ORIGINAL RESEARCH

Using Telemedicine in Mass Casualty Disasters

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ABSTRACT

Objectives: The goal of this study is to test an implementation and examine users' perceptions about the usefulness of telemedicine in mass casualty and disaster settings and to provide recommendations for using telemedicine in these settings.

Methods: Ninety-two US Army Forward Surgical Team (FST) members participated in a high-fidelity mass casualty simulation at the Army Trauma Training Center (ATTC). Telemedicine was implemented into this simulation.

Results: Only 10.9% of participants chose to use telemedicine. The most common users were surgeons and nurses. Participants believed it somewhat improved patient care, attainment of expert resources, decision-making, and adaptation, but not the timeliness of patient care. Participants reported several barriers to using telemedicine in the mass casualty setting, including (1) confusion around team roles, (2) time constraints, and (3) difficultly using in the mass casualty setting (eg, due to noise and other conditions).

Conclusions: There appear to be barriers to the use and usefulness of telemedicine in mass casualty and disaster contexts. Recommendations include designating a member to lead the use of telemedicine, providing telemedical resources whose benefits outweigh the perceived cost in lost time, and ensuring telemedicine systems are designed for the conditions inherent to mass casualty and disaster settings.

Key Words: biodefence, bioterrorism, disaster planning, disasters, organizational decision-making

Mass casualty events (MASCALS; defined as disaster events with a large number of victims that require rapid triage, acute assessment, few resources, and time pressure)[1] such as natural disasters (eg, storms, earthquakes, wildfires, floods), terrorist attacks, active shooter situations, and war battles are increasing. For example, the number of mass shooting incidents grew in the decade of 2008-2017 over 2.4 times greater than the preceding decade,[2] and major weather events (eg, extreme precipitation events, such as Hurricane Harvey) are increasing in intensity and frequency.[3] MASCALs require rapid triage, stabilization, and treatment of multiple patients simultaneously, and individuals injured in MASCALs often have complex or unclear injuries requiring diagnoses and/or care from specialized medical expertise that is not readily available on site (eg, head trauma). Many first responders lack the training to triage and provide care for severely injured patients and those with complex injuries.[4] In these cases, telemedicine (defined as the provision of health services at a distance through technological means) can allow more experienced health-care providers to advise, assist, and act as surrogate caregivers to first responders on the site of the disaster.[4]

While evidence suggests that telemedicine in mass casualty settings can be beneficial for patient outcomes,[5] prior work has not provided guidance on *how* to best use telemedicine in MASCALS. The implementation of telemedicine has been mostly studied in hospital and primary care settings[6]; settings that commonly have conditions such as controlled spaces, quiet telemedicine rooms, and buildings with reliable Internet connection. Such work has provided recommendations for telemedicine implementation and use, such as engaging in "more eye contact,"[7] using "active listening,"[7] and ensuring "robust support infrastructures."[8] However, MASCALs have conditions that differ vastly; conditions of loud noises, continuous danger, few resources, time pressure, multiple patients, and often unreliable Internet connections are inherent to the MASCAL context. These conditions make using telemedicine more challenging and make applying traditional telemedicine implementation recommendations often impossible.

The goal of the current study is to begin to close this gap, by examining both how telemedicine is used, as well as end users' perceptions of the usefulness of telemedicine in a MASCAL setting. In so doing, we seek

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to provide recommendations to help inform future design and implementation of telemedical devices for use in mass casualty and disaster events.

METHODS

We used a mixed method design that included both quantitative and qualitative approaches to best understand the *perceived* benefits and drawbacks of telemedicine in this setting. Specifically, we used surveys to glean perspectives quantitatively, and structured debriefs to supplement and serve an explanatory role to the survey responses. Below, we provide detail on the simulation itself and both data collection approaches.

