Medical Error Prevention in ED Triage for ACS: Use of Cardiac Care Decision Support and Quality Improvement Feedback

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Acute coronary syndromes (ACS) is the most common serious condition requiring emergency and acute care. Among the 8 million patients who present to emergency departments (EDs) in the United States each year with symptoms consistent with a cardiac problem, about 25% prove to have actual ACS. About one third (8%) of the presenting group prove to have acute myocardial infarction (AMI), of whom approximately 40%, or 3% of the overall group, have early-stage AMI deserving reperfusion treatment. The problem for the ED physician, therefore, is to identify, triage, and treat promptly and accurately the small proportion of patients who require immediate emergency care while efficiently dealing with the great majority who do not have ACS. This issue has been a focus of the time-insensitive predictive instrument (TIPI) approach to improving ED triage and treatment decision-making [1–5] and the TIPI Information System (TIPI-IS) feedback reporting system.

In the care of such patients, errors are made; thus, important opportunities exist for improvement in these ED triage and treatment decisions.

In ED triage in the United States each year, about 12,000 patients who present with AMI and 14,000 who present with unstable angina (UA) are mistakenly sent home from the ED [6], which nearly doubles their expected mortality rates [6]. Reflecting this problem is that ED cases of missed ACS perennially represent one of the largest cost categories of adult malpractice claims in the United States. In ED treatment of patients who present with AMI, the lifesaving impact of coronary reperfusion therapy is directly related to the timeliness of implementation [7,8], yet many are not treated promptly and about 90,000 per year are not treated at all. These errors in triage and treatment for ACS are critical to the patient and occur on a scale that makes them a public health issue. Thus, they present important opportunities to reduce medical errors.

Reducing these medical errors requires innovative changes to patient care processes, existing equipment, and performance improvement activities that can be achieved through the use of information technology (IT).

Computerized physician order entry systems and electronic medical error reporting software are patient safety systems that require changes to, or additional layers in, the patient care workflow. These systems prove challenging to introduce effectively and without disruption to patient care. More easily introduced is IT that is seamlessly built into workflow and that enhances existing patient care and performance improvement activities. Representing this approach, the conventional computerized electrocardiograph is
an IT tool that can be adapted to improve patient safety by providing clinical decision support in real-time, without changing the patient care process. The device also provides workflow tools to prevent medical error and identifies patients for inclusion in performance and outcome measurement systems.

Development of real-time decision support, concurrent event alerts, and retrospective feedback reporting

A series of decision support and risk reduction tools for real-time use in the ED have been developed in addition to an information system to provide concurrent missed AMI event alerting and retrospective feedback reports for improvement of the management of ACS patients. The core of this approach is the ability of a “time-insensitive predictive instrument” (TIPI) to compute, for every ED patient on presentation, a 0% to 100% probability that a patient truly has acute cardiac ischemia (ACI), and if having an AMI, the likely outcome benefits of thrombolytic therapy. A key feature of this prediction is the “time-insensitive” aspect of TIPIs, which refers to the fact that they compute, for a given ED patient, the same probability of value when used in the real-time ED setting or when used retrospectively for review of medical care. As now available in conventional electrocardiographs, besides printed on the ECG header as a decision aid for the physician the computed TIPI probabilities are stored in the electrocardiograph’s computer, can be saved in a database, and then used to trigger concurrent flags about ongoing care and to generate retrospective reports and feedback for clinicians.

Real-time decision support for emergency department triage: the original acute coronary ischemia predictive instrument

