REVIEW ARTICLE

Emergency Medicine Informatics: Information Management and Applications in the 21st Century

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RECEIVED:
15-10-2008

ACCEPTED:
28-10-2008

CONFLICT OF INTEREST:
None

Emergency Medicine Informatics (EMI) is the collection, management, processing, and application of emergency patient care and operational data. EMI is transforming and improving our prehospital care systems and emergency department (ED) operations, is critical for public health surveillance, and will enable us to expand clinical research in our institutions, regions, and nations. EMI is one of our most important tools for improving emergency care and positively impacting the health of the public.

For prehospital care, EMI systems provide information to analyze the cost-effectiveness of clinical interventions, to organize EMS operations, to coordinate communication for service requests, to monitor quality control and educational needs, and to track patient outcomes.

The practice of emergency medicine in the ED requires the capture of many data and time elements so that ED care is efficient. EMI modules support triage acuity and tracking, patient tracking, nurse and physician charting, clinical decision support, order entry, and discharge instructions and prescription generation. There must be coordination of the EMI with hospital, laboratory, and radiology reporting systems, and access to hospital and ambulatory clinic records.

Clinical information should be aggregated into an ED Database which can then be used for clinical investigation. The cooperation and support of the hospital information services department, hospital administration, emergency medicine physicians, and emergency medicine researchers, is necessary so that the ED database will be well constructed, and most importantly, well used to improve patient care.

Because the information from aggregated ED databases provides population-based information about acute illness and injury, ED databases are now one of the key elements of public health surveillance. An effective syndromic surveillance system based upon ED Chief Complaint (CC), nursing triage note, and ICD-9 or-10 CM codes requires the cooperation of hospital information systems professionals, hospital administrators, ED directors, and public health professionals. [Emergencias 2009;21:354-361]

Key words: Informatics. Emergency Medicine.

Introduction

The exponential growth of hospital, emergency department (ED), and prehospital information systems over the past decade has transformed the clinical practice of emergency medicine. Emergency Medicine Informatics (EMI)–the collection, management, processing, and application of emergency patient care and operational data- is one of our most important tools for improving emergency care and positively impacting the health of the public.

ED information systems (EDIS) have shifted physician tasks from the bed-side towards the computer-side, and emergency physicians have had to adapt to the challenges and benefits of computer-supported emergency care. This paper will discuss some of the important applications and challenges of EMI systems for prehospital care, ED operations, research, and public health surveillance.

EMI in prehospital care systems

Prehospital care is often defined as the connection between public safety, healthcare and public health[1]. The interface of these three elements is crucial, because prehospital systems are one of the main entrances to the healthcare system. The success of an emergency medical services (EMS) system depends upon good administrative and operational decisions. The best way to support decision making is with accurate near- real time electronic information, which is the foundation for EMS administration and operations.

EMS Administration

Administrative priorities vary according to local, regional or national perspectives. However, at the local level data systems are crucial for allocating operational resources to justify budgets to maintain the system. Data is needed to analyze the cost-effectiveness of specific clinical interventions so EMS managers can structure clinical priorities[2]. EMS data systems should be able to interface with other healthcare databases (trauma registries, hospital discharge records, ED data, and mortality registries) in order to identify outcomes and develop objective performance measurements. Table 1 lists the essential components of an EMS electronic record system.

There should be synergy and coordination between regional and local EMS systems in order to implement an electronic record system. The ultimate goals of an electronic record system are to provide the highest quality of care and the best possible clinical outcome, and to guide the development of public policy for specific systems of care such as cardiac arrest, trauma, and stroke.

EMS Operations

EMS system operations are divided into configuration and delivery, emergency response, personnel performance, and clinical care[3]. Prehospital data systems must include information on service configuration, region demographics, personnel levels, patient care capabilities, and must maintain a complete patient report card for every clinical encounter. All this data must be kept in secure servers that comply with confidential and security regulations.

Communications are a key link for a successful EMS operation. Most modern communication centers rely on the latest informatics technology to receive, triage and dispatch emergency calls. Computer-aided dispatch (CAD) systems are used to enter and track requests for service. In addition, tools such as automatic vehicle location (AVL) devices linked to global positioning systems assist in tracking EMS resources and provide real-time recommendations on the closest response units for each incident. These tools must interface smoothly with mobile data systems in the field, especially if there are multiple EMS systems within a geographical region.

