MEDICAL INFORMATICS: AN ESSENTIAL TOOL FOR HEALTH SCIENCES RESEARCH IN ACUTE CARE

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Abstract

Medical Informatics has become an important tool in modern health care practice and research. In the present article we outline the challenges and opportunities associated with the implementation of electronic medical records (EMR) in complex environments such as intensive care units (ICU). We share our initial experience in the design, maintenance and application of a customized critical care, Microsoft SQL based, research warehouse, ICU DataMart. ICU DataMart integrates clinical and administrative data from heterogeneous sources within the EMR to support research and practice improvement in the ICUs. Examples of intelligent alarms – "sniffers", administrative reports, decision support and clinical research applications are presented.

KEY WORDS: ICU, EMR, DataMart, alarm, dashboard, modeling

Introduction

The practice of medicine and biomedical research are information-based sciences which involve gathering, synthesizing, and acting on information. As early as the 19th century mechanical computers have been applied in the medical field. Herman Hollerith's "punched-card data-processing system," originally used for the US census, was subsequently developed to support surveys in public health and epidemiology (1). Medical informatics is the applied science of patient data management for the purpose of improving understanding of health and bioscience. It is, by its nature, a multidisciplinary science with interactions across a number of fields. Medical informatics was static until the invention of the first generation of digital computers in the 1940s. Since then it has played an increasingly important role in health care and as a novel academic discipline acts as a bridge between medical and information sciences (2). Health information technology, an example of which is the electronic medical record (EMR), consists of: the clinical data repository, clinical decision support tools, controlled medical vocabulary, computerized provider order entry, pharmacy, and clinical documentation applications. It supports in- and out-patient's EMRs, and is used by care providers to document, monitor, and manage service delivery within health care organizations. EMR has being broadly advanced by governments, healthcare providers, large employers, hospitals, and organized medicine (3, 4). The adoption of EMR brings an unprecedented opportunity for providers, but ill considered implementation can lead to information overload (5) and an increase in the very errors they are expected to reduce (6). Central to this opportunity is a means of organizing and analyzing large quantities of digital information; the principal task of medical informatics.

The relevance of ICU care to public health in the United States is reflected in annual figures of 4.4 million ICU admissions, 500,000 deaths, 13.3% of hospital costs, 4.2% of national health, and 0.56% of the gross domestic product expenditures (7, 8). The demand for ICU services is expected to increase as the US population ages; patients older than 65 years currently account for more than 55% of all ICU days (9, 10). Unmeasured burdens include a high degree of disability and associated loss of productivity for both ICU survivors and their caregivers (11-13).

Clinical and translational research benefits from the availability of a comprehensive medical record. Extracting information from the clinical record has always presented a challenge. The current generation of EMRs were not developed to support clinical research activities and do not routinely support systematic data access and queries. This significantly impedes the development of complex real-time alerts or reports for clinical practice, administrative and research purposes. Most data continues to be retrieved manually from the EMR and entered back into a research database. This process is time consuming, and error prone (14). A better solution would be to transfer data automatically, efficiently, and accurately between the EMR and research database (15). The medical records of all new patients coming to Mayo Clinic, Rochester, Minnesota, are in an electronic form since early 2005 (16, 17). Using this resource we have developed a customized near-real time open schema ICU data warehouse, "ICU DataMart". ICU DataMart accommodates 3 major strategic objectives: 1) practice monitoring, reporting and feedback, 2) intelligent alert systems and 3) education, research and decision support (18). In this article we share our initial experience in the design, maintenance and application of ICU DataMart to achieve those objectives.

Hospital Overview

Mayo Clinic, Rochester campus is an academic medical center with two hospitals. There are approximately 1900 beds and 135,000 hospital admissions per year (2006). The combined ICU capacity is 201 beds with 14,800 admissions per year (2007). As a national tertiary/quaternary referral centre Mayo Clinic, Rochester also provides primary and secondary care to all the residents of Olmsted County. Remarkably only Mayo Clinic provides ICU services to the county population. Access to a geographically defined cohort of patients allows us to conduct population-based studies. All ICUs are equipped with multiple Dell workstations, with password protected EMR and clinical database access, with 24/7/365 institutional IT support.

ICU DataMart Overview

The ICU DataMart project was approved by the institutional Critical Care Committee as a quality improvement project. All research projects require Institutional Review Board approval. The main platform is a Microsoft SQL based database which integrates a near real time copy of clinical and administrative data from the heterogeneous and distributed EMR. Data points are extracted and copied within 15 minutes (physiological monitors) to 4 hours (clinical notes) from entry into the EMR.