The original ACI predictive instrument [1] was developed to be an easy-to-use method to improve ED physician triage decisions so that fewer patients without ACI would be admitted to cardiac care units (CCUs), but without decreasing proper admission of those with ACI. Reasoning that a 0% to 100% probability value might be incorporated easily into physicians’ clinical decision-making, based on prospectively collected data on 2801 patients seen in six divergent hospitals’ EDs for 1 year, a logistic regression equation was developed that used seven variables and was applicable to all six hospitals. Using a programmed calculator, a patient’s 0% to 100% probability of having ACI could be computed in 20 seconds. In a 2320-patient 11-month prospective controlled trial of the predictive instrument’s impact on ED care, its use markedly improved physicians’ diagnostic specificity ($P = .002$), with no significant change in sensitivity. The false positive diagnosis rate improved significantly ($P = .004$), whereas the false negative diagnosis rate did not change. Accordingly, ED triage dispositions for patients who proved to have ACI were not changed from the appropriately high CCU admission rates, but for patients without ACI, CCU admission rates dropped from 24% during the control periods to 17%, and their ED discharge rates to home increased from 44% during the control periods to 51% ($P = .003$), a 30% reduction in CCU admissions for patients without ACI. The predictive instrument’s need for a calculator, however, was cumbersome. Thus, for better ease of use and attractiveness to clinicians, the authors designed the ACI-TIPI, its revised version, to be programmed into conventional computerized electrocardiographs.

Development of the acute coronary ischemia time-insensitive predictive instrument for real-time and retrospective decision support

Although improvement of CCU use might be done by real-time and retrospective interventions, the latter has had little formal evaluation. Use of real-time test results and decision aids are more familiar to clinicians than feedback systems. Attractive and clinically relevant reports on triage and treatment decisions, however, should facilitate continuous quality improvement by emergency medical services (EMS), physicians and institutions self-assessment. (Also, payors and organizations responsible for hospital and CCU use for coronary disease need a fair and accurate retrospective tool by which the appropriateness of CCU use can be measured.) Thus, there is a need for a clinically valid attractive measure for feedback on ACI/AMI care.

Ideally, a single tool should be able to serve prospective and retrospective purposes. Generally, however, tools designed for real-time use, such as our original ACI predictive instrument, have not been validated for retrospective medical record review, and tools for retrospective review of care have not been applicable to real-time use, limiting clinicians’ interest and confidence in
their use. Thus, the authors developed a “time-insensitive predictive instrument” for ACI (ACI-TIPI), valid for prospective real-time clinical use and retrospective medical record review, that accurately computes a patient’s likelihood of having ACI at the time of presentation [2]. Not only theoretically desirable as a tool usable by clinicians, administrators, and payors, the ACI-TIPI might have the added benefit of promoting cooperation between these groups. This ACI-TIPI was tested on the 2320 patients seen at the six study hospitals’ EDs during the second year, along with the original instrument, and both were compared with ED physician diagnostic performance [2]. Calculation of the receiver-operating characteristic (ROC) curve areas, which simultaneously evaluate sensitivity and specificity of a continuous scale test, yielded values of 0.88–0.89 for the ACI-TIPI and the original instrument, demonstrating excellent and similar diagnostic performance by both. Besides the ACI-TIPI, all subsequent predictive instruments, for mortality from ACI/AMI [3], for mortality from congestive failure [4], and the TPI [5] (see later discussion) meet TIPI criteria.

Incorporating acute coronary ischemia time-insensitive predictive instrument into electrocardiographs to support real-time emergency department/emergency medical services care

Convinced that the predictive instrument’s probability would be used more were it automatically printed in the text header on ECGs (Fig. 1), the ACI-TIPI was programmed into a computerized electrocardiograph [9]. To do this, an ACI-TIPI was written using Hewlett-Packard (now Philips) ElectroCardiographic Language [9,10]. This activity was done in repeating iterative cycles of programming ECG waveform-based measurement criteria and then comparing the program’s performance on sample ECGs to readings by the ECG reader who designed the original ACI-TIPI ECG variables (HPS).

Because it was felt that the ACI-TIPI and the approach of incorporating a predictive instrument into a computerized electrocardiograph would not benefit a maximal number of patients if restricted, we published all details of the ACI-TIPI’s formula and the incorporation of a TIPI into an electrocardiograph was put into the public domain. Marketed or prototype ACI-TIPI/TPI electrocardiographs exist by all United States EMS electrocardiograph manufacturers.

