Using Specialized Information Technology to Reduce Errors in Emergency Cardiac Care

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Abstract

Information Technology (IT) solutions to patient safety/medical error problems are promising, but only in the early stages of their development and implementation. Many current IT applications for patient safety are focused on hospital processes, such as physician order entry and clinical information system-based alerts for critical values. These interventions are broadly based, often targeting all medications ordered or all critical values for all patients, and, by necessity, are not specifically configured to address the care of patients with a particular condition or clinical problem. However, a condition- or problem-oriented IT system might better integrate into the care of frequent conditions and thereby be more effective. Accordingly, the authors focused on the use of IT for the most common serious conditions requiring emergency and acute care—the diagnosis, triage, and treatment of emergency department (ED) patients with potential acute coronary syndrome (ACS). This condition includes acute myocardial infarction (AMI), also known as acute cardiac ischemia (ACI), and unstable angina pectoris (UAI), a condition that can lead to AMI. The Acute Cardiac Ischemia Time-Insensitive Predictive Instrument Information System (ACI-TIPI-IS) Demonstration Project at Tufts–New England Medical Center used multiple IT applications for patient safety, combining real-time decision support, alerting, and retrospective feedback for performance improvement, all for the care of patients presenting to the ED with symptoms suggestive of ACS. A Web-based relational database system, the TIPI-IS, electronically compiled information from existing operational systems about all ED patients for whom an electrocardiogram (ECG) was done for possible ACS symptoms, and supported the patient safety aspects of the project. Real-time decision support was provided by the automatic printing of the probability of ACS on the ECG, as calculated by the ACI-TIPI. Various types of physician-specific alerts or retrospective feedback reports about the management and outcomes of patients with potential ACS, such as for patients with abnormal cardiac biomarkers discharged to home, were produced by the TIPI-IS and provided online via e-mail-linked access, and via paper formats, to support self-evaluation of staff, practice improvement, and ED operations oversight. Through the successful implementation and demonstration of the system, the authors identified barriers and lessons learned that will inform the continued development of this IT approach for preventing patients with missed ACS from being overlooked in the ED.

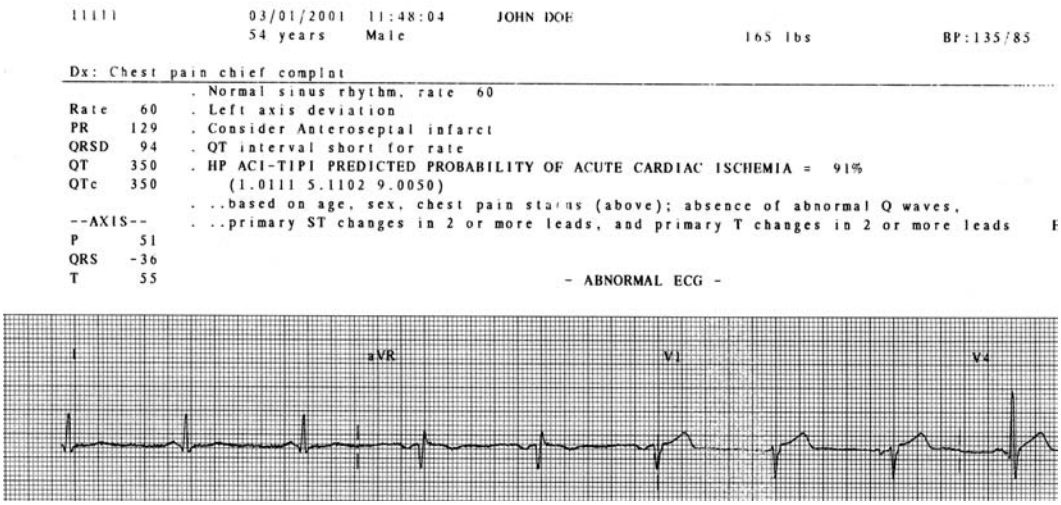
Introduction

Acute coronary syndrome (ACS) and the synonymous condition acute cardiac ischemia (ACI), both of which include acute myocardial infarction (AMI) and unstable angina pectoris (UAP) that can lead to AMI, are the most common serious conditions requiring emergency and acute care. Among the 7 million patients who present to emergency departments (EDs) in this country each year with symptoms consistent with a cardiac problem, about 25 percent will prove to have true ACS. About a third of the group with confirmed ACS (about 8 percent of apparent cardiac patients), will prove to have AMI. About 40 percent of patients found to have AMI (about 3 percent of the overall group) will have early stage AMI and can benefit from reperfusion treatment. Thus, the problem for the ED physician is to promptly and accurately identify, triage, and treat the relatively small proportion of patients who require immediate emergency care, while efficiently dealing with the great majority who do not truly have ACS. This has been a focus of our research over the past 2 decades, which includes the development of the time-insensitive predictive instrument (TIPI) approach to improving ED triage and treatment decisionmaking.[1–5]