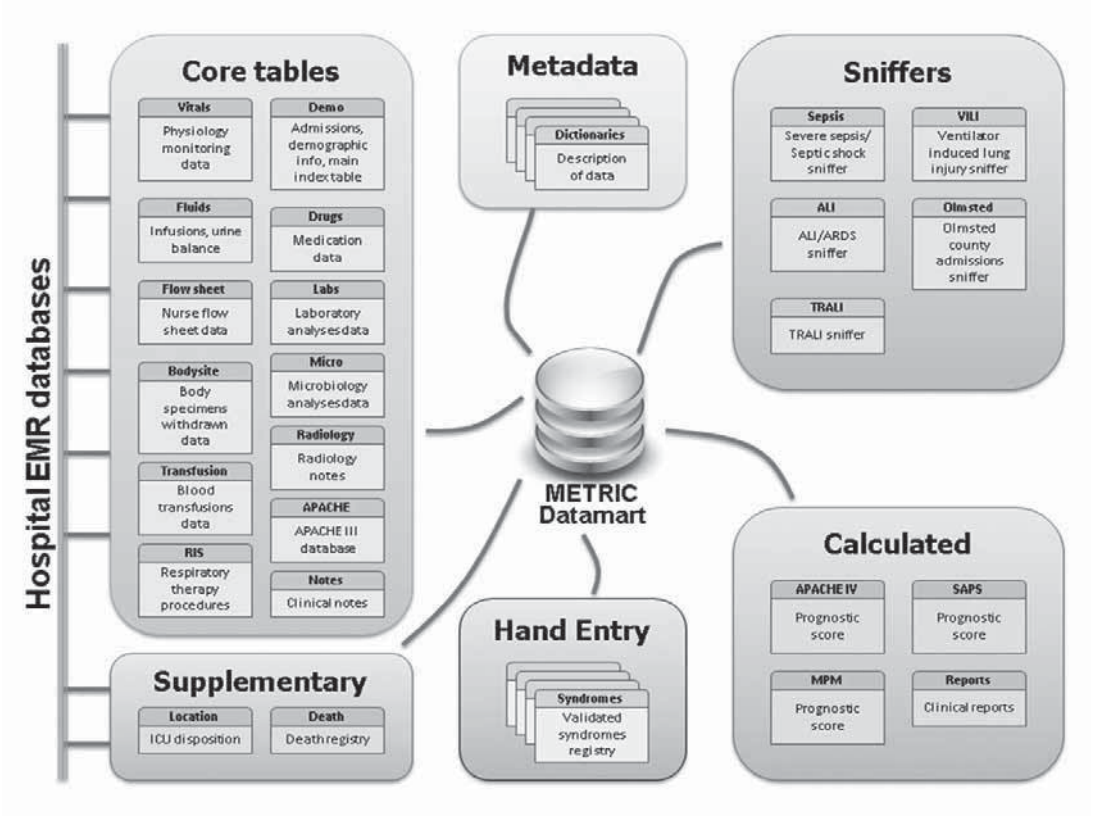

FIGURE 1. Data Sources and Core Tables in the ICU DataMart

Data from external sources (Minnesota death registry) are updated once per quarter. The components of METRIC DataMart are schematically outlined in Figure 1.

Data Security and Confidentiality

Patient oriented research projects guarantee patients' confidentiality and security in accordance with institutional policy and Health Insurance Portability and Accountability Act (HIPAA). Providers require an institutional, single log on, password and must have successfully completed a review of HIPAA in order to access patient data

User Interface

For end users, who are not technical "gurus" the most important requirement when designing a database is the availability of a simple, intuitive user interface (UI) which does not require specialized programming knowledge. As the UI for research purposes we have adopted the JMP statistical software (SAS Institute, Cary, NC), a standard statistical analysis tool available at each workstation within the institution. JMP's advanced intuitive query builder (Figure 2.) not only allows easy access to data but also provides a means for advanced statistical analysis. The institution provides JMP user education classes and extensive online support materials.

Database Management

For database development and administration we have used the EMS SQL Manager 2008 for SQL Server (EMS, New York, NY), which is a flexible, high performance tool for Microsoft SQL Server database administration. The versatile array of tools available include; Visual Database Designer which supports the creation of SQL Server database in few clicks; Visual Query Builder and advanced SQL editor which allow the user to build complex SQL Server queries. SQL Manager has an intuitive graphical user interface.

