Enabling Patient Information Handoff from Pre-hospital Transport Providers to Hospital Emergency Departments: Design-Science Approach to Field Testing

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Abstract

The transfer of complete patient information between EMS personnel and hospitals ED staff is a major challenge in emergency medical care. This study used a design science methodology to design, demonstrate in use, and field test a mobile and web based EMS software solution that provides textual and multimedia information for emergency responses. The system was field tested for a period of three months in rural Minnesota. A mixed method approach was employed to assess the system use and perceptions of value in patient handoff. Data was drawn from system log files over a 3-momth period and in-depth interviews conducted at the end of the study with an equal number of representatives from EMS personnel and ED staff. Findings suggest the use of mobile and web based EMS solutions may be more appropriate in rural settings with long transport times and for more sever incidents – where participants found value in the use of information for patient pre-registrations and early notifications. A systematic longer-term testing of clinical use of the system is suggested as the next step in further demonstrating the value of such a mobile solution.

1. Introduction

The transfer of patient care and responsibility from one care provider to the next is referred to as patient handoff, or handover [35]. Transfer of accurate and timely information during patient handoff is a critical clinical and organizational process to ensure continuity of care [1, 28] and to secure patient safety [25]. Communication failures in patient handoff have been cited as a major cause for a range of medical errors (nearly 70%) in healthcare [38]. The communication challenges are further magnified in fast-paced, short-stay, and critical care environments such as the ambulance or emergency department (ED) [9, 28, 37]. The nature of the communication process in emergency medical settings is complex and cognitively taxing for clinicians, further increasing information handoff challenges [30].

Prior research on pre-hospital emergency medical services (EMS) information handoffs to hospital emergency departments has identified numerous challenges in the handoff process [28, 37], including limitations with existing mobile software based documentation systems such as the electronic patient care record (PCR) [12, 37], and outdated and/or immature information infrastructure [8, 32]. The literature has also noted potential improvements including more robust and usable software systems [29] and increased use of emerging mobile technologies [15]. Prior work has also suggested use of mobile health (m-Health) applications to improve the timeliness of information handoff may have greater impact on patient care for EMS incidents that present a higher level of severity (e.g., major trauma) and longer transport times (e.g., in rural and remote environments). These situations require reliable, accurate, and timely information while providing opportunity for adequate review of information by ED staff and the ability to make pre-arrival decisions and preparations [2].

While a variety of commercial m-health applications have recently been introduced to the EMS marketplace, there is a paucity of research-based development and testing. The goal of this study was to explore, design, and build a software system to address the information handoff challenges as found in the EMS handoff literature. A field demonstration and evaluation of the system's applicability was conducted in a rural field test location with an EMS provider and

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hospital in Northwest Minnesota (MN). More specifically, this research aimed to design a mobile web-based system adapted to the rural EMS context and then explored the utility and practitioner perspectives of that system.

2. Background: Information Handoffs

It is quite evident that there is a growing interest in handoffs. Perhaps the biggest reason behind such interest was the decision made in 2006 by the Joint Commission to make requirement 2e part of its National Patient Safety Goals [17]: "Implement a standardized approach to 'hand off' communications, including an opportunity to ask and respond to questions." [18]. To date, improving the handoff process with specified and standardized guidelines remains a challenge for many healthcare settings. An effective solution for handoff includes both a standardized process and set of policies as well as supportive technologies [1]. This paper presents a technology design and artifact that incorporates both a set of standard techniques for collecting and communicating information and a set of supporting mobile technologies [7].

2.1. Information handoffs in EMS

For EMS specifically, information processes frequently occur as verbal and written information exchanges. In a typical scenario, an ambulance paramedic unit collects patient and incident information from the patient, family members, or bystanders. These personnel may then write the collected information in various places such as a paper form, any available piece of scratch paper, a latex glove, or other convenient location [32, 37]. These information collection points act as a 'staging location' until electronic records can be completed. The paramedic unit will conduct a radio or cell phone call to the receiving ED and relay medic unit information, basic patient demographics, chief complaint, primary and secondary paramedic impression, noteworthy situational context (e.g., mechanism of injury), interventions performed, and estimated time of arrival. ED staffs do not always receive the radio communication, as it requires an available resource that may not be available at the time of the call. Frequently the patient will arrive at the ED in advance of a comprehensive electronic record [10]. The paramedic unit typically has not had time to transfer all of the information from the staging location into the record prior to patient handoff. Hence, a verbal information handoff to providers at the receiving ED is provided, many times in an environment that is not conducive to hearing and understanding important details [40].

