Design of an Enterprise Architecture for Electronic Patient Care Record (ePCR) Information Exchange in EMS

Completed Research Paper

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ABSTRACT

EMS is an organized and collaborative effort between several organizations providing different levels or tiers of care designed to transport sick or injured patients to the hospital. Significant challenges to efficient, accurate, and integrated inter-organizational information exchange exist for communicating pre-hospital EMS patient information to hospital emergency departments. The goal of this research was to investigate the requirements and design of a business process-oriented inter-organizational enterprise architecture for EMS from a multi-stakeholder perspective. This paper describes an action-design research effort aimed at improving information exchange across pre-hospital and hospital organizations in the Santa Clara County, CA Health and Hospital System. In this paper, we discuss challenges with integrated EMS information exchange, the research approach and process, resulting architecture, and implications for multi-organizational emergency health systems.

Keywords

Electronic patient care record (ePCR), emergency medical services, inter-organizational systems, health IT

INTRODUCTION

Emergency Medical Services (EMS) is often a patients’ first contact with the health care system. In the United States alone, an estimated 28 million patients were transported by EMS to Emergency Departments (EDs) in 2009, a number that has been growing each year (Mears et al. 2011). Globally, EMS is an organized and collaborative effort between several organizations providing different levels or tiers of care designed to transport sick or injured patients to the hospital (Pozner et al. 2004). Each EMS event is highly dependent upon timely and effective communications between and across emergency response organizations (Institute of Medicine (IOM) 2006; Schooley et al. 2007).

National leaders have long called for improvements to the underlying information systems and technology that support EMS. In recent years, leaders have noted the increasing need for improved data collection and sharing across pre-hospital organizations to improve decision making, reduce medical errors, improve resource utilization across regions, and increase operational efficiencies, and for achieving positive health outcomes for patients (Aase et al. 2011; Institute of Medicine (IOM) 2006; NHTSA 2007). However, prior research has identified significant challenges to efficient, accurate, and complete information exchange for communicating pre-hospital patient information to hospital emergency departments (EDs) including: 1) limited time for EMTs and paramedics to collect and transmit data on-scene or en-route using electronic patient care record (ePCR) systems, 2) a limited number of tools in the field for paramedics to collect value-added multi-media information (Schooley et al. 2010), 3) often fragmented communications or lack of information exchange standards and practices (Aase et al. 2011), 4) significant reliance on the use of synchronous two-way voice radio communication technologies (Chu et al. 2004; Xiao et al. 2000), and 5) frequently missed, unreported, or incorrectly reported verbal or written information to the ED especially for more severe medical incidents.

With the rapid advancement of a wide range of information and communication technologies ranging from commercial wireless networks (e.g. 3G and 4G), high-capability mobile devices, web-based technologies, enterprise software systems built on services oriented architectures, data exchange and integration platforms, open application programming interfaces
(API’s), data standardization, and others, there is need to understand how a pre-hospital inter-organizational enterprise could apply these concepts into the development of an EMS inter-organizational data exchange architecture (EMS-IDEA).

The goal of this research was to investigate how a goal-oriented inter-organizational enterprise system could be designed from a multi-stakeholder perspective. This paper describes an action-design research effort aimed at improving information exchange across pre-hospital and hospital organizations in the Santa Clara County, CA Health and Hospital System. In this paper, we discuss: 1) challenges with EMS data exchange, 2) the research approach and process, 3) the field study design, 4) data collection, and 5) evaluation findings.

INFORMATION EXCHANGE IN MEDICAL EMERGENCIES

The transfer of care from one care provider to the next is referred to as patient handoff, or handover (Riesenberge et al. 2009). Transfer of accurate and timely information during patient handoff is a critical clinical and organizational process to ensure continuity of care (Abraham 2011; Gandhi 2005) and to secure patient safety (Horwitz et al. 2009). Communication failures in patient handoff have been cited as a major cause for a range of medical errors (nearly 70%) in healthcare (Sutcliffe K 2004). The communication challenges are further magnified in fast-paced, short-stay, and critical care environments such as the ambulance or emergency department (ED) ((Benner et al. 2008; Wiler et al. 2010). The nature of the communication process in EMS settings is complex and cognitively taxing for clinicians, further increasing information handoff challenges (Laxmisan a 2007). This paper specifically addresses an information handoff gap between pre-hospital emergency medical services (EMS) and hospital emergency department settings (Schooley et al., 2011).