Participants

Participants were the potential end users of telemedicine in mass casualty and disaster situations: members of US Army Forward Surgical Teams (FSTs), which are medical teams that are highly mobile, agile, and largely disconnected from outside support.[9] The purpose of these teams is to deploy to areas in which urgent US Army medical care may be needed on-site. This care is essential for stabilization of critically ill or wounded patients who would not otherwise survive transfer to the hospital. As such, FSTs are mobile, working often in or alongside battles and other MASCAL situations, and typically work with few resources. FSTs operate in tents of 900-1000 square feet powered by generators that include emergency, operating, and recovery rooms.[9] These teams typically have enough supply to perform 30 operations over a 72-h period before needing to be replenished.[9]

FSTs typically are composed of 20 personnel, including 3 general surgeons, 1 orthopedic surgeon, 2 certified registered nurse anesthetists (CRNAs), 1 operating room (OR) nurse, 1 emergency room (ER) nurse, 1 intensive care nurse, 1 administrative officer, and a varying numbers of additional support staff including OR technicians, licensed practical nurses (LPNs), and combat medics.[10]

While participating in the training was mandatory as part of the FST members' jobs, participation in the study was voluntary. This study was approved by the University of Miami Human Subjects Research Office.

MASCAL Simulation

The nature of the work FSTs complete requires specialized training to allow team members to become familiar with one another and learn to work in MASCAL conditions to provide emergency care for critically wounded patients with few resources. Members of FSTs are often unfamiliar with one another and do not typically train together until arrival at what was previously called the U.S. Army Trauma Training Center (ATTC; now the Army Trauma Training Detachment, ATTD) in Miami, Florida. Each FST spends 2 weeks together at ATTC (now ATTD) before deployment, undergoing a variety of training initiatives.

The training provided at ATTC/ATTD is in partnership with the University of Miami and Jackson Memorial Hospital/Ryder Trauma Center. At the time of this study, the facility allowed for realistic simulation of a variety of conditions encountered by deployed FSTs, including a treatment area housed in a tent set up to mimic the layout of real FST treatment tents. In addition to didactic training, the facility had access to a variety of simulators to train teams on management of particular injuries they were likely to be exposed to when deployed. Training ended with a capstone event in which the FST trained together in the simulated tent. FST members were dispersed between 4 different clinical areas (triage, pre-op, surgery, post-op) in the treatment tent, creating 4 treatment teams within each FST.

FSTs trained with only the resources that would be available to them in deployment, with simulated realistic conditions, to treat a complex load of simulated patients. In the current study, FSTs worked under numerous simulated conditions that resembled a MASCAL scenario. Specifically, we manipulated noise by playing music and noises that were likely to be encountered in the region teams would be deployed to (eg, helicopters whirring, gunfire, explosions). We manipulated time stress by scripting in a large number of incoming simulated patients with complex and emergent injuries, who arrived intermittently, with the number of upcoming arrivals unknown by participants. The simulation took place over a 12-h period in the overnight hours to ensure fatigue, a likely condition encountered in a MASCAL setting. We also simulated other realistic features that would pose additional challenges to the team, such as a patient with a simulated improvised explosive device (IED) that exploded and "killed" team members, and a simulated suicide bomber entering the treatment tent, removing team members from the simulation who did not notice the bomber and were, therefore, "killed." These "kills," realistic issues in this context, posed a challenge by resulting in a loss of manpower and expertise for the team.

Telemedicine Implementation

We introduced telemedical devices to the MASCAL simulation and trained participants on how to use it. In addition to receiving technical training on using the system (including information, demonstration, and opportunity to practice using the device), participants were told that the telemedicine would connect them with experienced surgeons in neurology and orthopedics who could help guide them in treating cases. Participants were told that activating the telemedicine was voluntary and could be used as needed. They were instructed that any member of any team could initiate the use of the telemedicine.

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Equipment

The telemedical device used was an Apple® iPad (Apple, Cupertino, CA) using DiMobile Care. We placed 1 iPad at the foot of each bed, at each station (eg, emergency, operation, recovery) in the treatment tent to allow all team members to access it. To provide an opportunity for the use of telemedicine, we scripted 2 complex patient cases that were likely to require expertise outside of the team to treat. The 2 cases were (1) a head trauma and (2) a pelvic fracture. These particular cases were selected as physician faculty at the ATTC believed that the competencies to treat these cases generally lay outside of the FSTs' expertise (eg, requiring neurosurgery and advanced orthopedic expertise), and as prior evidence suggests that diagnosis and treatment of extremity and pelvic injuries is among the most common reasons for teleconsults.[11] The telemedicine could be activated with the simple push of a button. On the receiving end of the telemedical device was an expert physician who gave guidance to the FST members that called in. The physician's responses were scripted so that each team who called in received a standardized response.

Measures

As previously stated, we used both quantitative (survey) and qualitative (structured debrief) measures.

Survey-Based Measures

The survey examined demographics, use of telemedicine during the simulation, and participants' perceptions regarding the usefulness of the telemedical device.