Besides enabling presentation of the ACI-TIPI on the ECG, its incorporation into a computerized electrocardiograph allows transfer of patients’ ACI probabilities into a database, which is central to the development of a performance measurement and feedback system, the TIPI information system (TIPI-IS). Thus, the probability, ECG, and data entered into the electrocardiograph in clinical use (age, sex, presenting symptoms, physician, location) can be combined with other data and used for reports and analyses. This information allows clinicians and operations personnel of EMS and hospital organizations to use the same clinically valid risk-adjusted outcome predictions/measure (without medical record review).

The multicenter acute coronary ischemia time-insensitive predictive instrument clinical trial

In our 10-hospital, 10,689-patient clinical trial of the ACI-TIPI electrocardiograph’s impact on ED triage of patients with symptoms suggestive of ACI conducted in public, private, community, and tertiary hospitals in urban, suburban, and semi-rural areas, the ACI-TIPI improved ED triage [11]. In doing so, it demonstrated differential impact depending on whether patients had ACI or not, whether the hospital had high or low cardiac telemetry unit capacity, and whether the triaging ED physician was an unsupervised resident or not. Even as the ACI-TIPI reduced unnecessary admissions, it did not reduce appropriate hospital and cardiac unit admission for patients with true ACI, either UA or AMI. This result further confirmed the ACI-TIPI’s safety and effectiveness in ED use. Given that about 6% of ED patients presenting with symptoms suggesting ACI prove to have stable angina, such reductions would correspond yearly in the United States to approximately 30,000 fewer hospitalizations and 20,000 fewer CCU admissions, and about $728 million saved [11].

Studies of failure to hospitalize emergency department patients with acute coronary ischemia

Among our studies of factors contributing to ED triage and treatment errors [12–24], the authors have sought the causes for failing to hospitalize ED patients who have ACI [6,25,26]. In the authors’ first such study, based on the care at the hospitals that participated in the original
ACI predictive instrument trial, approximately 2% of ED patients with AMI were sent home mistakenly [25], most commonly related to problems in physician use of the ECG [6,25]. Among ED patients sent home with AMI, 35% had ECG abnormalities consistent with ACI noted by the physician but not given sufficient weight in the triage decision [25]. Additionally, 25% had ECG abnormalities suggesting AMI (ST elevation) that were missed by the ED physician [25]. Analyses showing errors in physician ECG reading of ST segments and T waves contributing to suboptimal ED triage supported these findings [26].

In the authors’ study of failure to hospitalize ED patients with ACI (AMI or UAP) in the ACI-TIPI Trial hospitals, the results were consistent with earlier findings [6]. Among the 10,689 ED patients studied, of those with AMI (n = 889), 2.1% were sent home, and of those with UAP (n = 966), 2.3% were not hospitalized. Yearly in the United States, this corresponds to 26,000 ED patients with ACI mistakenly not hospitalized: 12,000 with AMI and 14,000 with UAP. Of note, failure to hospitalize for ACI was more likely if the patient was nonwhite (2.2 times more likely, and 4.5 times more likely if having an AMI), a woman under age 55 (6.7 times more likely) had a primary symptom of shortness of breath rather than chest pain (2.7 times more likely), or a normal or non-diagnostic ECG (3.3 times more likely, and 7.7 times more likely if having an AMI). These failures to hospitalize showed a statistical trend for greater mortality: nonhospitalized patients with AMI were 1.9 times more likely to die than similar patients who were hospitalized, and nonhospitalized patients with UAP were 1.7 times more likely to die than similar patients who were hospitalized.

These findings possibly reflected physicians’ overdependence on generalities. Among ED patients, it is true that ACI is less likely in younger women, African-Americans, those without chest pain, and those with normal ECGs; but some such patients do have ACI. Physicians must be careful not to over-generalize about certain groups, and for these patients, the ACI-TIPI and TPI may help (see later discussion of TPI Trial on use of coronary reperfusion therapy for women). The wide range in hospitals’ rates of failure to hospitalize (0%–11%) suggests that hospitals should monitor, and continually improve, their ED performance. Of note, “chest pain centers” did not have better performance; it seems that what is
important is not the ED label, but that its physicians fully evaluate the entire patient, and understand the proper use of diagnostic technologies and receive feedback about diagnostic performance [27,28].