Table 1. Essentials of EMI for EMS Systems

- Sufficient Financial Resources.
- Adequate and well-supported Technology Infrastructure.
- Electronic Interfaces between ED and hospital data systems.
- Operational Tracking: service configuration, region demographics, personnel levels, patient care capabilities, response times.
- Communication Tracking: receipt, triage and dispatch of emergency calls.
- Completeness: a patient report card for every clinical encounter.
- Clinical Tracking: performance measures and skill proficiency.

EMS Quality Control and Education

Information technology is also necessary for the development and tracking of quality control and performance measures. Traditionally EMS performance measures have been linked to response times and cardiac arrest survival rates[4]. However, new performance measures are needed. The 2007 US Metropolitan Municipalities EMS Medical Directors Consortium published a position statement laying out a multifactorial model for EMS system performance measurements[4]. Metrics from this model will help develop specific educational programs for EMS providers and will also guide operational policies in EMS systems. Data sets that record clinical interventions provide invaluable information about providers' skill proficiency. The ultimate goal is to have better EMS personnel, a better EMS system, and most importantly, better patient care.

EMS Research

Historically, prehospital care protocols evolved from experiences extrapolated from the ED setting. Most protocols were not driven by objective scientific evidence at the time. Consequently, there is a lack of scientific evidence supporting the efficacy and effectiveness of the majority of clinical care delivered in the prehospital setting[5]. There have been some recent advances in both the quality and quantity of EMS research, but substantial knowledge gaps still remain[5]. One of the major challenges in pursuing quality EMS research is the lack of outcomes data. As new equipment, technology and techniques become available to EMS, the use of EMI will transform most of prehospital practices. Modern EMS databases will be helpful to guide research efforts by linking all prehospital records to ED and hospital discharge records. This provides an enormous amount of information on patient outcomes.

The Western Australian Emergency Care Hospitalization and Outcome Linked Data Project is a model of a modern EMS database. This project links electronic records from the ED to ambulance services and mortality databases[6]. In the US, the project called NEMSIS (National EMS Information Systems) has as its main objective the implementation of an electronic EMS documentation system in every local EMS system around the country, and the submission of all data to the national database[7]. The future is bright for EMI in prehospital care.

EMI in the Emergency Deartment: The ED Tracking System and Electronic Medical Record

While electronic health record (EHR) usage is gradually increasing, estimated usage rates by physician groups as of 2005 were only about 12-20% with smaller physician groups being less likely to utilize this technology[8]. More recent estimates do not show substantial increases in these percentages. As of early 2008, only 13% of US ambulatory clinics had adopted EHRs[9]. The primary barrier to adoption is cost.

The practice of emergency medicine requires the capture of many data and time elements that challenges the format and structure of an ED EHR. These elements (Table 2) are developed as modules and together comprise a comprehensive ED Information System (EDIS). Current utilization of EHRs in emergency medicine is higher than in ambulatory care, with up to 25% of hospitals employing an EDIS in some form[10]. The primary benefit of an EMR for the emergency physician is increased data availability. This includes records from the laboratory, radiology, previous ED, hospital and clinic visits. It has been said that "Data is information, and information is knowledge—when seen in the right context by the right person at the right time"[11]. In other words, while access to this information has the potential to greatly improve patient care and reduce medical errors, it must be available in a timely manner.

Potential drawbacks of electronic documentation in the ED include, but are not limited to, increased documentation time resulting in decreased patient throughput and the potential need for increased staffing, access control issues and time-out delays requiring the frequent need to log on to one or several programs, data overload from excessive amounts of available information and the need for training of both new physicians and learners, especially in the academic environment. System response time is an important factor affecting physician satisfaction and performance when using an EDIS. When system responses take one second or more to occur, it appears sluggish and many users will experience cognitive drift, increasing the likelihood of medical error. When response takes more than ten seconds, users may begin addressing unrelated activities[12].