In emergency medical settings, written and verbal information is often forgotten, misplaced, omitted, or unreadable [3, 32]. For example, in one study, necessary information such as patient's name (only reported 67.6% of the time) was not included in the verbal report [43]. In another study, verbal information handoffs occurred for only 44% of patient handoffs [9]. Additionally, communication and information problems have been sited to be responsible for 70% and 20% of adverse events in healthcare institutions in the US, respectively.

Indeed, several challenges have been found in the literature on EMS handoffs and validated through prior work by the research team through interviews with paramedics and ED staff [2]. These EMS handoff challenges have been identified in relation to the combined process, information and technology tools available to support handoff. These can be summarized as follows:

1. Limited time for paramedics to collect data on-scene [32],
2. Gaps in information flow due to workflow interruptions with the emergency practitioner,
3. End-user resistance to use technology due to perception that technology will get in the way of patient care [21],
4. Few mobile, portable electronic tools for paramedics to efficiently collect patient information,
5. Lack of information exchange standards and practices [1, 5], and
6. Frequently missed, unreported, or incorrectly reported information to the ED [41].

A systematic study review [7] recommended standardization and technology solutions to address the communication and information availability challenges in order to improve the information handoff process. The following section addresses the literature on standardization and information use in EMS.

3.1. Standardizing Patient Handoffs

Although standardization is not the only path of improvement for patient handoffs, it represents one major approach towards improvement and has been a focus of regulatory organizations [16]. Differing goals, supporting technologies, and processes across individual caregivers and their organizations makes suggesting a single uniform pattern of handoff behavior very difficult [20, 33]. In the context of this paper, two types of standardization are addressed, 1) handoff content, and 2) handoff procedure.

Standardizing content includes listing essential information that should always be provided in handoffs [16]. Process standardization includes defining the important needs of caregivers that should be addressed as they develop or evaluate their handoffs practices [16]. Indeed, many emergency care providers are unable to identify a standard operating procedure for the information handoff period [11]. It has been suggested that the lack of conformity and structure during critical information traffic is a significant cause for redundant or omitted information, most of which is either verbal or handwritten [4]; this can lead to medical errors [14]. The literature is rich with handoff observations that fail to communicate important information, often with critical consequences for patients [6, 22, 42]. These observations suggest that handoff standardization may reduce errors that lead to negative patient care consequences [13, 26]. For example, according to [23], standardization of handoff protocols could have prevented an estimated 11% to 35% of observable errors in a sample of surgical malpractice cases.

Yet, a standard procedure in and of itself may not improve handoff at all. For example, [39] found that 56.6% of the information given at verbal handover by ambulance crews was accurately retained by ED staff before the introduction of a structured information handoff process. Several techniques have been identified to help reform the handoff process. The potential use of these tools/techniques is to prevent information loss during the process and to insure the timely and accurate exchange of information. Medical organizations typically adopt the tools/techniques that best suite their culture and needs. The following list provides an example of such techniques adopted from [36].

Audiotapes/Audio recording: Audio recording a verbal handoff is one of the fastest and most effective ways of communicating patient information. Its effectiveness increases more if it is combined with the use of checklists. It enables caregivers to handoff detailed patient information to one another easily. However, it does not promote a 2-way communication through which the receiving caregivers can ask the outgoing caregivers questions. Ideally, the outgoing caregivers will wait until the audio recording is reviewed by incoming caregivers, allowing for face-to-face discussion. In the context of EMS, it is often difficult for a medic to wait at the hospital until the ED staff members have reviewed all available information, especially during a busy time of day. Audio recordings allow for freeform information collection for reporting any number of contextual variables.

Forms and Checklists: These are developed for the purpose of reducing information loss. Standardized forms enable fast and consistent communication of patient information. Unlike audio recordings, caregivers can look through them quickly allowing for more time to ask and answer questions during handoffs. However, these predefined forms may not necessarily encompass a full range of contextual details or specific patient conditions.