Demographics

We asked participants to indicate their gender, professional role, number of months of experience in trauma care, and prior experience with telemedicine, to examine potential confounders. We also asked about the clinical area(s) in which the participant worked during the simulation (triage, pre-op, surgery, post-op).

Telemedicine Use

To measure use of telemedicine, participants were asked whether they used the telemedicine during the simulation, and if so, for which patient case.

End Users' Perceived Telemedicine Usefulness

To determine end users' perceived usefulness of telemedicine in this context, we asked FST members to fill out a self-report measure. Items were on a 5-point Likert scale (1 = not at all; 5 = very much), and asked about multiple dimensions of telemedicine usefulness, including perceptions of its impact on improving patient care, facilitating attainment of expert resources, improving decision-making, increasing adaptation, and its effect on timeliness of patient care. A sample item includes, "To what extent did the use of telemedicine improve patient care?" See the Online Data Supplement for all survey items used in this study.

Structured Debrief

To better understand end users' experiences with telemedicine in this setting, we conducted postsimulation debriefs, also called "after action reviews" with each group of participants. The intent was to gather additional data that would serve to explain in richer detail the objective data. We used a semi-structured protocol that allowed for flexibility in the debrief process. Debriefs were facilitated by a trained facilitator.

Opinions on Telemedicine in the MASCAL Setting

To better understand opinions on how telemedicine was (or was not) useful in the MASCAL setting, we used the following debrief questions: "We noticed some teams initiated telemedicine, and some did not. Can those who did not please describe why? Can those who did describe their experience?", "What were barriers and facilitators to initiating telemedicine; that is, what made it more or less difficult/useful?", "How did treating the patient with [the head injury, the pelvic fracture] differ with and without use of telemedicine?", "What did you find to be the most valuable component of telemedicine?", "What did you find to be the least valuable component of telemedicine?", "Was telemedicine a distraction; that is, did it detract from patient care?", "What are implications of using telemedicine to enhance teamwork in emergency situations?", and "Would you find telemedicine useful on the job?"

Analyses

We examined descriptive statistics for the demographics. For telemedicine use, we computed frequencies and percentages. We examined usefulness of telemedicine for the subgroup that indicated that they did use the telemedicine. Due to the small sample size of this group, only descriptives were computed. Missing data were dropped. To examine opinions on telemedicine in the MASCAL setting, we identified overarching common categories and themes and used them to help explain survey data.

RESULTS

Demographics

Ninety-two clinicians participated. Team size ranged from 18 to 20 team members. Participants were mostly male (70.4%), had a variety of professional roles (eg, surgeon, nurse, medic, etc.), had a range of trauma experience levels, and most (85.3%) had no prior experience with telemedicine (see Table 1 for demographics).

Use and Usefulness of Telemedicine in the Mass Casualty Context

Only 10 of the 92 participants (10.9%) used the telemedicine system. This small sample size precluded advanced statistical

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TABLE 1

Demographics

Variable	Level	*n*	%
Gender		71	
	Male	50	70.4
	Female	21	29.6
Role		72	
	Surgeon	8	8.7
	Orthopedist	2	2.2
	OR RN	8	8.7
	CRNA	8	8.7
	Nurse	3	3.3
	ICU RN	1	1.1
	ER RN	2	2.2
	LPN	10	10.9
	OR Tech	8	8.7
	Medic	16	17.4
	Admin Officer	3	3.3
	Other	3	3.3
Trauma care experience (# months)		56	
	0-6	25	44.6
	7-12	5	8.9
	12-18	4	7.1
	19-24	1	1.8
	30+	21	37.5
Prior experience with telemedicine		75	
	Yes	11	14.7
	No	64	85.3

Abbreviations: RN = registered nurse; CRNA = certified registered nurse anesthetist; OR = operating room; ICU = intensive care unit; ER = emergency room; LPN = licensed practical nurse.

analyses; thus, we examined the descriptives in depth. Telemedicine users included 3 surgeons (30.0%), 2 nurses (20.0%), 1 orthopedist (10.0%), 1 administrative officer (10.0%), and 3 people who did not state their role (30.0%). Users had similar levels of trauma experience than nonusers (M = 40.00 [SD = 37.25] versus M = 24.50 [SD = 39.40] months, respectively; $t(39) = 0.83$, $P = 0.41$). Users and nonusers also had similar levels of previous experience with telemedicine ($n = 1$; 10.0%, and $n = 7$; 11.7%, for users and nonusers, respectively).