For EMS, information processes frequently occur as verbal and written information exchanges. An EMS event typically begins with a request for EMS (e.g., 911 phone call). This results in the dispatch of EMS resources (i.e., law enforcement, fire, and ambulance may all respond) to the scene. At the scene of an event, an EMT, paramedic or both will assess the patient. With the patient’s assent, the EMS professionals will treat and usually transport the patient to a facility that can adequately continue patient care. Within a short period of time, patient care documentation must be completed and the EMS vehicle must be cleaned, restocked, and returned to service. In a typical scenario, each responding agency will collect patient and incident information from the patient, family members, or bystanders. Each may write the collected information in various places such as a paper form, any available piece of scratch paper, a mobile device, a latex glove, or other convenient location (Orthner, 2005; Schooley and Horan, 2007; Institute of Medicine, 2006). These information collection points act as a ‘staging location’ until electronic records can be completed – one by each responding organization. A two-way radio call or wireless phone call is then made to the receiving ED to report patient status and an expected arrival time. Frequently the patient will arrive at the ED in advance of a comprehensive electronic record. 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.

E-PCR Systems and Handover in EMS

An electronic tool that is used in EMS to help facilitate incident and patient data collection is the electronic patient care record (ePCR) (Meislin et al. 1999; Spaite et al. 1995). EPCR systems were conceptualized and have been designed to improve EMS record availability and legibility for ED clinicians, as well as to improve quality assurance, outcomes research, and billing for EMS agencies (Landman et al. 2012). EPCR systems may aggregate data across 9-1-1 call centers, first responders, and transport organizations; capture over 400+ standardized data elements (Dawson 2006; Mears et al. 2001); and record health care procedures, patient assessments, medications, protocols, patient history, demographics, and situational context information for each incident. EPCR systems have become more comprehensive and standards based over time.

However, the purpose for which ePCR systems were designed often stands in contrast to efficient handover of essential information across emergency response agencies and to the ED (Schooley et al., 2010). For example, an analysis of over 22,000 EMS transports across one California County showed completion of an ePCR took an average of 39 minutes 42 seconds (median 33 minutes 59 seconds) after EMS arrival and patient handoff to an ED (Schooley, 2007). A larger study showed that only 49% of EMS Agencies report collecting some electronic data at the patient’s side prior to arriving to an ED (Williams, 2008). A statewide California survey of EMS Administrators and Medical Directors found that 70% of the respondents did not know how long it usually takes to complete the ePCR and that there exists no standard reports, metrics, or methods for evaluating the timeliness of ePCR completion (Schooley et al., 2010). Indeed, a recent study reported that the ePCR is often not available for decision making in the ED (Bledsoe et al. 2013). Available research on the topic, and our past
findings illustrate that 1) ePCRs are commonly completed well after patient arrival to the ED, especially for the most critical incidents, and 2) there are very few studies that demonstrate the efficacy or effectiveness of ePCR systems for facilitating handover and clinical decision making at the point of care.

This research was motivated by the gap described above, including the inefficiencies found in the EMS information handoff process. A need exists to improve EMS data collection and handoff processes with a wide range of cooperating organizations and associated information systems, including electronic health record (EHR) systems across the continuum of emergency care, to enable pre-hospital data exchange for point of care decision making and post care system-wide clinical quality improvement initiatives. This paper describes the methodology and research process, findings from a field study, the resulting architecture, and conclusion and implications.

FIELD STUDY LOCATION
Understanding significant data exchange challenges existed across EMS organizations, the Santa Clara County EMS (SCCEMS) System Data Assessment Project was conducted to provide SCCEMS with a high-level architecture and recommended design for an integrated EMS data system. SCCEMS sought to increase data sharing across all participating EMS organizations. Researchers participated together with the SCCEMS Project Steering Committee to conduct an assessment of the current inter-organizational EMS data system inclusive of workflow processes, data elements, software applications, and IT systems used across all SCCEMS partner agencies. The goal was to develop an enterprise wide architecture, driven by all EMS organizations in the County that could support information exchange efforts. A list of EMS organizations that participated, and the number of participants from each organization, can be found in Table 1. The County EMS Agency identified the National Emergency Medical Services Information System (NEMSIS) data elements as the backbone of their data system requirements and expanded them to include (local data elements as well as trauma, STEMI and stroke registry data).