The Five-Ps: Sentara Health Care in Norfolk, VA developed a technique for the purpose of simplifying the patient information handoff process with 5 specific information prompts. One disadvantage of the Five-Ps over forms and checklists is that the Five-Ps is dependent on the caregiver's ability to understand and provide the right information for the right category of the Five-Ps. Medics receive different levels of training and education making it difficult to assume they will each use the technique in the same way. Issues such as consistency and completeness are concerns when using such techniques. The Five-Ps include:

1. **Patient:** Name, Identifiers, Age, Sex, Location
2. **Plan:** Patient Diagnosis, treatment plan, next steps
3. **Purpose:** Provide a rationale for the care plan
4. **Problems:** Explain what's different or unusual about this specific patient
5. **Precautions:** Explain what's expected to be different or unusual about the patient.

SBAR: A technique to facilitate communication between a team of caregivers about a patient's condition. The acronyms stand for:

1. **S:** Situation - Complaint, diagnosis, treatment plan and patient's wants and needs
2. **B:** Background - Vital Signs, mental and code status, list of medication and lab results
3. **A:** Assessment - Current provider's assessment of the situation
4. **R:** Recommendation - Identify pending lab results and what needs to be done over the next few hours and other recommendations for care.

While the patient handoff standards described above have been implemented in various health care settings, little is known as to their effectiveness when compared to each other. Each standard has identified strengths and limitations associated with its use. Furthermore, the literature has not addressed how these standards could be best supported with software-based technologies for the specific EMS handoff context, a gap addressed in this paper.

4. Research Design

The research design of this study applied a design-science research (DSR) approach, using case-study methodology with qualitative and quantitative data collection and analysis techniques for evaluation. The primary design, development, and evaluation of the artifact component of the design-science research approach was based on the DSRM Process Model put forth by Peffers et al [34]. Justifications to why the general DSR approach and the specific DSRM model are provided below.

The design science research approach has been sited to fit studies aiming fundamentally to follow certain guidelines and principles in designing and evaluating artifacts that solve specific problems [24]. This approach fits this study as it aims to design a system to improve patient information handoffs between ambulance providers and ED staff for emergencies in rural areas. The DSRM process model put forth by Peffers et al [34] was chosen because: 1) it is consistent with the DSR literature as its main components were extracted from seven highly sited DSR papers, 2) it provides researchers and reviewers with a nominal process that is clear to follow and evaluate, and 3) it also provides researchers and reviewers with a mental model that is easy to understand and remember.

Table 1: DSRM Process Model

Activity	Description
Problem Identification	Define a specific problem
Objective of A Solution	Define a set of goals to be accomplished
Design and Development	Design and develop the IT artifact
Demonstration	Find a suitable context to use the artifact to address the identified problem
Evaluation	Observe how the artifact addresses the problem and use quantitative or/and qualitative metrics as measures
Communication	Report the contributions of the study

A mixed method fits well this study given that: 1) qualitative inquires will be used to explore the social or human aspect of the study, e.g., user perceived values of the system, to understand the context and build a complete picture about the phenomena [19]; and 2) quantitative inquiries will be used to explore the system's usage and performance. Additionally, this research study is best suited to be conducted within a natural setting (field study), which has been sited to have many advantages over experimental studies [83]. Leroy et al. [83] listed some of the advantages including the ability to: 1) help answer difficult questions such as: why was the system not utilized, and, how could it have led to incorrect decisions? 2) Consider several context characteristics of the work environment, culture, lifestyle and personal preferences when searching for explanations, 3) study normal activities in their normal environment, and 4) generate very rich data.

4.1. Objectives of the Solution

When thinking about the objectives of the design solution, there are three main aspects that need to be considered as shown in Figure 1. **First,** the technology solution in-use must be efficient and easy to use. Thus, it should help facilitate patient information exchange between pre-hospital providers and ED and trauma center care providers in rural areas and in near-real time fashion in a way that does not interfere with the treatment of the patients. **Second,** the solution shall enforce the use of data collection techniques/standards to overcome missing data problems and therefore aid in the reduction of medical errors. **Finally,** the solution should overcome the challenges imposed by the fast-based nature of the EMS settings, the cultural barriers of stakeholders to accept using cutting edge technology interventions in their daily operations, and the individual's resistance to change, especially in regards to new process change requirements.