In May of 2004, the Society for Academic Emergency Medicine convened a consensus conference on Emergency Medicine Information Technology which resulted in the development of consensus recommendations on physician generated ED clinical documentation[13,14] (Table 3). No one method of documentation was recommended as long as the end-product was electronically retrievable. The selection of an EDIS should be evidenced based, although a collection of evidence was not currently available and that further research was required in this area. The system should promote the efficient collection of high-quality information and should integrate this information by use of standards that can be applied across other healthcare information systems. Clinical information must be exchanged in a bidirectional, real-time fashion between care providers and should incorporate patient specific information from other electronic sources within the healthcare system. From a financial standpoint, documentation systems should facilitate billing for ED services. The final recommendation from this group was that these systems should promote bedside documentation, although there is some evidence that both care providers and patients may not be in favor of this as it has the potential to interfere with the doctor-patient or nurse-patient relationship and may in fact, increase documentation time[15,16].

Once an EDIS is chosen, the process of implementation and the question of return on investment still remain. Successful implementation is

Table 2. Essential Components of an ED Electronic Health Record

- – Triage Acuity and Tracking.
- – Patient Tracking.
- – Nurse Documentation and Charting.
- – Physician Documentation and Charting.
- – Integration with laboratory and radiology reports, and medical records.
- – Clinical Decision Support.
- – Physician Order Entry.
- – Results Reporting.
- – Patient Discharge Instructions and Prescription Generation.

best achieved by working closely with the system vendor and following their recommendations for hardware and training and staffing during the implementation period. Whether the EDIS system is phased in or all components are put into operation simultaneously is a system and hospital dependent decision.

Table 3. Society for Academic Emergency Medicine Consensus Recommendations for EDIS[13,14]

- – Electronically retrievable information.
- – Evidence-Based system selection.
- – Uses electronic standards that are applied across other healthcare information systems.
- – Interfaces with other hospital and prehospital data systems.
- – Facilitates billing for ED services.

ED Database for Clinical Research

The ideal ED database contains standardized data elements which are electrically (not manually) captured as part of normal ED operations; collected in near-real time fashion; and which can be aggregated with other ED databases in the region, site, or nation. Aggregated ED data are an excellent proxy for population-based data on acute illness and injury. Hospital databases track only admitted patients. In the US, this is about 12% of ED visits[17]. Specialized registries, such as the National Registry of Myocardial Infarction (NRMI)[18] or trauma registries, track only selected illnesses or injuries on hospitalized patients. Hospital databases typically do not code ED diagnoses, but only code hospital discharge diagnoses, so they do not represent symptoms or complaints, and they do not represent the diagnostic impressions of the emergency physician.

Constructing an ED Database

There are four key steps for constructing an ED database are listed in Table 4.

Key Stakeholders

The key stakeholders are the hospital information services department, the emergency medicine physician database champion, and the database users[19].

The first two work together and recognize the importance of ED data, and give the ED information tasks priority. The users would include hospital infection control, emergency medicine administration, ED medical directors, EM researchers, and public health professionals. The more users that are involved, the more stakeholders there will be to champion the ED database.

Key Features

Establish the key features of the ED database at the beginning of the project. The prerequisite for an ED database is an electronically captured administrative and clinical dataset (data elements such as ED visit identifier, date of birth, sex, date and time of ED registration, method of transport to the ED, ED disposition, chief complaint, triage notes, nursing and physician clinical notes, physician disposition diagnosis, final ICD-9-CM or ICD-10 CM code etc)[20]. The system should be as near real-time as possible and readily accessible to emergency medicine and information services leaders so they can extract important information. Data must be secure and confidential, so that patients cannot be tracked by name unless a public health emergency develops.

Hospital Database

The hospital should provide a data dictionary so that those who construct and use the ED database will understand the sources for, and definitions of, the data elements. An ED database will only be as good as the data that is input into the system. Times are notoriously inaccurate unless they are electronically captured at the time data is entered. Even then, if data is entered by healthcare workers after the fact of care, times will not reflect reality. Missing data should be minimized.