Errors are made in the care of such patients; thus, there are important opportunities for improvement in these ED triage and treatment decisions. For ED *triage*, about 12,000 patients with AMI and 14,000 with UAP are mistakenly sent home each year in the United States, which nearly doubles the expected mortality rates.[6] In light of this, it is not unexpected that cases of ACS missed by ED personnel represent from year to year one of the largest cost categories of adult malpractice claims in the United States. Regarding ED *treatment* of patients with AMI, the lifesaving impact of coronary reperfusion (especially by use of thrombolytic therapy) is directly related to the earliness of use. An hour's delay, which is common, can halve the mortality benefit[7, 8]—yet many AMI patients are not treated promptly, and about 90,000 patients per year are not treated at all. These errors in triage and treatment for ACI are clinically critical to the patient and occur on a scale that makes such errors a public health issue, and thus present important opportunities to reduce medical errors.

The Acute Cardiac Ischemia Time-Insensitive Predictive Instrument Information System (ACI-TIPI-IS) Demonstration Project used multiple information technology (IT) applications for patient safety by combining real-time decision support, alerting, and retrospective feedback for performance improvement for a single group of patients: patients presenting to the ED for ACS. A Web-based relational database system, the TIPI-IS, electronically compiles information from existing operational systems about all ED patients for whom an electrocardiogram (ECG) was done and supports the patient safety aspects of the project. Real-time decision support was provided through the use of the ACI-TIPI electrocardiograph, which calculates the probability (expressed as a value from 0–100 percent) that the patient is truly having ACS; this probability is printed on the top of the ECG (Figure 1).

Figure 1. Computerized electrocardiograph version of the Acute Cardiac Ischemia Time-Insensitive Predictive Instrument (ACI-TIPI)



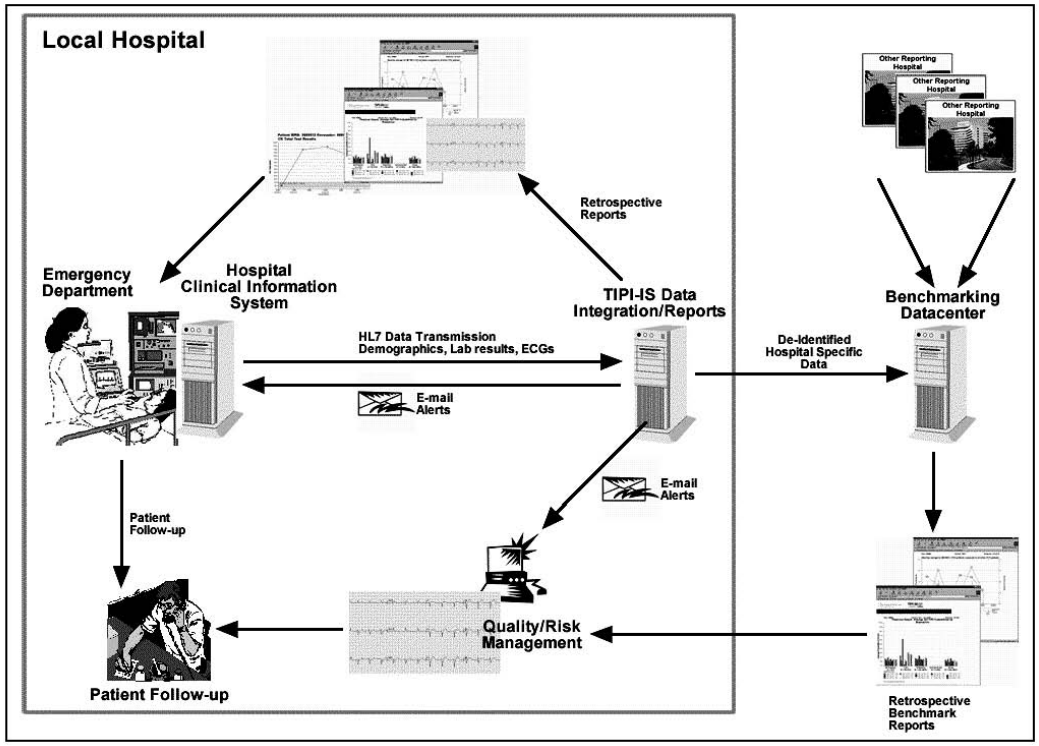
Upon detection of abnormal cardiac biomarker results, the TIPI-IS generated alerts concerning patients who had been sent home from the ED, supporting followup review and action, if warranted. Physician-specific feedback reports about the management and outcomes of patients with potential ACS were compiled by the ACI-TIPI-IS and were available online. These reports were provided via e-mail to staff with system access and also in paper format, to allow self-evaluation of clinical practice and to support oversight of ED operations. The goal of the project was to demonstrate the ability of a completely electronic safety system to provide necessary decision support and feedback to clinicians by way of real-time, concurrent, and retrospective IT systems. The project made use of the data already collected in the course of patient care through an electronic data collection and reporting system. Through the successful implementation and demonstration of the system, we identified barriers and learned lessons that inform continued development of this technology and approach to prevent missed myocardial infarctions in the ED, and that serve to inform further research in this area. This article describes the development and implementation of IT that integrates our existing ACI-TIPI decision-support technology into a patient safety/quality improvement reporting TIPI-IS database and feedback system.