Data Validation and Integrity

It is the fundamental goal of any medical informatics project to provide secure, accurate and reliable data storage. The main challenge for the support team is the provision of effective outage detection and repair responses such that data and application integrity are always maintained. A customized monitor application runs every 2 hours and checks the status of each table within the database. If a table is out of range for

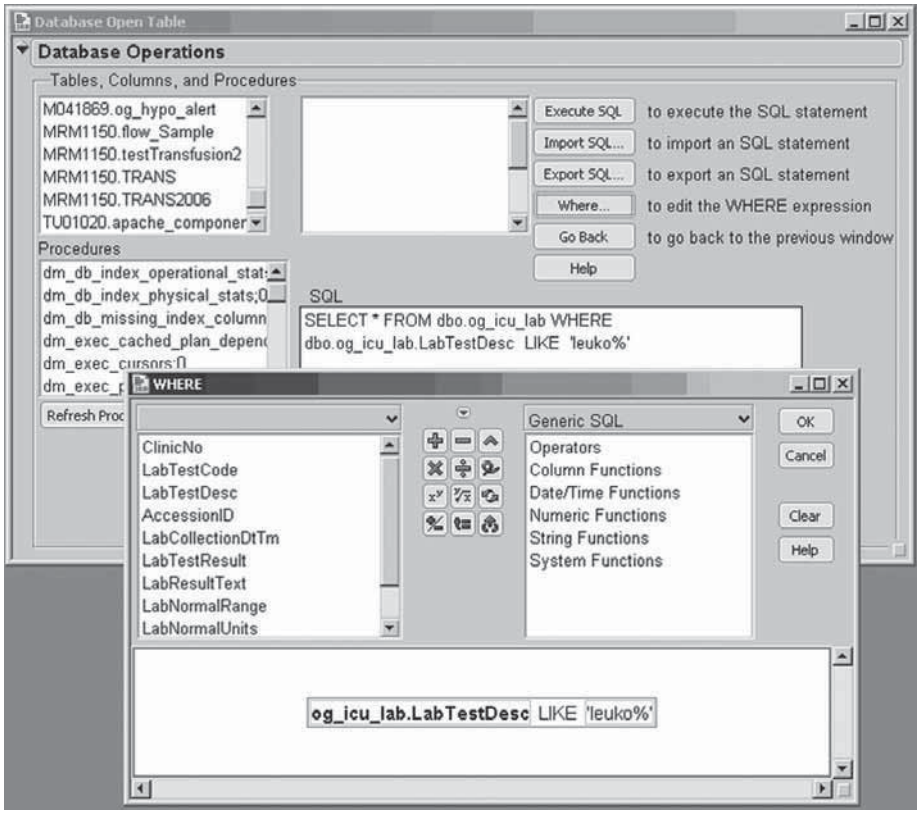

FIGURE 2. JMP- an Advanced Query Builder

updating, an alert message is issued to the ICU DataMart administration team via pager and/or email with specific detailed information (table, time of outage etc.). In this way the team can find and repair the problem and fill any resulting data gap in a timely fashion. A web based dashboard continuously displays the status of the database including the latest time each table had been updated. Descriptive statistical data analyses are run at monthly intervals to discover any unusual data patterns. As part of the quality control process we perform regular historical data auditing in which we randomly compare selected data sets from ICU DataMart to source data from the original EMR.

Sniffers: Intelligent Alert System for Decision Support and Research

The availability of large quantities of data within the EMR can cause information overload (19) and the impact this has on clinical judgment is of genuine concern. Neither EMR nor modern Clinical Information Systems provide effective solution to these problems. On the other hand, the availability of data in an electronic format provides an opportunity for automated solutions, including electronic patient surveillance. Early detection of critical care syndromes such as sepsis, shock and acute lung injury (ALI) can improve outcome and decrease the cost of medical care (20). Bedside ICU monitors are not designed to recognize complex physiologic syndromes. Most generated alarms are clinically insignificant, and serve only to distract bedside providers (21). While syndrome surveillance technology has been widely used in public health, of the availability of an EMR facilitates the expansion of these techniques into the areas of clinical medicine, quality improvement, patient safety and research. By using patients' data from ICU DataMart we have designed, tested and implemented syndrome surveillance in the ICU. "Sniffers" are custom built, JAVA computer programs which facilitate syndrome surveillance and allow rule based query building. These rules are easily modified with a limited need for additional coding with each new query (22, 23). Sniffers run at pre-specified intervals and when they detect that a patient's condition has met some predefined criteria they trigger a system response. This response is initiated through an alert message directed to the appropriate person(s) via email and/or pager. From a technical prospective, sniffers utilize object-oriented design, and are implemented through open source technologies such as Java. This renders them platform and data source independent. Sniffers can be deployed across multiple databases with simi-