RESEARCH PROCESS
A multi-method research methodology was applied to the action-design research approach to understand existing information systems and the characteristics of a next generation EMS architecture. Initially, a survey was administered to each organization to understand what software systems, data types, data standards, technical infrastructure, and human resource assets and capabilities exist at each separate organization. Each organization listed in Table 1 completed a survey. An inter-organizational process model, guided by the process model prescribed by Horan and Schooley (2007), was then developed specifically for each organization based on survey results. The process model pertaining to each organization was then brought to a group interview with representatives from that organization to understand how patient and incident data is collected and exchanged within and across organizations for each emergency incident, and where improvements could be made. The process model included high level inter-organizational business processes including: 1) Event Notification/Dispatch, 2) Response & Enroute, 3) Patient Assessment, Treatment and Handoff, 4) Patient Data Aggregation and Documentation, 5) Information Handoff and Exchange, 6) Reporting & Analytics.

Each workshop followed a sequential discussion using the above 6 categories. Organizations described, in varying detail, how they receive and process dispatch information, how they communicate while enroute to an incident, how they collect and process pre-hospital patient data, how they transfer pre-hospital patient data among other transport providers and external business partners, and how they utilize pre-hospital patient data for reporting together with their associated programs. Notes were taken at each meeting and the process model was revised accordingly. An inter-organizational process-driven enterprise architecture was then constructed from workshop findings. Finally, the architecture was presented to a group of leaders representing each of the case study organizations to validate its accuracy and ability to fit the needs of each separate EMS organization in the county. Findings and the resulting architecture are described below.
Organization | Number of Participants | Participant Position
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American Medical Response ground transport | 9 | 1 County IT Rep, 1 EMS operations expert, 2 EMS Administrators, 2 Operations Staff (Medics), 2 Data System Administrators
Cal-Star Air Transport | 3 | Chief Flight RN, Data System Admin, Communications Supervisor
County Communications, Emergency Dispatch Center | 5 | Communications Director, 2 IT/Data System Administrators, Communications Specialist, Operations Manager
Gilroy Fire Department | 4 | Battalion Chief, Data System Admin, Network Admin, Communications and Operations
LifeFlight Air Transport | 2 | Chief Flight RN, Communications Specialist
Milpitas Fire Department | 4 | Battalion Chief, EMS Captain, Data System Admin, Communications
Mountain View Fire Department | 2 | Battalion Chief, IT and Data Systems Specialist
Golden State Ambulance ground transport | 1 | Operations and Communications
WestMed Ambulance ground transport | 3 | EMS Administrator, IT Specialist, Operations
Silicon Valley Ambulance ground transport | 4 | EMS Administrator, IT Specialist, Communications, Operations
Palo Alto Fire Department | 2 | EMS Coordinator, Dispatch and Communications
San Jose Fire Department | 5 | EMS Chief, EMS Deputy Chief, Clinical Quality Improvement, IT and Data System Admin, Operations Specialist
Santa Clara County Fire Department | 5 | Captain, EMS Coordinator, Data System Admin, Support Services Chief, IT/Support Manager
Santa Clara City Fire Department | 4 | Battalion Chief, Deputy Fire Chief, Clinical Quality Improvement, IT/Data Systems Admin
South Santa Clara County Fire Department | 2 | EMS Battalion Chief, Clinical Quality Improvement
Sunnyvale Public Safety District (combined police/fire) | 3 | EMS Program Director, Sr. Program Analyst, Senior Dispatch and Communications Administrator
Trauma Registry Users Group (TRUG) | 15 | Trauma Coordinators and Registrars, and Data System Admin from all 3 county trauma centers: Stanford Medical Center, Santa Clara Valley Medical Center, Regional Medical Center of San Jose
Stroke Registry Group | 3 | Clinical Quality Improvement Specialist, Analyst, Stroke Registry Data System Admin
STEMI Registry Group | 3 | Clinical Quality Improvement Specialist, Analyst, STEMI Registry Data System Admin
County EMS Agency | 3 | EMS Communications Supervisor, Operations Manager, Section Chief
County EMS Agency | 3 | Medical Director, Clinical Quality Improvement Specialist, Clinical Data Analyst
Total Participants | 85 | ---