Project overview

As with our previous work using real-time decision support,[1-5] at the core of our integrated TIPI-IS approach is the use of a predictive instrument, an algorithm contained in the electrocardiograph's software. This algorithm (ACI-TIPI) was used to compute a probability (expressed as a percent) that patients presenting to the ED with complaints of chest pain or related symptoms truly had ACS (or, specifically, of ACI). The predictive instrument's result—a value ranging from 0–100 percent—was calculated on the basis of the ECG waveform measurements,

and the patient's age, gender, and presence of chest pain, as entered. The resulting value is automatically printed on the ECG's text header as a decision-support aid for the physician. In addition to being printed on the ECG header, the ACI-TIPI probability was stored in the electrocardiograph's computer and then transmitted to the TIPI-IS. When the ECG files were transmitted to the TIPI-IS, the patient's ACI-TIPI probability and basic ECG data became part of the ED's patient safety database. Added to this were data from other hospital information systems, including the patient's demographic data, cardiac biomarker results, and ICD-9-coded diagnoses and procedures. All of these data were integrated in the database, to create the TIPI-IS patient records.

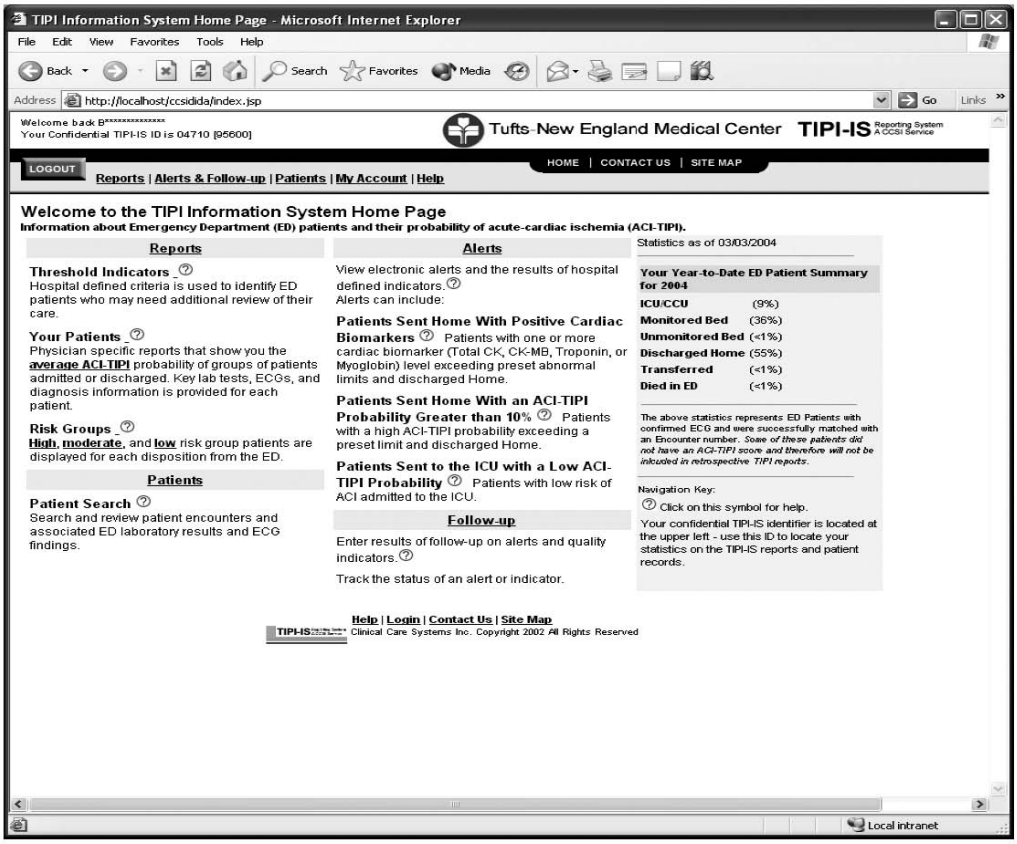
Figure 2. How the TIPI-IS fits into the hospital's network of information systems



The collected data elements included those that allowed us to define specific alerts (using criteria based on significant clinical variables), along with demographic and clinical data for retrospective reports and research analyses. These reports supported initiatives involving ED staff, leadership, quality improvement (QI), and resource use.

