faculty from the 2 nursing colleges was essential to the process. Considerations were made to ensure beneficial outcomes for both the students and the research team and provided a ready pool of participants for the FE.

Limitations

MCIs in real-life are unpredictable, and an FE simulation may not fully address all the issues that occur in an MCI. While the FE was not identical to the Graniteville incident, it did provide a similar environment to test EDICT. This article describes how a properly executed FE can effectively support the development and testing of MCI informatics tools.

Another limitation includes the use of nursing students as simulated patients. Nursing students are familiar with technology and medical terminology. Their use of EDICT may differ from a typical patient who has limited exposure and understanding of medical terminology and software.

CONCLUSION

Chemical exposures continue to occur around the world and validated informatics tools are needed to improve patient outcomes during chemical MCIs. Triage informatics tools must be developed and tested to improve the management of victims during chemical MCIs. When testing new technology and informatics tools, a large-scale FE can successfully simulate an MCI and provide essential feedback on the future development of these informatics tools.

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AUTHOR CONTRIBUTIONS

SBD, ERS, JVR, AST, JBC, NDB, HV, SRD, and JMC contributed to the conception, drafting, and revising of the manuscript; approved the final manuscript draft; and agreed to be accountable for the accuracy and integrity of the work reported.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *Journal of the American Medical Informatics Association* online.

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CONFLICT OF INTEREST STATEMENT

None declared.

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