Acute coronary ischemia time-insensitive predictive instrument risk management tool: an ECG-based form for avoiding medical errors

Based on these studies, cases of patients who presented with AMI and mistakenly sent home were reviewed to devise a way to reduce such errors. A "risk management form" was developed and integrated into ACI-TIPI software so the form is generated and partially filled-out automatically by the electrocardiograph at the time of the patient’s initial ECG (Fig. 2) [29]. The intent was that the form prompt consideration and documentation of the key clinical factors for such cases, be immediately and conveniently available for real-time use, and include the electrocardiograph’s computerized interpretation in its text, along with the ACI-TIPI probability of ACI, to lessen the likelihood that ECG abnormalities and high-risk patients would be missed.

To assess the potential impact of the risk management form, the form was retrospectively applied to 20 cases that came to malpractice litigation. This information was also compared with what the impact would be were the form not automatically generated by the electrocardiograph, to see whether this approach was warranted. With the electrocardiograph-generated version, 61% of cases were seen as much less likely or certain to not come to malpractice litigation, versus 37% for the nonautomatic version ($P = .001$). Moreover, for those that would have come to litigation, had the automatic electrocardiograph-generated version been used, 80% would have had a significantly better outcome, including 59% who were judged to be likely to have a better outcome ($P = .001$). The provision of the ACI-TIPI probability should help the clinician appreciate the importance of such ECG abnormalities as contributors to the patient's likelihood of having ACI. The clinical information needed to fill out the rest of the form should provide the kind of documentation that better reveals appropriate care, and the process of filling-in the items was created in the hopes that it deter suboptimal care in the process of such documentation. Based

Fig. 2. ECG risk management form.
on this, the authors worked with Hewlett-Packard (now Philips) to incorporate the automatic form into their electrocardiograph.

Financial implications of the impact of the form exist. For the 12 case records for which complete financial data were available, the legal and processing expenses averaged $45,000 and settlements averaged $337,000 [29]. With the form automatically generated by the electrocardiograph, the mean projected savings per case was $382,000, corresponding to $1.2 billion yearly savings in the United States. These savings should serve to make the ACI-TPI approach attractive to hospitals, especially those with their own “cap-tive” malpractice companies.

Development of the thrombolytic predictive instrument to assist recognition and treatment of ST-elevation myocardial infarction

Emergent coronary reperfusion therapy, used promptly, can be lifesaving for patients with ST-elevation myocardial infarction (STEMI) [7,30–32]. In emergency settings, however, this can be difficult, especially for less obvious candidates, and when key physician decision-makers are not on-site. Intensive efforts by physician leaders, the National Heart Attack Alert Program, organizations interested in quality of care, and others [32–41], have helped increase use and promptness of coronary reperfusion therapy [42]. Further improvement is needed [42,43], especially for other than anterior STEMI, the category of AMI for which thrombolytic therapy was first recognized as effective [7,30] and for women, who have received less coronary reperfusion therapy than men [43,44]. Also, a need remains for ways to support prompt and accurate coronary reperfusion therapy decisions in hospitals and prehospital EMS settings where consultation with off-site physicians is required.

To assist treatment decisions, the TPI was developed, a collection of five component predictive instruments designed to accurately assess the likely patient-specific benefits and risks from the use of thrombolytic therapy for STEMI. This tool helps clinicians identify patients for coronary reperfusion therapy based on their probabilities of benefits and complications and facilitates earliest possible use of coronary reperfusion therapy [5,45]. With manufacturers, programs were developed for conventional computerized electrocardiographs, so that when significant ST-segment elevation of STEMI is detected, TPI predictions are automatically computed and printed on the ECG header. These predictions include probabilities for acute (30-day) mortality if and if not treated with thrombolytic therapy; 1-year mortality rates if and if not treated with thrombolytic therapy; cardiac arrest if and if not treated with thrombolytic therapy; thrombolytic therapy-related stroke and major bleeding requiring transfusion.