The TIPI-IS integrated the data it received through the multiple interfaces to create patient records. The flexible design of the TIPI-IS accommodates changes in transmitted data, such as the future conversion to ICD-10 coding, without requiring changes to the TIPI-IS software. A Web-based interface allowed access to individual and group data and reports. The TIPI-IS homepage is presented in Figure 3.

Figure 3. TIPI-IS homepage



The database was a rich source of information that could be used to identify actual or potential patient safety issues, and to support the quality improvement cycle. Physicians, managers, and quality improvement staff accessed the TIPI-IS database through a Web-based interface that allowed them to view and print reports, view triggered alerts, enter followup information, search for individual patients and groups of patients, and view patient-level details, including ECGs.

Patient safety alerts

Development of alert criteria

In conjunction with ED physician leadership, we developed patient safety alert criteria to identify cases thought to require case review and followup. The alerts included patients sent home from the ED with abnormal cardiac biomarker test results, and patients sent home from the ED with an ACI-TIPI probability value that was moderate (11–55 percent) or high (>55 percent). An iterative process was required initially to refine the alert definitions and their triggering criteria. The cardiac biomarker alerts, once triggered, were delivered to staff at each hospital ED for immediate review. The ACI-TIPI alerts were also transmitted to the hospitals, but were scheduled for retrospective case review by

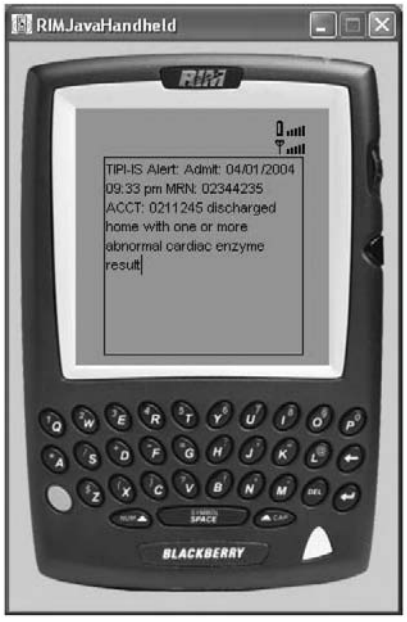
the ED physician-director. Each alert contained information that described the type of alert, the date and time transmitted, patient identifiers, and patient contact information for followup.

Each triggered alert was stored and accessible via the TIPI-IS at each hospital. The Alert and Follow-up Web page displayed a record of each alert and a form to collect followup data. Users who had appropriate access could log onto the system and view the alerts by type, time period, and by followup status. The results of reviews of alerts were entered through this form and summary reports were available.

Alert delivery methods

The alerting process provided a mechanism to let physicians know when a patient was sent home who met criteria for patient safety alerts. When the TIPI-IS received information indicating that an ED patient who met alerting criteria had been sent home, a message was sent to the ED requesting review of the case. These messages were sent by e-mail, as a text message to a pager, or to a specified printer (Figure 4). Each alert functioned separately from other alerts. If positive cardiac biomarker test results were identified for a patient who had been sent home, that alert would be triggered and sent to the ED, whether or not the patient had a high ACI-TIPI probability or even had an ECG in the database. The intention of the alert was to notify the staff at the earliest possible moment that a patient might require immediate followup, to prompt further evaluation or treatment.

Figure 4. TIPI-IS alert



The method of alerting used at each hospital varied: in some cases, the existing process for notification about critical lab values was used; in others, a more structured delivery process was put in place. Some hospitals used multiple delivery methods, to ensure that alerts were received and followup was performed.

In the first hospital to use the TIPI-IS, alerts were sent to a dedicated e-mail address that was already used by the hospital's Clinical Laboratory and Radiology Departments to communicate important results to the ED. E-mail alerts were printed by the ED unit secretary and handed to the ED physician on duty. The e-mails also were sent to the project staff so they could understand the alert followup process. The second participating hospital used a combination of text paging and e-mail alerts. The text message was delivered to a pager at the ED secretary's desk as well as to the QI nurse in the ED. Both the physician on duty and the QI nurse were responsible for followup. At a third hospital involved in the project, the alerts were sent by text message to the ED director's pager who then contacted the physician on duty for followup. The fourth hospital requested that alerts be sent to a dedicated printer in the ED, as well as to the hospital QI coordinator and to the ED physician-manager.