The treatment areas in which telemedicine users worked included surgery ($n = 4$; 40.0%), post-op ($n = 1$; 10.0%), and those who moved between areas (eg, an admin officer floating between areas, a nurse providing advanced trauma life support, etc.; $n = 4$; 40.0%). Seven ($n = 7$; 70.0%) used the telemedicine for a neurology consult in relation to the head injury case, 1 ($n = 1$; 10.0%) indicated using the telemedicine for the pelvic fracture case, and 2 ($n = 2$; 20.0%) did not say for which case they used the telemedicine.

Those who used the telemedicine believed it somewhat improved patient care (M = 3.78; SD = 1.39), attainment of expert resources (M = 3.89; SD = 1.54), decision-making (M = 3.67; SD = 1.50), adaptation (M = 3.44; SD = 1.67), and that it did not improve the timeliness of patient care (M = 2.78; SD = 1.72) in the MASCAL context (see Table 2).

Opinions on Telemedicine in the MASCAL Setting

Participants reported that the simulation felt realistic, yet there were several barriers to using the telemedicine. Major barriers identified from themes included: (1) confusion around team roles, (2) time constraints, and (3) difficultly using telemedicine in the MASCAL setting. We expand on each of these themes in the discussion section.

DISCUSSION

Despite the fact that the current sample had relatively little experience in trauma care, with almost half having 0-6 months of experience, only 10.9% of participants chose to use the telemedicine in the simulated MASCAL context to consult an expert to assist with complex trauma procedures. This indicates that there were likely several barriers to choosing to use the telemedicine in this setting, despite its purported benefits. Furthermore, those who used it found it only moderately or not useful in the mass casualty context. As previously mentioned, we explored these issues in more depth during postsimulation debriefs. Themes from these debriefs and lessons learned are summarized below.

Barriers to Telemedicine Use in the Mass Casualty Setting: Lessons Learned and Three Key Recommendations for Design and Implementation

Role Ambiguity

Team role ambiguity was cited as a barrier to telemedicine use. Specifically, participants reported that they were not sure if there was a particular team member that was designated or should lead the decision to initiate the telemedical consultation. This lack of clarity and direction led to diffusion of responsibility and, ultimately, low rates of telemedicine use. Supporting this, our results show that a variety of roles used the telemedicine, including surgeons, orthopedists, nurses, administrative officers, and others. As such, we recommend that response teams be trained to select a designated team member who is responsible for initiating use of the telemedicine. This recommendation is echoed by Rolston and Meltzer (2015),[4] who state that "designating a telemedicine leader within the incident command system could improve planning, communication, and coordination of disaster relief efforts."

We recommend that the team member selected to lead the choice to activate and use telemedicine be assertive, respected by the team, and have the latitude to lead this decision. Alternatively, a shared model could be used wherein 1 team member makes the decision to use telemedicine, and another is responsible for then activating the system and coordinating

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TABLE 2

Perceived Usefulness of Telemedicine in the MASCAL Context as Reported by Telemedicine Users

Item	M (SD)
To what extent did the use of telemedicine improve patient care?	3.78 (1.39)
Indicate the extent to which you believe telemedicine helped your team find and obtain "expert" resources.	3.89 (1.54)
To what extent did the use of telemedicine improve the quality of the leader's decision making?	3.67 (1.50)
Indicate the degree to which you believe that the use of telemedicine influenced the way your team adapted its patient care plan.	3.44 (1.67)
To what extent did telemedicine improve the timeliness of patient care?	2.78 (1.72)

$n = 10$; Scale for all items was 5-point Likert scale, with 1 = not at all, 5 = very much.

its usage. While it has been recommended to fill such roles by dedicated resource such as a technician or specialized nurse,[12] this is not logistically feasible in a mass casualty response team that has limited resources. Thus, clinicians will need to be trained to engage in, and in roles for using, telemedicine.