Table 1. Study Participants

**FINDINGS**

Participant responses were aggregated, commonalities and differences were categorized, and a system architecture was designed to support varying business processes across EMS organizations. Overall, findings indicate a large proportion of existing ePCR data systems and capabilities that could be leveraged and utilized in the design of a next-generation business process driven architecture. There are several organizations that have limited or no ePCR functionality that may benefit from an implementation of a shared ePCR data system. There also exists a limited amount of automated data exchange across 911, fire, ambulance, and hospital systems, with the major exception being between 911 (i.e., CAD systems) and ePCR systems. Finally, advanced analytics and Business Intelligence functionality is either non-existent or under-utilized by provider organizations. While data exchange is currently limited across organizations, findings from each individual group interview revealed a high interest and willingness to exchange data for the purposes of improving inter-organizational cooperation and patient care. In general, organizations that utilize ePCRs want to continue to use their existing systems and prefer to develop
a county wide interoperable information exchange between existing systems as opposed to migrating to new ePCR, CAD, and hospital registry systems.

**ePCR System Findings**

Several providers (5) have paper based systems, not yet using electronic PCR systems. Twelve (12) providers have ePCR systems, the majority of which are compliant with the NEMSIS data standard at the Gold level. Most ePCR systems (>90%) enable unique identification of incident, patient, station, employee, and unit. Few EMS providers use advanced analytics tools such as Business Intelligence (BI) solutions to create reports or ad-hoc data queries. Few EMS providers currently collect device data (e.g., EKG) electronically and automatically into an ePCR application. First responders utilize paper run sheets on scene and then document their ePCR back at the station after the incident has been completed. Ground transport providers document primarily at the hospital post patient hand-off at the hospital and are required to complete them within 24 hours of incident completion. While there is a high degree of computer aided dispatch (CAD) to (ePCR) integration (i.e., CAD systems send dispatch data to the relevant agency ePCR), fire agency record management systems (RMSs) do not exchange data with ePCRs. Some participants felt that data collection efficiencies could be achieved if ambulance crews could build from the data collected by fire first responders when creating their ePCR reports. ePCR systems currently do not send data to other ePCR systems, to the County EMS agency, to hospitals, or to trauma, stroke, or STEMI registries. Finally, participants reported that 50% of fire and EMS agencies are collecting approximately 79% of the NEMSIS data element checklist. Participants described key features of a future SCCEMS system will be to exchange data across existing clinical and business processes (i.e., from 911, to Fire, to ambulance, to hospital ED), and to construct a data warehouse structure and architecture to enable system wide analytics.

A common need addressed by participants was for the EMS Agency to create a “living” comprehensive data collection policy that standardizes data elements and the exchange thereof through the development of a comprehensive data dictionary that defines required data fields. In addition, participants thought the EMS Agency should develop a set of mechanisms to communicate data system policies to providers in a timely manner; including through automated and electronic communication and through the establishment of a County EMS Data Systems Committee.

**A New Architecture for SCCEMS**

Participants agreed on a wide range of system capabilities to guide architectural design. Over 41 core and secondary capabilities were developed aimed at improving prehospital to hospital data exchange. The 12 highest priority architectural capabilities as described by study participants are presented below, with a visual illustration of the general architecture depicted in Figure 1 (Santa Clara County Solution Architecture).

**Capability to import Computer Aided Dispatch (CAD) data elements into e-PCR systems.** Automating the collection of CAD data across all agencies provides 1) a set of unique incident identifiers to connect records across all responding agencies, and 2) enables adherence to NEMSIS reporting requirements (e.g., response times, chief complaint reported by dispatch). These data elements are essential for analytics and reporting and provide the basis for integrating essential dispatch information with ePCR patient data into an SCCEMS central repository.

**Capability to create and store a unique incident and patient ID among 911 call centers (PSAPs).** Creating a unique incident and patient ID eliminates duplication of ID’s within and across County dispatch centers and ePCR systems and supports building a pre-hospital Master Patient Index database for conducting analyses and for retrieving patient data for point of care decision making.

**Capability to exchange ePCR data via standard interfaces.** Many different ePCR data systems will continue to exist in the County for the long term. Integration and exchange of data within and across these systems represents a practical and cost effective solution.

**Capability for electronic and secure field data capture of all NEMSIS required data fields and multimedia information.** The system should enable capture of clean, formatted, and standardized data from fire and ambulance ePCR systems, as well as digital photos, audio recordings, and video recordings from mobile devices.
Capability to link a complete ePCR (first responder and ambulance crew) with patient outcome data from hospital data systems and Registry databases using standardized data formats. Linking complete pre-hospital data with hospital patient data is a core function of the data system. This would enable health outcomes based reporting and feedback loops to pre-hospital practitioners.