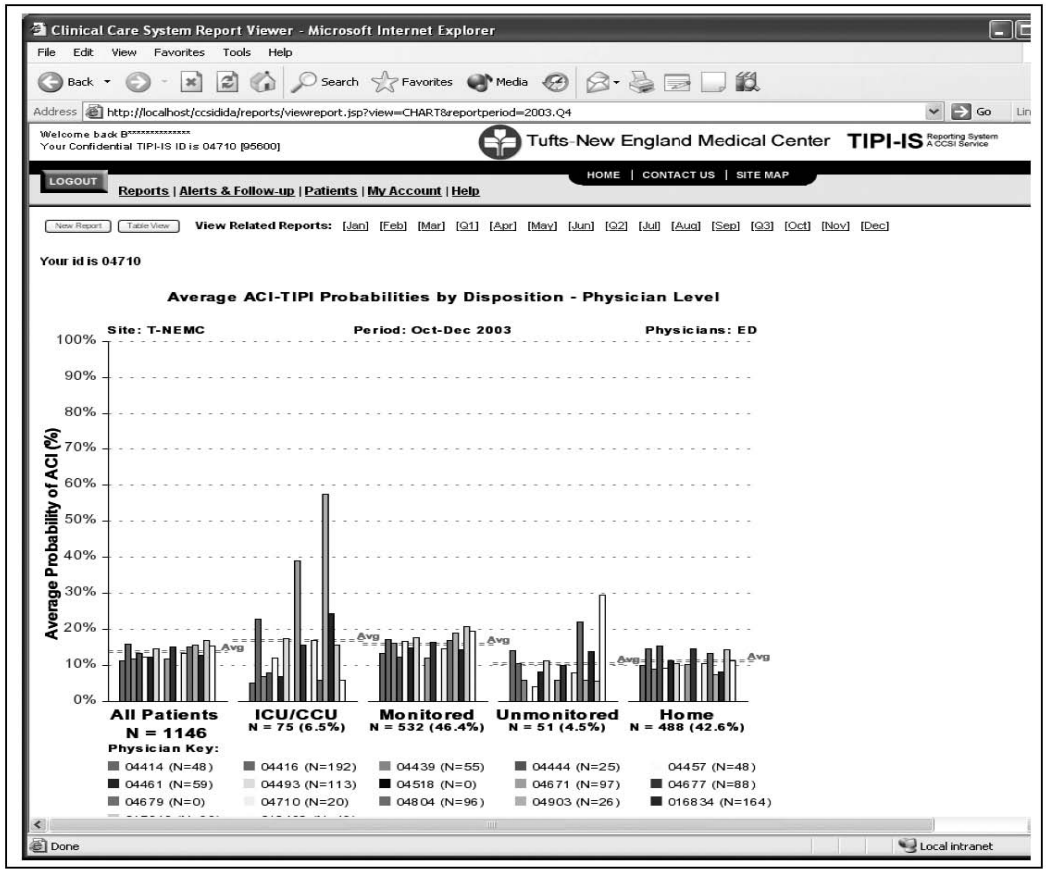
Review of alerts

Each alert was reviewed and the results entered into the followup database. Review of the alerts resulted in a greater awareness of the variability in managing patients with chest pain, issues of communication between resident and attending staff, insufficient documentation of laboratory results and patient management, and the need for consistent followup of patients with positive biomarker results who left the ED against medical advice. A small number of patients returned to the ED for followup and were admitted for further care. The issues identified by the ED directors were addressed with staff during monthly Morbidity and Mortality meetings and in individual feedback discussions.

Retrospective reports

The TIPI-IS was used to provide monthly physician- and hospital-level feedback reports on the management of ED patients from the point of the patient having an ECG with an ACI-TIPI probability. Physicians were provided a summary of graphical reports about patients they treated in the ED and their subsequent disposition: i.e., to the intensive care or coronary care unit (ICU/CCU), a monitored bed, an unmonitored bed, or home. They could view the percentages of patients they hospitalized or discharged to home, compared to the group average, and could view details about each patient. Reports also focused on patients who were sent home with high ACI-TIPI probabilities (>55 percent) and patients admitted to the CCU/ICU with low ACI-TIPI probabilities (≤10 percent). Demographic data about patients were provided along with ECG results, cardiac biomarker test results, and coded ICD-9 diagnoses and procedures (Figure 5).