The TPI database, on which the TPI’s five component models were developed and tested, include the original data on patients who presented with AMI from 13 clinical trials and registries, including 107 hospitals of all types throughout the United States, totaling 4911 patients [1,45–57]. Separate logistic regression predictive instruments were developed for each outcome. For each, clinically important and statistically significant variables were selected for preliminary models, alternative forms and combinations of these variables were investigated, and models reformulated to optimize performance while preserving parsimony. This included creating two special ECG variables to reflect two determinants of the impact of thrombolytic therapy: a measure of AMI size and an indicator of “earliness” in the AMI’s course [56]. In addition, to satisfy the need for a regression method that could accommodate the rapidly changing influence of ECG-based infarct size, QT interval, and coronary reperfusion therapy use in the first hours of ACI/AMI, a new method of regression was devised [58].

Thrombolytic predictive instrument clinical effectiveness trial: impact on use and promptness of coronary reperfusion therapy

To test whether the electrocardiograph-based TPI improves ED selection of patients for coronary reperfusion therapy and promptness of treatment, a 22-month randomized controlled clinical effectiveness trial was run on the use and impact of thrombolytic therapy and overall coronary reperfusion therapy. Given our interest and the demonstrated need for improvement in the use of coronary reperfusion therapy [42,43], especially for other than anterior AMI [7,30] and for women [43,44], our study hypotheses focused on these groups, and also on hospitals where consultation with off-site physicians was required. Study endpoints were percentages of patients receiving (a) thrombolytic therapy; (b) thrombolytic therapy within 1 hour of ED presentation; and (c) all coronary reperfusion therapy, either by thrombolytic therapy or percutaneous transluminal coronary
angioplasty (PTCA). The trial ran in EDs at 28 urban, suburban, and rural hospitals across the United States, from major cardiac centers to small community hospitals.

Included in the trial were all consenting patients at least 35 years old presenting to any study hospital with STEMI. At participating hospitals, software-generating TPI predictions was installed on conventional computerized electrocardiographs. When a significant ST-elevation characteristic of STEMI was automatically detected, the electrocardiograph randomly assigned the patient to the control or intervention group. If assigned to the intervention group, the electrocardiograph automatically prompted the user to enter information needed to compute the TPI predictions: age, sex, history of hypertension or of diabetes, blood pressure, and time since ischemic symptom onset. The remaining variables, based on ECG waveform measurements, were automatically acquired by the electrocardiograph. Then the ECG was printed with TPI predictions on its header (Fig. 3). If variables were missing, TPI predictions were not calculated, but an alert listing missing variables was printed, allowing entry of missing data, if available. For patients in the control group, the ECG had only the header text customarily used in that ED.

Collected data included: sociodemographic data; initial and follow-up clinical features; ECGs and cardiac biomarker test results; triaging physician training level, specialty, and whether ED-based; whether on-site or off-site (telephone) consultation was used for the coronary reperfusion therapy decision; whether the patient received thrombolytic therapy or PTCA; and how long after chest pain onset was the therapy received.

TPI software automatically acquired clinical variables required for TPI calculations and ECG Q-wave, ST-segment, and T-wave measurements. Site physicians, blinded to study group, assigned confirmed diagnoses based on presentation, clinical course, initial and follow-up ECGs, and biomarker tests, using the World Health Organization criteria [59]. Patients’ ED care was classified by whether consultation with an off-site physician was used in making the treatment decision. Hospital size, type, whether having on-site ED staff, and physician type were used as potential explanatory variables.