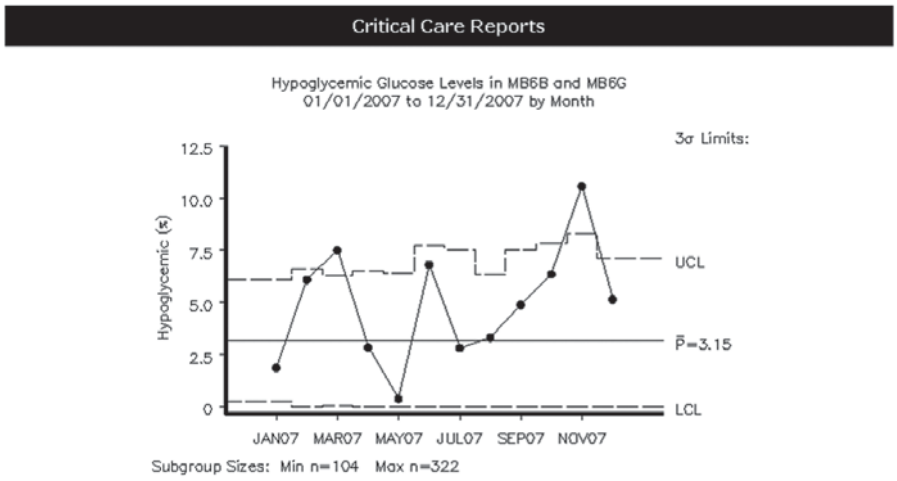

FIGURE 3. Example of ICU statistical control chart representing hypoglycemic episodes in patients treated in the two ICUs (MB6B and MB6G). Values in March and November are statistically significant and warrant investigation into the causes of observed findings

lar characteristics. The growing list of applications in the host institution includes; decision support for ICU discharge decisions,; personalized mechanical ventilation orders (24), ;detection of transfusion complications; acute lung injury prevention; (25) and enrollment into time sensitive clinical research studies (26).

Practice Reporting

Quality of care is usually estimated in structure, process, and outcome. The metrics describing those domains are often poorly defined and difficult to measure. However, the measurement and analysis of processes of care are essential components of quality improvement initiatives. Administrative reports should be readily available to a management team tracking service utilization, costs, quality and billing. Unfortunately, most of the high level administrative reporting is meaningless as it is based on flawed data (27, 28); most elements known to be important indicators of processes of care are either not captured, or are captured with insufficient accuracy to be useful (29). The EMR, on the other hand, is a rich source of pertinent information. The current generation of clinical information systems do not routinely support the generation of practice management reports. Statistical process control (SPC) is an effective method of monitoring a process through the use of visual charts. This approach is increasingly common in the analysis of health care processes (30). Using the SPC approach we have developed and implemented the SAS (SAS Institute, Cary, NC) based administrative Clinical Reporting Tool (CRT) and Score Calculation Tool (SCT). CRT is a web-based reporting tool which generates customized reports of the main ICU processes of care and resource utilization. A total of 47 variables were selected for inclusion by the institutional Critical Care Committee. The leadership teams in individual ICUs can choose to report any combination of these variables, (e.g. length of ICU and hospital stay, ventilator free days, admission source and service code, etc). The output can be represented either in chart or table formats (Figure 3). Add-hoc reports are available on request.

One of the first quality improvement projects supported by ICU DataMart focused on reducing ICU readmissions. Unintended readmission to the medical intensive care unit (MICU) is associated with worse outcome (31) and the providers ability to predict which patients are likely to deteriorate after ICU dismissal is limited. Our group has developed and implemented an automated tool which identifies discharged patients at high risk for ICU readmission. The tool calculates each patient's Stability and Workload Index for Transfer (SWIFT) score (31), a calculation based on ICU admission source, ICU length of stay, and day of discharge neurologic (Glasgow Coma Scale) and respiratory (arterial blood gas) dysfunction. Results are displayed on a web-based dashboard and are used daily for ICU discharge decision making by clinical providers.

Clinical Research

ICU DataMart has been extensively used in observational research projects and facilitates screening of patients who may be eligible for enrollment into clinical trials. Automated alerts notify study coordinators via e-mail or pager when patient characteristics fulfil study specific enrollment criteria, thus greatly improving the

efficiency of clinical research in the acute setting. Novel research applications supported by ICU DataMart include simulation modelling of sepsis resuscitation, physiologic modelling of acute lung injury development and complex adaptive system modelling of critical illness and life support interventions in the community.

Conclusion

The reduction of error and waste is one of the key strategic goals of modern hospitals. The availability of data in electronic format facilitates the development of novel medical informatics approaches in support of quality improvement and research in complex hospital environments, such as the ICU.

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