Figure 5. Average ACI-TIPI probability by ED disposition



As part of their training, emergency department physicians are expected to track the outcomes of patients they hospitalize as well as those whom they discharge from the ED and who subsequently return. Using the TIPI-IS for hospitalized patients, physicians could view the sequence of biomarker results to determine if a patient met criteria for AMI. They could also view the coded ICD-9 diagnoses and the cardiac procedures the patient had after admission. Through the Web site, the physician could view the patient's ECGs throughout their stay, including the ACI-TIPI probability in the ED, and the confirmed ECG interpretation. The length of stay is available, as well as the patient's final disposition. Information was provided to ED physician-managers on the volume of patients admitted and the proportion who were ruled in for AMI among those who had ECGs and cardiac biomarker tests performed.

Different levels of feedback reports were made available to staff with different functions. All physicians could view their own data and compare results to the group and to other, unidentified physicians. Physician directors and QI staff could view identified data for all staff. Followup data entry was limited to QI staff and ED leaders. These TIPI-IS Retrospective Reports included:

- Patients sent home with positive biomarkers or high risk level ACI-TIPI probabilities (scores >55 percent).

- Patients who returned to the ED within 72 hours and required hospitalization.
- High-, moderate-, and low-risk patients by ED triage disposition.
- Patients admitted to the ICC/CCU with low ACI-TIPI probabilities.
- Average ACI-TIPI probabilities by ED triage disposition.

Distribution of reports

Reports were made available to physicians through the Web-based TIPI-IS system, as well as being sent directly to their offices. When a physician logged onto the TIPI-IS to view their reports, a drill-down feature allowed them to view all available data on each of their patients. The system server was placed on the hospital Intranet and a TIPI-IS link was located next to the ED's own home page link. The TIPI-IS link also was e-mailed to participating physicians each month. Paper versions of the reports were distributed monthly through mailings to physicians' offices, and they could access the same reports through their desktop PC.

Site selection

Hospitals that had (1) ED electrocardiographs with ACI-TIPI capability, (2) institutional readiness to install the system and related computer system interfaces, and (3) the leadership's willingness to support the project were identified as potential sites for this project. Self-insured hospitals that were clients of the malpractice liability broker Marsh, Inc., a strong supporter of the project, were also approached, because these hospitals—while motivated to maintain quality—directly bear the financial risk of missed AMI. Electrocardiographs with ACI-TIPI decision-support software are available through the two largest electrocardiograph vendors. A third manufacturer, which made the electrocardiograph model used by one of the hospitals, developed the software in response to their customer's request to participate in the study and will continue to make the software available to the hospital.

In discussing the project with potential participants, we found it challenging to reach consensus among parties within a hospital. In some cases, hospital leaders were interested in participating and implementing patient safety systems, but ED leadership did not believe they were at risk for missing patients with ACS. In other instances, ED leadership was willing to participate, but they were unable to motivate their colleagues in the cardiology department. Cardiology departments in some hospitals were interested in installing the decision support software, but the same institutions' EDs didn't believe that they needed to improve their management of patients with chest pain or ACS. In one case, in a hospital that did not participate in the study, all clinical and administrative parties were motivated, but the IT staff did not believe they had adequate resources. Of the many sites considered for participation, the most common barrier to participation was

reaching consensus among clinical groups, and least frequent barrier was technical issues related to system interfaces or IT resources.

Development, implementation, and testing of the TIPI-IS

Hardware, software, and architecture

Each participating hospital received a TIPI-IS server to handle all the local data aggregation, reporting tasks, and provide Web-based access to the TIPI-IS ED patient database. Each of these local TIPI-IS systems were further linked to the central TIPI-IS datacenter server over a secure Internet connection. The central database aggregated de-identified data across hospitals for multihospital benchmarking reports.

To enable system flexibility across diverse hospital ED project sites, from small rural clinics (with as few as two beds in their EDs) to large regional teaching hospitals, the TIPI-IS used standard technologies (object-oriented programming, Java™, XML, SQL database) and communication standards (e.g., HL7, HTTP, TCPIP), as well as standard approaches from financial and e-commerce. The TIPI-IS architecture and technologies functioned without regard to the specific operating system and hardware in each hospital's IT environment. To keep costs low, each hospital implemented the TIPI-IS using commonly available hardware (Windows® 2000 Server on PC servers) and proven open source software for its Web server (Apache.org's Tomcat Webserver) and relational database (MySQL 3.23). The TIPI-IS application clients were standard Web-browsers (Microsoft® Internet Explorer 5.x and Netscape®), available on all PCs within each hospital.