Of 2875 patients who presented with AMI at the participating hospitals, 1243 (43%) had
ST-segment elevation. Of these, 1197 were randomly assigned to study groups; 732 (61%) had inferior STEMI, and 465 (39%) had anterior STEMI. Of patients with inferior STEMI in the control group, compared with the TPI group, 61% compared with 68% \((P = .03)\) received thrombolytic therapy; 53% compared with 59% \((P = .08)\) received thrombolytic therapy within 1 hour; and 68% compared with 75% \((P = .03)\) received coronary reperfusion therapy overall, either as thrombolytic therapy or primary PTCA. Of patients with anterior STEMI in the control group compared with the TPI group, 60% compared with 54% \((P = .03)\) received thrombolytic therapy; 51% compared with 45% \((P > .2)\) received thrombolytic therapy within 1 hour; and 68% compared with 64% of TPI patients \((P > .2)\) received overall coronary reperfusion therapy. Among women \((n = 398)\) in the control group compared with the TPI group, 48% compared with 58% \((P = .03)\) received thrombolytic therapy; 41% compared with 48% \((P = .10)\) received thrombolytic therapy within 1 hour; and 56% compared with 66% \((P = .04)\) received overall coronary reperfusion therapy. Of patients who required physician consultation by telephone \((n = 271)\) in the control group compared with the TPI group, 47% compared with 63% \((P = .01)\) received thrombolytic therapy; 41% compared with 54% \((P = .04)\) received thrombolytic therapy within 1 hour; and 51% compared with 66% \((P = .01)\) received overall coronary reperfusion therapy. Thus, the trial showed that the TPI increased use of thrombolytic therapy, use of thrombolytic therapy within 1 hour, and use of overall coronary reperfusion therapy by 11% to 12% for patients with inferior STEMI, 18% to 22% for women, and 30% to 34% for patients with an off-site physician. The TPI’s effect was minimal on patients who exhibited high baseline coronary reperfusion therapy rates, such as for men who presented with anterior STEMI. For the targeted groups (those more often missed, women and those with less obvious STEMI, and situations in which physicians were off-site), however, the TPI increased recognition of STEMI and use and timeliness of coronary reperfusion therapy.

In the TPI Trial, it is of interest that the TPI’s impact was not seen among patients with anterior STEMI, and when combining STEMI locations, it was not seen among men. This is thought to be because anterior STEMI has received longer-standing emphasis for coronary reperfusion therapy and are more easily recognized in the precordial leads of the conventional ECG, and thus physicians already do a good job of detecting them as appropriate candidates for coronary reperfusion therapy, and treat them. Similarly, AMI presents more “classically” in men and is already better recognized (and treated) in men than women [6, 60, 61]. The high rates of coronary reperfusion therapy for anterior STEMI and men when seen in experienced centers may require little improvement. Less than 5% of the TPI Trial’s patients, however, were seen in hospitals without on-site ED physicians, and no patients were included while in transit by way of EMS (when all physician input would be remote). Thus, it is important that the TPI did improve the speed and use of coronary reperfusion therapy among all patients who presented with AMI (including anterior and men) when the ED physician or needed physician consultants are off-site. Because many hospitals’ EDs still are not staffed 24 hours daily, and, especially in rural settings, long transport times may mandate EMS use of thrombolytic therapy or a decision for direct transport to one of the 20% of United States hospitals that are primary PTCA-capable [62], it seems likely that the TPI may improve coronary reperfusion therapy use for patients with anterior STEMI in these settings.

The TPI is particularly attractive for EMS use. Prehospital thrombolytic therapy is indicated for situations in which transport times are long [63–66], and the recent availability of single bolus thrombolytic therapy [67–69] and the increasing use of 12-lead ECGs in ambulances [70–74] provide a foundation for this approach [75–77]. The provision of TPI predictions for patients with STEMI in the field can support EMS use of thrombolytic therapy. Also, for patients who present with contraindications to thrombolytic therapy, prehospital identification as a reperfusion candidate by the TPI can help avoid transport to a facility lacking primary PTCA capability, avoiding the need for re-transport to a PTCA-capable center. Clarifying reperfusion needs and options in the field, especially in rural areas, can save time, and improve patient outcomes [78]. That the TPI increased overall coronary reperfusion therapy use suggests it should facilitate decision-making for both types of reperfusion in prehospital EMS use. Also, even with hospital-based coronary reperfusion therapy, advance notice by EMS, as in the MITI Trial [63], prompted by the TPI, should reduce delays after arrival.
Having shown that ACI-TIPI’s predictions on ECGs provide effective real-time decision support, the TIPI-IS demonstration project was undertaken. An ACI-TIPI-IS was created to measure the impact of real-time, concurrent, and retrospective ACI-TIPI interventions on medical errors in ED triage. Also, through a series of user tests, the system’s attractiveness and use for various users was evaluated, and its reports were modified to improve their usefulness in identifying and addressing medical error.