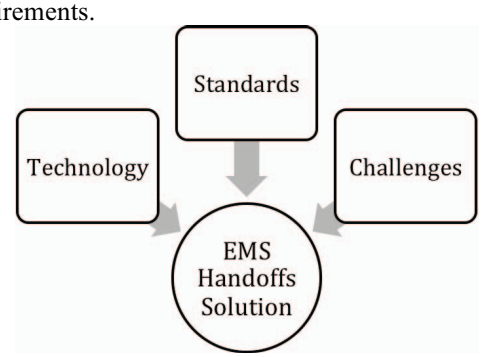

Figure 1: Considerations for the New Solution

4.2. Design and Development

The proposed system leverages a mobile application and smartphone capabilities to allow pre-hospital providers to capture digital images, record both video and audio records and collect basic patient information and send this information to the desired ED or trauma center [2]. The mobile application utilizes commercial 4G wireless networks to securely transmit the information to an application middleware subsystem, which immediately sends notification messages to designated ED nurses using pager, email

and/or phone call. The transmitted data can be accessed using a secure web application interface in ED and trauma center. Upon logging to the web application, ED nurses can browse the newly sent incident and notify paramedics that the incident was received (acknowledge). The web application allows ED nurses and paramedics to exchange text messages if further communication is needed. Furthermore, the web application interface combines location-based services, cloud-computing storage, visualization toolkits and web-services technologies enabling incident records to be visualized in list, map and detailed views via an easy to use interface. The following three sections 4.2.1, 4.2.2, and 4.2.3 respectively describe the design and development decisions taken to address each of the three main aspects mentioned in Section 4.1.

4.2.1. Efficiency and ease of use. Successfully designing and implementing an efficient and yet easy to use solution has been part of a multi-year design and development process resulting from:

1) Experience acquired through close interactions with users via observations, questionnaires, interviews, and focus groups on the ground. Combining such interactions with an agile methodology allowed us to enhance the system to align with user expectations and needs. Examples of specific enhancements include adding a "Date of Birth" field to the mobile application and emergency room (ER) website, adding the automated phone notification feature to tell the ER listener if notes, pictures, or audio recordings were provided by the medic, adjusting the medic mobile app so that the medics are not required to fill in every data element if they do not want to, and installing a mobile phone at the emergency room nurses station in order to receive automated phone notifications from EMS.

2) Art acquired through shifting the system's complexity from the front end to the system's backend. Utilizing a service-oriented architecture (SOA) has enabled us to integrate multiple advanced technologies, such as telephone services, security services, and geographical information services, to create a seamless patient information communication experience for all users. Also, with the entire burden shifted to the backend, we managed to create a simple mobile and web interfaces that allow users to navigate to the most advanced features of the system in less than four clicks.

3) Discipline acquired through the use of a systematic approach in measuring performance. For example, we implemented customized system logs to capture the user experience through registering user clicks and the time users spend performing selected activities, such as recording audio and entering patient information. Thus, we managed to have quantitative indicators to measure system performance, analyze information, and make evidence based adjustments.

4.2.2. Utilizing a standardized data collection technique. Section 3.1 listed five examples of the common data collection techniques used in patient information handoffs. To our knowledge, none of these techniques have been cited in the literature as having been used within a mobile software based solution to address EMS patient information handoff between paramedics and ED staff. The following table presents the suitability of these In general, pictures, text messaging and videos were less useful techniques to fit the EMS patient information handoff context.

Table 2: Data Collection Techniques in Patient Handoffs

Technique	EMS Patient Information Handoffs	
	Suitable?	**Why?**
Audiotapes	No	Does not allow for 2-way communication
Forms and Checklists	No	Predefined, lacks flexibility, difficult to customize for each patient
The Five-Ps	Yes	Simple, short, flexible, and not too abstract or too specific
SBAR	No	Includes reports for pending lab results making it more suitable for handoffs in other care settings

Although more abstract and loosely defined than the other techniques mentioned in Table 2, the Five-Ps technique allows for the flexibility and customization of information needed to fit the EMS context and thus we incorporated this technique in our mobile application in the following way.