Define Clinical and Research Goals and Objectives of the ED Database

A team with the skills, motivation, and enthusiasm for using the ED database for clinical or administrative research should be assembled, and these individuals would identify the data elements critical to their tasks. Administrative or operational research will need elements such as critical times (triage, registration, room placement, admission, discharge etc); orders written or treatments given; ED disposition and return ED visits. Research or clinical assessment of focused clinical questions would need a chief complaint, a standardized triage acuity scale, outcomes from a clinical or hospital note, and the ED diagnosis. Quality and safety research requires pre-coordinated data elements for easily retrieval. For example, for acute

Table 4. Key Steps in Constructing an ED Database

– Identify key stakeholders and collaborators.
– Determine key purposes and features of the database.
– Learn the construct of the hospital database.
– Define the emergency medicine clinical and research goals and objectives.

coronary syndrome or acute myocardial infarction, a checkbox on the electronic medical record indicating the administration of aspirin would be a pre-coordinated data element. Other checkboxes, such as patient medications, allergies, or other quality measures, could be designed depending on the focus of research or clinical care. Epidemiologic studies, that is, comparison of, or aggregation of, ED visits from multiple institutions, are the highest level of ED databased-research. This requires coordination of diverse information systems, standardization of important and common data elements (such as triage acuity); consistent definitions of terms and data elements; high data precision; and minimal missing data. An ED database will not meet all user needs all of the time, but it should be structured so it meets the basic needs for administration and clinical care. Refinements can then be added as users identify new needs[21].

ED Database for Public Health Surveillance

Electronically available ED data is often used for biosurveillance for many reasons. ED data is population based. In 2006 there were almost 120 million ED visits annually in the United States[22] representing patients from all age groups, geographic areas and socioeconomic classes. EDs are also the likely point-of-care for many patients potentially involved in disease outbreaks of public health significance. Additional features that make ED data valuable for public health surveillance include its electronic availability and timeliness. Even hospitals without comprehensive EDIS typically collect registration and chief complaint (CC) electronically. Those hospitals with an EDIS may collect additional data elements useful for surveillance such as the nursing triage note, initial vital signs, and final diagnosis codes and code descriptions. Less commonly collected data elements which may also contain information of interest to public health are the full physician and nursing notes, and initial physician impression. Surveillance types which are commonly conducted using electronic ED data are traditional diagnosis based public health surveillance, syndromic surveillance and situational awareness.

Traditional Method of Public Health Surveillance

Traditional public health surveillance relies on health care provider reports of certain communicable diseases, either clinical diagnoses based on physician impression or confirmed diagnoses based on laboratory evidence[23]. This is customarily done within 24 hours through telephone contact for high priority diseases with great potential public health impact (e.g. CDC Bioterrorism category A agents, certain food borne illnesses), certain sexually transmitted diseases (e.g. syphilis, gonorrhea), and more severe highly communicable diseases (eg. meningococcal disease, S.A.R.S., tuberculosis). Early detection and reporting to public health authorities decreases the time to confirmation and investigation of an outbreak, and results in greater opportunity for control. Automated transmission of ED diagnoses of reportable communicable diseases, directly to public health, could ensure that suspected (based on initial ED diagnosis field or ICD-9-CM diagnosis code) or confirmed (based on laboratory results) cases are reported in a timely fashion.

Syndromic Surveillance

It may take days to weeks to provide ED diagnosis codes for traditional public health surveillance. However, CC are available within hours to days of the patient's ED visit and are now the most widely used ED data elements for electronic surveillance[24,25]. CC typically contain symptoms and not diagnoses. In order to perform surveillance using CC, public health has turned to syndromic surveillance, also called early event detection[26]. Syndromic surveillance is defined as "the ongoing, systematic collection, analysis, interpretation, and application of real-time (or near real-time) indicators for diseases and outbreaks that allow for their detection before public health authorities would otherwise note them"[27]. Syndromic surveillance is done by processing CCs in order to identify symptoms or sets of symptoms related to specific disease syndromes[28]. The three most common syndromes monitored by syndromic surveillance systems are respiratory, gastrointestinal and constitutional/influenza-like-illness.