Capability of EMS data system to push ePCR data to hospital systems: electronic charting, EMR, EHR, Trauma Registry, ED registry, and other registries. Enabling timely exchange of prehospital data to hospital systems will enable effective patient handoff to the ED, will make the ePCR data available in the data systems used by hospitals, and provide much needed data to downstream providers in the trauma, stroke, cardiac, or other units of the hospital. This will also enable outcome based reporting and analytics.

Capability for EMS to pull patient records (CCD/CCR) from hospital EHR or HIE systems. The ability to pull data from EHRs from across multiple hospitals would enable prehospital practitioners to pull critical information, such as medications, allergies, conditions, etc. to the field and aid in making patient care and transport decisions.

Capability for remote mobile access to County EMS Agency reference information (i.e., policies, protocols, notifications, medication dosage information, etc.). EMS rules and regulations can be extensive and change from time to time. Paramedic unit access to up-to-date information from the EMS Agency increases provider education, awareness, and compliance with policies.

Capability of e-PCR system to record and attach patient monitoring/telemetry (12-Lead, Defibrillator, AED, Pulse Oximetry, etc.) data to an ePCR per NEMSIS standards. This capability could allow for a significant workflow improvement for the collection, storage, and automatic transmission of patient vital signs and other telemetry data across first responders, ambulance, and EDs. The need to visualize this information in the ED in an integrated manner is also critical.

Capability for existing Hospital Resource Management and Patient Tracking systems to interface with ePCR and Dispatch systems to enable situational awareness across Dispatch, First Responders, Transport Providers and Hospital ED’s. Enabling all dispatch/CAD and ePCR systems to leverage existing hospital availability data in the field would provide for more informed decisions about which hospital to transport a patient; and allow for data communication between providers potentially reducing radio communications.

Capability to track, link and review patients within an MCI event. This capability enables linkage, grouping, and tracking of patients for mass casualty incident (MCI) situations and communication of that information across providers.

Capability to perform customized data queries, standard reporting, ad-hoc reporting, data extractions in a variety of formats (CSV, TEXT, XML), web-based query’s, and data mining. Allowing for a full range of reporting and data analytics would improve Clinical Quality Improvement (CQI) efforts, tracking Key Performance Indicators (KPI), and facilitate specialized analysis and research.

Taken together, these capabilities provided the foundation for the design of an SCCEMS data system architecture that included 5 key components. These components were derived from the list of system capabilities through the SCC project analysis process. These components include:

- SCCEMS Central Data Repository to aggregate and store all CAD, ePCR, and RMS data across the County
- Advanced Analytics / Business Intelligence system for research and reporting
- Integration Bridge (Data Exchange and Integration) to facilitate data integration and exchange across existing county EMS data systems and hospital systems
- County Communications CAD system Regional Information Broker (RIB) will enable data exchange across CAD and SCCEMS ePCR data systems
- County web based ePCR system provides small EMS providers the capability to collect ePCR data without having to purchase their own vendor system
- Security & System Administration are essential for maintaining access controls, user authentication, and compliance with other HIPAA guidance
Santa Clara County Solution Architecture

Emergency Call Center Computer Aided Dispatch (CAD) Environment

- Data Matching / Reconciliation
- Data Formatting
- Data Normalization
- Unique Incident ID Reconciliation
- Data Exchange

MRT / NDC  GPS / AVL / GIS  ENB / MPDS

SCCEMS Data System Environment

- SCCEMS Active Data Management System and Repository
- SCCEMS Historical Data Management and Repository
- Policy Management and Comm.
- NEMESIS Compliance & Export

Integration Bridge

Other Leveraged Resources

- Patient Data Management (unique ID)
- Master Patient Index
- Advanced Analytics, Data Mining, Business Intelligence
- Reporting

EN Resource / EM Task
- Emergency Surveillance

Hospital Environment

Figure 1. Santa Clara County Solution Architecture
ARCHITECTURE VALIDATION

The analysis described in the previous sections provided the basis for developing architecture design options and directions. The architecture and associated capabilities were presented to a meeting with management level decision makers from all 20 County EMS organizations. In total, there were 34 participants to discuss architecture implications. Participant responses described the architecture and capabilities to:

- Be feasible to accomplish
- Provide options to stakeholders
- Leverage emerging best practices in EMS data system design
- Enable all EMS providers the capability for electronic data collection
- Leverage existing data systems in the County
- Leverage proven enterprise data exchange technologies
- Be flexible to varying business processes
- Be scalable for future growth
- Leverage existing data standards in EMS and healthcare
- Leverage existing and proven data exchange methodologies
- Facilitate compliance with security and privacy regulations