Table 3: Mapping the Five-Ps with the Mobile App Features

The Five-Ps	Audio Tab	Image Tab	Patient Tab	Free Notes

Patient: Name, Identifiers, Age, Sex, Location	✓		✓	✓
Plan: Patient Diagnosis, treatment plan, next steps	✓		✓	✓
Purpose: Provide a rationale for the care plan	✓			✓
Problems: Explain what's different or unusual	✓	✓		✓
Precautions: Explain what's expected to be different or unusual	✓	✓		✓

The table above shows that all the information collected through the Five-Ps technique can be delivered using the digital audio and free notes features. The images are designed to explain what is different or unusual about a specific patient, as well as what is expected to be different or unusual. The patient tab is designed to capture basic textual information about the patient, such as name, gender, age, data of birth, mechanism of injury, and interventions given on the scene (see Figure 2).

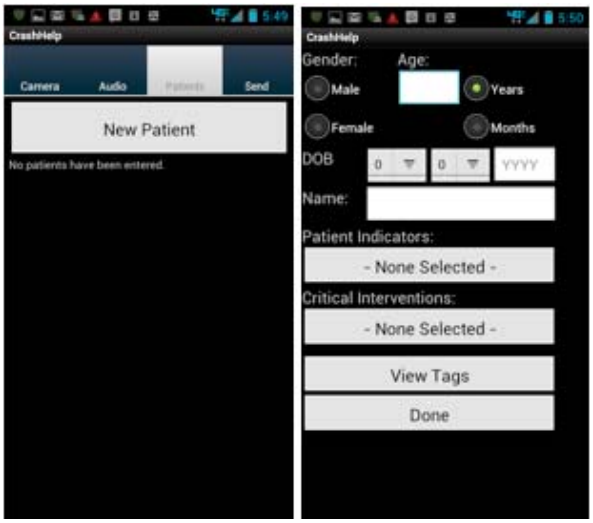

Figure 2: Textual Patient Information Screen

4.2.3. Designing for challenges. Section 2.1 listed the EMS handoff challenges. In Table 4, we present the features we designed to overcome these challenges.

Table 4: Mapping System Features to Challenges

Information handover Challenges	Design Features
1) Limited time for paramedics to collect data on-scene	Touch screen, large buttons, few clicks, few tabs, voice recording/dictation, simple camera use, few data collection points
2) Gaps in information flow due to work flow interruptions with the emergency practitioner	Enable asynchronous two-way communications. Enable permanence of data for later retrieval at clinician convenience
3) Resistance to use technology due to perception that technology will get in the way of patient care	Leverage mobile Smartphone technologies. Many medics already use personal phones on scene
4) Few mobile, portable electronic tools for paramedics to efficiently collect data value-added contextual data	Leverage build in camera and audio devices to capture patient and multimedia information
5) Lack of information exchange standards and practices	-Information prompts (VOMIT: Vital signs, Oxygen, Monitory, IV, Transport/Treatment)
	Utilize exchange, communication, and process standards (e.g., XML, SMS, HTTPS)
6) Frequently missed, unreported, or incorrectly reported information to the ED.	- Enable multiple forms of information collection
	-Allow ED to request more or missing information though SMS
	-Prompt users to enter information (e.g. VOMIT)
	Provide a web interface to allow multiple groups access the information at the same time.

5. Field Demonstration and Usage Data

The software was implemented and pilot ("beta") tested in central Minnesota (MN) at the Cuyuna Regional Medical Center (CRMC). CRMC is a rural full service, Level 3 trauma hospital with its own ambulance service. The pilot test was conducted for a period of three months from August to November 2012. The goal was to test the use of the system and to understand in what way it was used or not used. At the beginning of the study all medics and nurses received in-person training for using the application. During the study, thirteen paramedics sent 88 incidents. Each medic used the application a minimum of 5 times, though the use was skewed toward regular use among a core group of (5) medics. The types of medical conditions where the application was used include:

- General Medical (n=35),
- Altered Level of Consciousness (n=11),
- Ground Level Fall (n=10),

- Shortness of Breath (n=9),
- Chest Pain (n=6),
- Code Neuro (n=5),
- Motor Vehicle Crashes (n=3),
- Cardiac Arrest (n=2),
- Seizure (n=2),
- Code Green (n=2),
- Level 1 Cardiac (n=1),
- General Trauma (n=1),
- Abdominal Pain (n=1).

All 9 ED registered nurses accessed the 88 incident records, including accessing 72% of audio reports, and 59% of images. Details about the field assessment are provided in the next section.