Perceived Time Constraints

In addition, participants reported that they believed they did not have time to initiate and participate in a telemedical consultation, despite its benefits. In hindsight, this finding makes sense, as teams were overwhelmed with an influx of critically wounded simulated patients in a chaotic and time-stressed context. Activating the telemedicine would require describing the patient's condition and engaging in a potentially time consuming 2-way conversation. To address this barrier, we recommend that the system be designed and marketed to provide the most benefit for users with the least perceived time loss.[13]

Additional work should be done to determine the conditions and assistance that is of greatest need by responders to mass casualty and disaster settings. Initial recommendations include providing telemedical resources for triage, stabilization, and treatment of complex trauma conditions that occur in these settings but whose treatment is typically outside the scope of a first responders' skillset, eg, neurological trauma, cardiology, ophthalmologic issues. For instance, in this study, we found that the telemedicine was used most frequently to consult on a closed head injury with neurological implications, requiring advanced expertise that lay outside of the typical FST. Furthermore, these resources should be quick and easy to access and use. That is, the system should be able to be activated with little preparation; complicated operation and protection features, such as multiple buttons, clicks, and passcodes can be a potential barrier to use under time pressure.[12,14]

Along these lines, work investigating user-centered design of other types of emergency response technologies used in MASCAL events (eg, patient monitoring systems) suggests that users prefer simple systems that hide unnecessary functions and show only essential, nonredundant information.[15] Furthermore, the response by the person or resource on the other end of the telemedicine should be quick, accurate, and reliable. Having a system that is slow to respond or unreliable will disincentivize future use. In addition, providing ample training opportunities for participants to learn and practice using the telemedicine in lower-stakes conditions should also decrease the barrier of perceived time constraints. That is, having sufficient experience initiating and using the telemedical device during training should reduce the technological learning curve of this system. The increased familiarity and comfort with the system gained from this should lead users to increase their perceptions that the telemedical system can be used easily and swiftly in a context in which their cognitive resources are more limited.

Perceived Utility of Telemedical System in MASCAL

For those participants who did use the telemedicine, as shown in Table 2, they perceived that it had only moderate or low utility in this setting. When discussed in the debriefs, a key issue that was mentioned was noise. Simply put, it was difficult to hear the expert on the other end of the telemedicine consultation, given the conditions of loud noise in this setting. This is similar to other studies on technological communication in mass casualty disasters, wherein participants commonly reported issues with radio and phone communications, miscommunications, and associated delays due to communication issues.[16]

For a similar reason, prior work examining the needs of mobile users in MASCAL settings has cautioned against hardware features such as operation by means of voice commands.[17] Prior work has recommended providing headphones to overcome the challenge of communicating in a noisy environment.[18] Additional work should be done to explore this in more depth. For example, wireless Bluetooth headphones are now widely available, which can allow for the provider to be mobile rather than being wired into a telemedicine system. Emerging research is also exploring the use of augmented reality headset systems with real-time feedback for warzone telecare.[19] However, it is unknown how features such as Bluetooth functionality and augmented reality would work in many mass casualty and disaster

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TABLE 3

Recommendations for Telemedicine Design and Implementation in Mass Casualty and Disaster Settings

Recommendations	Strategies to Enact
1. Train response teams to have a designated team member responsible for initiating use of telemedicine	• Select a role or a person who is responsible for *deciding to initiate* telemedicine • Select a role of a person who is responsible for *activating and connecting with* telemedicine • Train team on members' individual roles and responsibilities around telemedicine • Provide teamwork training around assertiveness, psychological safety, situation monitoring, and backup behavior to equip team members to speak up, assist, and share leadership when the designated telemedicine leaders are unavailable or failing to recognize the need for, or failing to appropriately use, telemedicine
2. Provide telemedical resources that are amenable to use in time-pressured situations	• Provide training to reduce perceived burden and increase perceptions of benefit of telemedicine (e.g., advertise ease of use and instant availability of specialized resources for complex cases) • Enable a simple, 1-button activation of system • Limit or remove passcodes and other constraints to access system • Build in capability for immediate response by expert • Provide experts for the most difficult cases in which responders likely do not have expertise (e.g., head injury/neurology) • Utilize technology that reduces lag time
3. Provide tools to facilitate appropriate telemedicine use in conditions around the mass casualty/disaster setting	• Provide a post that the telemedicial device can hang onto near the patient, to allow it to be seen easily from multiple angles (if not a standalone or headset device) • Choose a device with a large screen size to improve visibility • Choose a device that can be operated while wearing gloves (i.e., non-touchscreen) but that does not rely on voice commands for operation • Choose a device with a long battery life and provide portable battery charger packs to allow recharge without access to an outlet • Consider adding wireless headphones to system to allow responders to better hear expert while retaining mobility • Use features that are agile and robust in areas with limited or damaged infrastructure

settings with limited or destroyed technological infrastructure. In addition, such headset augmented reality systems as well as traditional headphones would allow for only 1 person on a team to hear and interact with the specialist, unless multiple headsets were provided for the entire team (more of a logistical, and financial, burden). It is often beneficial for the whole team to be in the communication loop to develop shared mental models and facilitate work.[20,21] Thus, more work needs to be done to determine best practices for using telemedicine in a noisy environment.