The local TIPI-IS server aggregated hospital admission/discharge/transfer (ADT) data, cardiac laboratory results, and ECG data from hospital information operational systems (using HL7 interface engines and ECG management systems) through standard data interfaces (HL7 and FTP). The TIPI-IS linked the patient data elements into a local SQL database for concurrent alerts, retrospective reporting, and single-point, Web-based access to the ED patient profile. Although nurses and physicians were able to access all these data elements from existing clinical information systems, the TIPI-IS provided a single point of access to view ED patient demographics, ICD-9 diagnoses and procedure codes, ED encounter and hospital data (including length of stay and repeat visits), and ECG waveform and analysis results (including ACI-TIPI scores).

System installation

Installation of the TIPI-IS at each site included seven steps:

1. Site assessment and development of a detailed installation and testing plan.

2. Customizing of the TIPI-IS to address hospital-specific operational and technical needs.
3. Installation of the TIPI-IS server on the hospital's Intranet.
4. Preparation of the hospital's ECG equipment.
5. Linking and integrating each hospital's key databases to the TIPI-IS server via electronic interfaces.
6. Testing interface data.
7. User training.

A detailed site assessment was conducted, and an installation plan was developed with each participating hospital to address their technical needs and available resources. Each site identified key data dictionaries and completed a questionnaire about the process of care delivery in the ED. Modifications were made to the TIPI-IS to address unique IT needs, including special processing of account numbers and filtering of interface data. Hospital-specific alerting criteria and feedback report parameters were also programmed.

Hospitals' IT departments received detailed specifications for each variable to be transmitted to the TIPI-IS, using standard HL7 transaction protocols and data formats. Many hospitals already use these HL7 interface engines to transmit data across internal systems and, whenever possible, the hospitals used existing interfaces to avoid repeated effort. Tests were conducted of interfaces from feeder systems to the TIPI-IS at each site to ensure that the system captured the data completely and mapped key data elements accurately for reporting.

Training for nursing technicians and nurses consisted of a brief overview of the project and a hands-on demonstration of the use of the ACI-TIPI software in the ED electrocardiograph. Training materials were provided, and simple instructions were placed on each electrocardiograph for staff reference. Physicians received an overview of the project in a group meeting and samples of the ACI-TIPI ECGs and details on the development and testing of the ACI-TIPI in the form of research publications. ED managers and QI staff were trained in the use of the TIPI-IS and data entry of followup information.

Data collection

Data were collected at each site for a 6-month baseline period, followed by a 12–18 month intervention period. The advantage of the electronically collected database was that staff did not need to identify cases and perform manual data collection and data entry. Once the system was implemented, all cases meeting data collection criteria were automatically identified and all appropriate data collected. This process allowed us to compile a database of more than 415,000 patient encounters across the five hospitals, including 130,000 ECGs with ACI-TIPI probability scores. The inclusion of ICD-9 diagnostic codes and cardiac biomarker results allowed us to provide analyses of patient outcomes.

The creation of the TIPI-IS proved to be an effective method for quickly compiling data into one system for use in a patient safety system. The compiled information was not available to these hospitals in any other single system, including the institution's electronic medical record. Criteria for initiating alerts were applied continually to the transmitted data, and alerts were triggered 24 hours a day, without requiring staff intervention. Feedback reports were compiled at the conclusion of each month and posted on the system.

Collecting data through automated interfaces had certain disadvantages: the need for detailed tracking of data quality for large data sets; and the likelihood of unanticipated disruptions in data transmission to the system, due to system downtime, upgrades, and operational changes to interfaces or feeder systems that affect the interface. Part of the preinstallation assessment process involved working with the local IT department representatives to identify requirements for disaster recovery and downtime procedures, and adherence to hospital data center policies and procedures. The local hospital IT group provided the same uninterruptable power services, backup and recovery services, antivirus protection, and constant (24-hour/7-day) server monitoring services to the TIPI-IS that it would to any other clinical and administrative data server operating within the hospital data center facilities. While HL7 interfaces are fairly standardized, they are interpreted differently by different organizations, and processing of the same type of data may differ among hospitals. If a third-party vendor provides IT services, the internal IT department may have limited knowledge about the system and may have to pay the vendor for even minor interface changes.

Successes and lessons learned

Real-time decision support

The ACI-TIPI software was available at or supplied to each of the participating hospitals, the staff was trained in its use, and the completeness of the data was monitored. Approximately 50–85 percent of the ED ECGs had complete real-time data entry, such that the ACI-TIPI probability was printed on the ECG for real-time decision support. It is not clear what the optimal proportion with complete data should be. Not all ECGs in an ED are performed for suspicion of ACS, in which case the ACI-TIPI probability would not be indicated. Nonetheless, initially, available data on patients' presenting symptoms suggested that many patients for whom the ACI-TIPI would be appropriate did not have the required data entered (age, sex, and chest pain status). Actions were taken at each hospital to improve the completeness of the ACI-TIPI data entry, including feedback to nurses and technicians about missing and incorrect data.