6. Field Assessment

The level of evidence for a research study can be measured by the study's methodological approach and implemented design [31]. According to [27], there is a need to use a mixed-method approach of qualitative and quantitative methods to fully investigate the complexity of handoffs. Quantitative data was extracted from the system logs and database, analyzed and discussed below. Also, in a review of the current literature, Manser and Foster [31] identified six qualitative methodological approaches to evaluate patient handoffs. These include clinical evaluation of handoff practices, evaluation of caregivers to a specific handoff, observation of behavior, retrospective studies of adverse events, observational outcomes studies, and experimental outcomes studies.

In this study, we applied the clinical evaluation of caregivers to handoff practices because this approach fits best with: 1) the fast-based dynamic nature of EMS handoffs does not permit interrupting caregivers after each handoff in order to get their assessment of specific handoffs; 2) to our knowledge, there does not exist a database of EMS handoffs for conducting retrospective studies; 3) to our knowledge, there does not exist one widely accepted standard for handoffs in EMS settings to guide caregivers' actual behavior and provide the basis of comparisons; and 4) this is an exploratory study due to the novelty of the topic and solution and thus a randomized controlled study would be premature.

A total of 10 participants at CRMC were interviewed in-depth to assess their perceptions on the use of the system. Interviews included 5 paramedics and 5 charge nurses. The 5 from paramedics were those (of the 13) that had used the system through the trial and have significant enough experience with technology to comment on its value. Similarly, the 5 from ED were those charge nurses and ED staff that had worked with the system throughout the trial. Interviews were held in person and/or via telephone conference call and were recorded, transcribed, and analyzed. We evaluated the system through mapping each component to an evaluation measure. As shown in Figure1, the design of the system incorporated considerations for: 1) an appropriate standardized data collection technique (the Five-Ps), 2) a system that facilitates the communication between pre-hospital transport and hospital organizations, and 3) the challenges for EMS information handoffs. We have identified and mapped three measures/hypotheses to evaluate each of the above listed three considerations as follows.

- **Measure 1:** The standardized data collection technique shall improve information collection by on scene EMS personnel
- **Measure 2:** The system shall improve communication and notification time between pre-hospital transport and hospital organizations.
- **Measure 3**: The challenges shall be overcome through designing an easy and functional mobile and web based application for EMS personnel and ED staff.

The outcome measures assessed for EMS and ED participants (respectively) are presented below along with summary findings from the interviews.

6.1. Emergency Medical Services Participants

6.1.1. Measure 1: Improved information collection by on-scene EMS personnel. The use of a standardized data collection technique, the Five-Ps, and the use of a prompting feature on the mobile application have improved consistency in reporting on-scene important patients' information. Compared to a previous field test [2], the percentage of incidents sent by EMS personnel that have the essential patient's information, (name, gender, date of birth (DOB), and mechanism of injury), has improved from 64% to 78%. Section 6.2.2 will discuss some of the new added value gained from improving the availability of basic patient's information from the ED staff perspectives.

6.1.2. Measure 2: Improved communication between pre-hospital transport and hospital organizations. Providing EMS personnel with the freedom to choose their preferred ways of using the mobile application to collect on-scene patient information has improved the communication between medics and ED staff. Audio, images, video, and text information can be used alone or combined to provide extra means of communication. We found that many of the EMS

participants preferred using the digital audio recoding feature over entering data onto the mobile screen. One paramedic explained:

"I found it easier to just record my audio and explain it [the incident] in the audio"

Other participants viewed pictures as valuable, especially in severe incidents where it is not easy to capture most of the incident details in words. For example, a paramedic said:

"Pictures really do add to the intensity of the injury…if I'm not great at describing it, the pictures really were helpful"

Details such as the intensity of an injury, point of intrusion, and mass casualty sometimes found in motor vehicle crash (MVC) incidents was found difficult to capture by EMS personnel without the use of images. One paramedic explained:

"*I really think that there would be some really good value in using it (digital images capturing feature) more to crash scenes"*

Also, communication via the system was found more valuable for longer transports as prep time increases significantly. Thus, knowing patient information prior to arrival enabled readiness in the ED, such as assembling a stroke, cardiac, and trauma team. One paramedic confirms:

"If we have a cardiac arrest patient that we're coming in, it's helpful to get those teams in the facility activated and waiting"

In contrast, for many of the short transports (from in town) to the ED, medics found that they are "in the door" very soon, limiting its usefulness in this regard.