Another hardware challenge identified in prior user-centered work in this area is that of touchscreen technologies.[17] The touchscreen functions on many tools are inoperable when wearing gloves, thus creating a barrier to use in a medical setting. While many technologies that rely primarily on touchscreen functions also support use by means of voice commands, as mentioned above, use of voice commands to operate technology could be difficult in the MASCAL setting due to noise. As both of these features are prevalent in mobile technologies that support telemedicine, future work should examine these issues in more depth.

These barriers and associated recommendations are summarized in Table 3.

LIMITATIONS AND FUTURE RESEARCH

As with any study, there are several limitations in the current study. First, our work was conducted under simulated conditions. While this simulation was highly realistic, and allowed us to manipulate and control some factors in the study, further study is needed to examine the usability (ie, the extent to which an interface facilitates the device's ability to be used) of telemedical device interface designs in real mass casualty and disaster settings. Namely, user design needs may change in the presence of extreme environments, including the presence of increased stress (eg, MASCAL).[22] It is beyond the scope of the current study to provide complete guidance on usability assessment(s); however, we direct readers to the common usability assessments that leverage subjective and objective metrics[23] often including (but not limited to): satisfaction, learnability (ie, how quickly a device's use can be learned and applied), contextual features, and outcomes.[24]

In addition, 10 participants chose to use the telemedicine. This was an important finding in itself, showing that there were barriers to using telemedicine in this setting. However, this small sample size also limited our ability to assess a potentially wider range of opinions on the use of telemedicine in this setting. It is possible that with a larger sample of users, we would have uncovered additional interesting usability barriers. Future work should be done requiring participants to activate the telemedicine in this setting to help uncover additional issues. Similarly, as our data were subjective and based on simulated patients, we are limited in what we can conclude with regard to objective outcomes of telemedicine in the MASCAL context. Future work should investigate factors such as the time difference between triage and treatment with and without telemedicine in the MASCAL context, as well as patient outcomes.

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Despite these limitations, there are several strengths in this study. Key among these is our sample of real FSTs, clinicians who are true first responders to mass casualty situations, increasing external validity. Thus, while our sample was small, it was composed of a select group of key end users of the technology in this context. In addition, the simulation used was high-fidelity, in that it was designed by faculty with trauma care expertise and military experience, and supported by the Army to ensure conditions were as realistic to a real mass casualty as possible. This increases external validity of our findings.

CONCLUSIONS

Telemedicine has the potential to improve disaster and mass casualty response by connecting responders with global experts who can consult and assist in patient triage and treatment. However, we uncovered several barriers to the use of telemedicine in this context. We recommend that teams designate a member to lead the use of telemedicine, to provide telemedical resources whose benefits outweigh the perceived cost in lost time, and to ensure telemedicine systems are designed for the conditions inherent to mass casualty and disaster settings (eg, noise, time pressure). More work should be done to uncover additional barriers and to test potential solutions to improve telemedicine design, implementation, and usefulness in this setting.

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Authors' Contributions

M.E.G. helped to design the measurement and evaluation plan, analyzed the data, and wrote the first draft. S.C.S. helped guide the study design and measurement plan and oversaw evaluation. A.M.H. helped to design the measurement plan and evaluation. A.M. helped to design the study, and designed the physician cases used in the simulation, including the telemedicine cases. C.S. helped to design the study, and designed the physician cases used in the simulation, including the telemedicine cases. E.S. designed and oversaw the study. All authors read and approved the final version of the manuscript.