Participants also discussed significant challenges that could impact the complexity of the architecture. These included: 1) Timeliness of data, or how immediate data is needed from one data system to another (i.e., real-time, daily batch data, weekly data dumps, etc.); 2) Direction of data flow – Which direction data is required to flow (i.e., one-way, two-way, multiple directions simultaneously); 3) Number of interfaces – How many different data systems are required to interface with each other (i.e., CAD to PCR, PCR to repository, repository to RMS, PCR to PCR, SCCEMS repository to registry, PCR to EHR, HIE to PCR, RMS to PCR, etc.). As such, participants discussed the potential for the architecture to enable three different levels of integration:

- Basic integration – publish ePCR data to a centralized SCCEMS repository owned and operated by SCCEMS
- Intermediate integration – publish and subscribe to/from SCCEMS repository, mobile devices, and hospital registries
- Advanced integration – publish and subscribe to/from SCCEMS repository, mobile devices, hospital registries, fire RMS systems, hospital EHR/EMR systems, and partner systems with more advanced integration capabilities at each provider site/location

These discussions were used as inputs to revise the architecture design. The final design in Figure 1 most resembles the “Intermediate integration” option above, as 1) most hospitals in the County had yet to implement EHR systems capable of exchanging information, and 2) EMS data exchange had not yet become a high enough priority for hospitals. Some participants thought the advanced integration attributes would be important to target now in order to achieve greater levels of flexibility and scalability in the future. The integration bridge in Figure 1 is an essential component of the architecture. It should also be noted that the Regional Information Broker (RIB) integrates across all 911 call center CAD systems providing a unique incident and patient identifier to be used by ePCR, RMS, and hospital registries. Integration “spokes” are also important depending on the number and extent of integration that must occur on the EMS provider end of the data exchange.

Challenges and future design directions

Besides the larger architectural considerations and design, participants also discussed significant challenges not fully addressed by the architecture in terms of improving EMS handover in the future. First, it was suggested that one improvement could be to create a network of EMS notifications inside of hospitals. Second, the amount of time required to create and send information on emerging mobile devices through a 3G or 4G network would need to be taken into consideration. Third, a significant challenge is the need to address varying work flows across hospitals. Not all hospitals communicate with paramedics in the same manner, nor are EHR systems all constructed the same, built on the same standards, or provide open interfaces for integration purposes. Future work should focus on understanding how these challenges and emerging developments would impact or be impacted by existing ED work flows, and/or how a work flow might be improved through incorporating other functionality. Finally, future work should track the implementation of the enterprise architecture described herein to track the benefits and challenges experienced relative to expectations across stakeholder organizations.
CONCLUSION

In this paper, we described the design of a business process driven enterprise architecture to facilitate information exchange across multiple cooperating EMS organizations. Findings indicated the potential impacts of an integrated prehospital information system on improving patient handover for medical emergencies. While service oriented architectures (SOA) have become commonplace in many industries, the architecture described herein, where business process flexibility is a key driver for competing and cooperating public and private organizations, the concept is still novel within and across inter-organizational EMS. In the initiative described herein, stakeholders believed the value that could be derived in the near future as a result of such an architecture would be to further improve clinical and operational excellence primarily across prehospital organizations. A future advantage that could be derived was believed to be clinical and operational excellence across prehospital and hospital organizations as hospitals increase their information exchange capabilities. This case illustrates the application of a business process design orientation in a critical health care setting, and the potential widespread role for service oriented architecture (SOA) to play across health, EMS, and public safety systems.

There are several limitations of this research that would encourage future work in this area. First, the study was conducted in one U.S. City. Second, not all hospitals in the County participated in the study. In contrast, all EMS organizations participated. Hospitals are traditionally a difficult participant group to access in health information technology studies. However, these participants represent a critical user group and thus should be included in larger numbers in future studies. Finally, this research was limited to a qualitative evaluation methodology for the architecture evaluation, which fit the exploratory action-design focus of the study. However, future studies should examine a much wider audience and utilize a range of other evaluation methods including surveys, experiments, and a larger sample of qualitative participants. While this study has its limitations and future research directions, from a methodological perspective, this study demonstrates the use of multiple research methods to iteratively design and develop an architecture from various public, private, and not-for-profit stakeholder perspectives.

REFERENCES