CC is defined by the Centers for Disease Control and Prevention (CDC) as the "patient's reason for seeking care or attention" in the ED. It is a challenge to identify specific symptoms in CC data as there is no standardized method of reporting, documenting, collecting and storing CC electronically. Even when CC are derived from picklists, they are usually stored as free-text. Free text data contain misspellings, ED-specific and locally-developed acronyms, abbreviations and truncations[29]. There are two main technical approaches to dealing with this problem. The first is to construct elaborate keyword searches into the syndrome queries by using statistical software such as SAS (Cary, NC) or SQL (Microsoft, Redman, WA)[30,31]. Or, data is preprocessed so that misspellings, local phrases, abbreviations, etc., are cleaned from CC text[32-34]. Both these methods are effective. Once ED visit records are sorted into the appropriate syndromes, statistical aberration detection algorithms are applied in order to detect unexpected increases in visits which suggest an disease outbreak or exposure. Two commonly used statistical techniques used for aberration detection with syndromic surveillance systems are cumulative sum (CUSUM)[35] and the CDC's Early Aberration Reporting System (EARS)[36]. De-identified records flagged by aberration detection programs can then be analyzed by public health professionals to help determine if further investigation is warranted. While CC is useful for syndromic surveillance and record review, the triage note provides much more detail and should be collected and made available if at all possible. When necessary, and with the appropriate safeguards in place, further investigation including patient identification, review of paper records and patient or physician contact must be possible.

Situational Awareness

In addition to early event detection, syndromic surveillance systems are used for situational awareness. Situational awareness is defined as "monitoring the effectiveness of epidemic responses and characterizing affected populations"[37] once a disease outbreak has been identified[17,18,38,39] or following a natural disaster or mass casualty event[19,40]. Users can monitor either existing syndromes if they capture involved patients, modify these syndromes as indicated or create new syndromes to monitor outbreak status or as a case finding tool.

Applying information technology to ED data has transformed public health surveillance by quickly detecting public health emergencies while simultaneously substituting electronic processes for what in the past was labor-intensive manual work.

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Informática en Medicina de Urgencias y Emergencias: Gestión de la información y aplicaciones en el siglo XXI

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La informática en Medicina de Urgencias y Emergencias (IMUE) es la recogida, gestión, procesamiento y aplicación de los datos de la atención prestada a los pacientes urgentes, así como los datos operativos. La IMUE está transformando y mejorando nuestros sistemas de atención prehospitalaria y las intervenciones de los servicios de urgencias hospitalarios (SUH). Es fundamental para la vigilancia de la salud pública, y nos permitirá ampliar la investigación clínica en las instituciones, regiones y naciones. La IMUE es una de nuestras herramientas más importantes para mejorar la atención de emergencias y repercutirá positivamente en la salud de la población. Para la atención prehospitalaria, los sistemas IMUE proporcionan información para analizar la relación coste-eficacia de las intervenciones clínicas, para organizar las operaciones del servicio médico de emergencias (SME), para coordinar la comunicación en las solicitudes de servicio, vigilar el control de calidad y las necesidades educativas, y para el seguimiento de la evolución de los pacientes. La práctica de la Medicina de Urgencias y Emergencias en el SUH requiere la captura de muchos datos y elementos temporales para que la atención del SUH sea eficiente. Los módulos IMUE apoyan el seguimiento y la precisión del *triaje,* el seguimiento del paciente, el control de médicos y enfermeros, la decisión clínica, el orden de entrada, las instrucciones de alta y la generación de prescripciones. Debe haber coordinación del IMUE con el hospital, laboratorio y los sistemas de información del servicio de radiología, así como con los registros sobre acceso al hospital y a las clínicas ambulatorias. La información clínica se debe agregar a una base de datos del SUH que luego se puede utilizar para la investigación clínica. Es necesaria la cooperación y el apoyo del departamento de servicios de información del hospital, la administración del hospital, los *urgenciólogos* y los investigadores de IMUE, para que la base de datos del SUH esté bien construida y, más importante aún, bien utilizada, con el objetivo de mejorar la atención al paciente. Ya que la información de las bases de datos agregados de SUH proporcionan información basada en la población sobre lesiones y enfermedades agudas, actualmente estas bases de datos constituyen un elemento clave para la vigilancia de la salud pública. Un eficaz sistema de vigilancia sindrómica basado en el *Chief Complaint* (CC) [Motivo Principal de Consulta (MPC) en urgencias], *nursing triage note,* [informe de *triaje* por enfermería] y los códigos CIE-9 o CM-10 requiere la cooperación de los profesionales encargados de los sistemas de información hospitalaria, los administradores, los directores del SUH y los profesionales de la salud pública. [Emergencias 2009;21:354-361]

Palabras clave: Informática. Medicina de Urgencias y Emergencias.