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Supplementary material

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REFERENCES

1. Killeen JP, Chan TC, Buono C, et al. A wireless first responder handheld device for rapid triage, patient assessment and documentation during mass casualty incidents. *AMIA Annu Symp Proc*. 2006;2006:429-433.
2. Office for Victims of Crime. Mass casualty shootings. Office for Victims of Crime website. https://ovc.ncjrs.gov/ncvrw2018/info_flyers/fact_sheets/2018NCVRW_MassCasualty_508_QC.pdf. Published 2018. (Accessed March 10, 2019).
3. Kunkel KE, Karl TR, Brooks H, et al. Monitoring and understanding trends in extreme storms: state of knowledge. *Bull Am Meteorol Soc*. 2013;94(4):499-514.
4. Rolston DM, Meltzer JS. Telemedicine in the intensive care unit: its role in emergencies and disaster management. *Crit Care Clin*. 2015;31:239-255.
5. Garshnek V, Burkle FMJ. Applications of telemedicine and telecommunications to disaster medicine: historical and future perspectives. *J Am Med Inform Assoc*. 1999;6:26-37.
6. Ross J, Stevenson F, Lau R, et al. Factors that influence the implementation of e-health: a systematic review of systematic reviews (an update). *Implement Sci*. 2016;11:146-158.
7. Bulik RJ. Human factors in primary care telemedicine encounters. *J Telemed Telecare*. 2008;14:169-172.
8. Broens THF, Huis in't Veld RM, Vollenbroek-Hutten MM, et al. Determinants of successful telemedicine implementations: a literature study. *J Telemed Telecare*. 2007;13:303-309.
9. Valdiri LA, Andrews-Arce VE, Seery JM. Training forward surgical teams for deployment: the US Army Trauma Training Center. *Crit Care Nurse*. 2015;35:e11-e17.
10. Department of the Army. *Employment of Forward Surgical Teams: Tactics, Techniques, and Procedures (FM 4-02-25)*. Washington, DC: Department of the Army; 2003.
11. Lambrecht CJ. Telemedicine in trauma care: description of 100 trauma teleconsults. *Telemed J*. 1997;3:265-268.
12. Gagnon MP, Duplantie J, Fortin JP, et al. Implementing telehealth to support medical practice in rural/remote regions: what are the conditions for success?. *Implement Sci*. 2006;1:18-26.
13. Obstfelder A, Engeseth KH, Wynn R. Characteristics of successfully implemented telemedical applications. *Implement Sci*. 2007;2(1):25-36.
14. Oviatt SL. Human-centered design meets cognitive load theory: designing interfaces that help people think. In: Proceedings of the 14th ACM International Conference on Multimedia, Santa Barbara, California, 2006:871-880.

https://doi.org/10.1017/dmp.2019.156 Published online by Cambridge University Press

15. Gao T, Kim MI, White D, et al. Iterative user-centered design of a next generation patient monitoring system for emegrency medical response. *AMIA Annu Symp Proc*. 2006:284-288.
16. Stanescu A, Boerlu C, Copotoiu S-M. Mass casualty incidents and disaster participation in real versus simluated events in Romania. *Acta Med Marisiensis*. 2016;62:15-20.
17. Mentler T, Herczeg M, Jent S, et al. Routine mobile applications for emergency medical services in mass casualty incidents. *Biomed Tech*. 2012;57:784-787.
18. Latifi R, Weinstein RS, Porter JM, et al. Telemedicine and telepresence for trauma and emergency care management. *Scand J Surg*. 2007;96:281-289.
19. Rojas-Munoz E, Cabrera ME, Andersen D, et al. Surgical telementoring without encumbrance: a comparative study of see-through augmented reality-based approaches. *Ann Surg*. 2019;270:384-389.
20. Mathieu JE, Heffner TS, Goodwin GF, et al. The influence of shared mental models on team process and performance. *J App Psychol*. 2000;85: 273-283.
21. Cannon-Bowers JA, Salas E, Converse SA. Shared mental models in expert team decision making. In: Castellan NJ, ed. *Individual and Group Decision Making*. Hillsdale, NJ: Lawrence Erlbaum Associates; 1993:221-246.
22. Hancock PA, Szalma JL. Operator stress and display design. *Ergon Des*. 2003;11:13–8.
23. Han SH, Hwan Yun M, Kim K-J, et al. Evaluation of product usability: development and validation of usability dimensions and design elements based on empirical models. *Int J Ind Ergon*. 2000;26:477-488.
24. Coursaris C, Kim D. A qualitative review of empirical mobile usability studies. In: Proceedings of the 12th Americas Conference on Information Systems, Acapulco, Mexico, 2006:2885-2897.

https://doi.org/10.1017/dmp.2019.156 Published online by Cambridge University Press