6.1.3. Measure 3: Easy to use and functional mobile application for EMS personnel. Leveraging smartphones capabilities, such as, touch screen, large buttons, and dropdown menus helped providing easy to use and functional mobile application that does not 1) inhibit EMS communication processes above and beyond current communications practices, or 2) get in the way of patient care. One paramedic acknowledged the ease of use by saying:

"*I thought that not only was the phone was pretty self explanatory… I think it was pretty simple to use. Straightforward, had enough tools there, but not so polluted"*

In addition, quantitative data collected from the phones' log files showed that paramedics spend an average of 1.8 minutes from the time they enter information to the time they send it. Such short time to communicate a standardized patient's information has indeed raised the confidence of some paramedics to use the system many times in the most time critical incidents, such as cardiac arrest (n=2), seizure (n=2), and code neuro (n=5) as noted in Section 5. This data also supports the finding from the previous section that the system use is more appropriate with severe and time critical incidents.

6.2. Emergency Department / Trauma Center Participants

6.2.1. Measure 1: Improved communication between pre-hospital transport and hospital organizations. The system audio records sent by medics were listened to by nurses in the ED, and were often replayed to brief other nurses and physicians on duty; the latter cannot be done with radio communication. Using the audio helped to improve information completeness and accuracy. One charge nurse explained:

"*Let's say a patient was having a stroke. We always make sure that the ER physician was there to listen to it ("the audio file"). It was pretty much all were involved in listening to most of the severe cases"*

In general, compared to audio reports, pictures, text messaging, and videos were less useful to the ED. These features were useful for some incidents, such as using pictures for certain trauma cases. One charge nurse specified:

"The ED physician, on seeing the image [of a deep tissue laceration], actually went ahead and, before the patient even arrived, contacted the surgeon and said, you know, I anticipate we're gonna need your involvement based on what I'm seeing here. And it just kind of expedited getting the surgeon here"

6.2.2. Measure 2: Improved notification times for rural and remote motor vehicle crash (MVC) trauma patients. In Section 6.1.1, we found that using the Five-Ps data collection standard provided consistency in the reported information. From ED/Trauma staffs' perspectives, this consistency in collecting patients' information (reported 78% of the time) enabled:

1) Pre-registration. A dominant use of the patient's name and date of birth was for pre-registration and faster information retrieval of essential information at the hospital. For example, patient medical history, medications, and prior surgeries could be looked up in the hospital electronic health record prior to patient arrival to enable faster registration, admissions, and radiology ordering. In this regard, one charge nurse said:

"*So that was a huge asset to us as getting people registered and being able to order stuff on them, being able to pull meds out for them and stuff like that, because if you don't have that info, it's hard to get all that stuff started"*

2) Earlier notification of rural and remote EMS incidents. According to a charge nurse:

"The E.R. would really benefit from having that pre-notification of the real critical ones ("incidents"), and those are the ones that are much more difficult to take the time to do the tap and go"

6.2.3. Measure 3: Easy to use and functional web based application for ED / Trauma Center**.** The web interface used by the ED provided patient information, medic unit information, incident information, and medic unit status information in a clear, easy to read, and usable format. Also, the interface provided easy access and retrieval of multi-media information (digital audio, pictures, videos) for the ED. One charge nurse confirmed:

"*I thought it was a very easy system to use. There was nothing particularly challenging about it. It's pretty straightforward"*

7. Conclusion

Patient information handoff is a critical component of emergency response care. This design science oriented field test examined the use of a mobile-based EMS solution that provided multi-media information to emergency responses in rural Minnesota over a three-month period. The use of the system and the interviews about its role in patient information hand-off suggests mobile-based systems can play an important role in ensuring more complete information handoff to enable action in the ED. However, challenges remain in terms of usability and incorporating technologies across patient care processes especially for severe and short transport time incidents.

While the present study achieved its aim to enact an EMS artifact using DSRM, the level of assessment was via "beta scale" evaluation. The next step is a more systematic use for a longer period of time with more in-depth examination of clinical uses in specific cases, such as for trauma care. In the end, it is not only about information hand-off, but how more robust information hand-off can inform quality patient care. This is the limitation of the current study, and these issues should be addressed in future research phases. Such research should include additional clinical evaluation metrics as well as considerations such as integration with Electronic Health Records (EHRs).

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