The project illustrated an important consideration in developing future decision-support models for real-time use by clinicians. While age and sex are fairly straightforward variables, the patient's chest pain status is more likely to be entered incorrectly, due to human error on the part of the technician or patient. The chest pain status identifies the absence or presence of chest pain as a primary

or secondary reason for coming to the ED. By "chest pain," we mean a family of related symptoms, including left arm pain, jaw pain, shortness of breath, upper abdominal pain, and dizziness or syncope. Potential errors include misinterpretation by the technician of the meaning of the chest pain variable, misinterpretation of the patient's response, patient misinterpretation of the question, or patient provision of incorrect or incomplete information. Since the chest pain status variable plays an important part in calculating the ACI-TIPI probability, the inevitable contribution of error by the patient or technician affected the score's accuracy and relevance for use in real-time and retrospective feedback reports.

Future development of decision-support models should take the potential contribution of patient or technician error into account by minimizing or eliminating the opportunities or effect of human error in the algorithm.

Concurrent alerts

The system for generating concurrent alerts was successfully implemented at each hospital, using criteria supported by that hospital's ED physicians and delivery methods appropriate to that site. The criteria and thresholds for alerts were specific to the needs of the organization to engender buy-in by users. The levels of false-positive diagnosis on triage (unnecessary hospitalization) or the potential for false negatives (failure to hospitalize a patient with ACS) were concerns when physicians decided on the alerting criteria. Once the alerting process was in place, adjustments in the criteria were made to account for higher-than-anticipated rates of false-positive alerts. False-negative alerts were difficult to identify, since there was no systematic method for following-up on all patients sent home. We devised a substitute method for identifying potential false negatives by screening the charts of patients sent home with moderate and high ACI-TIPI probability scores.

While the methods of delivering alerts varied in their success, the key to adequate followup was the presence of an invested third party, or champion, with the responsibility for alert followup. The e-mail alert process was effective in delivering the message, but successful followup relied on the unit secretary to deliver the e-mail to the ED physician on duty. A text pager at a secretary's desk was not an effective method to deliver alerts in a busy and complex setting, because the alerts were infrequent and the pager could be misplaced. Alerts communicated through a text pager in the hands of the responsible physician were effectively delivered, but false-positive messages due to incorrect identification by staff of the patient as being sent home from the ED were bothersome.

A three-level alert notification process, including e-mail messages to QI staff and the ED manager, as well as a printed alert in the ED, proved to be the most effective. This process ensured that those responsible for followup, as well as the ED manager, were aware of the alert and could ensure the followup took place.

Feedback reports

The feedback reports were compiled and made available through the Web-based system shortly after the conclusion of the given reporting period, and an archive of all reports were available online to all ED physicians at each hospital. In an anonymous survey of physicians at one site, 66 percent of physicians reported reviewing the reports and identifying their own performance among the group of physicians displayed on the report.

The disadvantage of the Web-based system was the perception that it was difficult to access the system to view the reports. Alternative forms of feedback report delivery were tried. Paper versions of the reports were distributed monthly, by mail, to each physician's office. An e-mail message with a direct link to the Web-based reports was devised that allowed easier distribution and access to physician reports, and avoided the need for the physician to log onto the system while still ensuring the security of the system. The e-mail message focused the physicians' attention on a few key reports rather than the large number of reports originally available. These reports were geared to helping the physicians followup on the outcomes of patients who had been hospitalized, as well as those who were sent home and who later returned to the ED.

Conclusion

This ACI-TIPI- and TIPI-IS-based project aimed at reducing errors in emergency cardiac care illustrates the use of usual clinical IT (conventional computerized electrocardiographs with ACI-TIPI software) and existent hospital IT, along with conventional PC-based and interface IT. The project successfully demonstrated that a patient safety system using a completely electronic data collection and feedback reporting system and offering real-time decision support, concurrent patient safety alerts, and retrospective physician level feedback reports could be implemented in a variety of hospital settings. Given the current health care system in the United States, it is certain that successful dissemination of the technology will require some form of commercialization. The optimal structure and process for doing this is yet to be determined. While there is clearly great opportunity for generic cross-cutting IT approaches to patient safety, in the short term, or in addition, we believe our project illustrates the potential of condition- or care-specific IT-based patient safety systems. Such targeted, limited, and less costly approaches may well be an important component of patient safety and QI activities and deserve further investigation in the wide variety of health care settings so in need of such efforts.

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Disclosure

The authors of this manuscript are the developers of the technology used in the project, and could have a financial interest in the technology if TIPI-IS is commercialized (which is not currently the case).

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