In the ACI-TIPI-IS demonstration project [79], the TIPI-IS provided concurrent and retrospective reporting and feedback for ED physicians and their hospitals. Implemented and used at five hospitals, the project provided a range of concurrent alerts and feedback reports to over 70 physicians at these facilities. This project has been successful in demonstrating the use of the ACI-TIPI probabilities within an information system providing concurrent alerting and retrospective feedback reports.

A prototype TIPI-IS database and web server-based user interface was created to (1) aggregate the ECG Management System data, ADT, Lab and ICD9 diagnostic coding data into a data warehouse database; and (2) create a TIPI-IS web server to distribute TIPI-IS reports and allow physicians (using a standard web browser) to explore the underlying patient data (Fig. 4). The web-based user interface was fully redesigned after repeated usability testing and enhanced with additional outcome information, including confirmed diagnoses of ACI after inpatient evaluation and whether patients had cardiac catheterization, PTCA or coronary bypass surgery. The system evaluation process included an iterative review with ED physicians leading to the redesign of screens and reports. Reports for comparison and benchmarking across groups of hospitals and for drill-down within a hospital were created and were additionally reviewed and revised by health plans and malpractice insurers to ensure that the reports met the requirements for risk reduction and medical error prevention programs (Fig. 5).

Implementation of the TIPI-IS had five major components: (1) preparation of the ECG equipment and ECG computerized management system; (2) installation of the TIPI-IS server within each hospital’s intranet; (3) linking and integrating each

![Fig. 4. TIPI-IS diagram. (Courtesy of Clinical Care Systems, Inc., Bedford, MA.)](image-url)
hospital’s key computerized databases through electronic data interfaces to the TIPI-IS server; (4) testing of interface data; and (5) user training. Testing interfaces from feeder systems to the TIPI-IS at each site was conducted to ensure TIPI-IS captured data completely and mapped key data elements accurately for subsequent reporting. Electronic data collection eased the resources required to compile a large database, but also posed challenges in collecting accurate data because it depended on the diligence of staff entering the data for operational purposes rather than research purposes.

Access to data and reports through the web-based interface improved availability of data, and despite user testing and redesign of the original system, the web-based system continued to be available for use. Frequent users of the system were project staff and ED department Quality Improvement (QI) staff who had operational needs to access the data. When new reports or information were posted on the website, each physician received an e-mail with the link to the web page. A key advantage of the TIPI-IS approach, which was successfully demonstrated, is the ability to compile large amounts of information for feedback reporting and error reduction through an automatic electronically compiled database. This process leveraged the clinical information systems already in place and minimized the resources required to collect and analyze data.

During the intervention period, ED QI nurses and physicians were given a general overview of the project and training in the use of the TIPI-IS, the content and significance of the concurrent alerts and feedback reports. These meetings were conducted with the ED physician leader who distributed physician-specific feedback reports with information from baseline data collection and a secure password to access their reports online.

Concurrent alerts were designed within the database system to signal patient cases that met criteria for immediate follow-up to prevent possible missed diagnosis of ACI. These thresholds included patients sent home from the ED with an ACI-TIPI value in the high-risk category or with a positive cardiac biomarker. The alert triggered an e-mail or pager message to the ED and ED

Fig. 5. TIPI-IS feedback report. (Courtesy of Clinical Care Systems, Inc., Bedford, MA.)
physician indicating a patient required follow-up/review (Fig. 6). The results of follow-up on these alerts were entered into the alert follow-up screen. Patients were contacted to return to the EDs if needed and hospitalized for further evaluation when appropriate.

Retrospective review of a sample of patients sent home from the ED with moderate- to high-risk ACI-TIPI probabilities was conducted to identify cases of missed diagnosis of ACI. This review, conducted at each site by the ED director, identified a series of issues ranging from incomplete documentation to variations in practice, sometimes within, though sometimes not within, standard expectations of that ED. Results were addressed with staff during monthly morbidity and mortality review, in individual feedback discussions, and in some cases, by changes in the ED’s practices.

Summary

Medical errors in the care of patients who present with ACS include errors in ED triage, such as the decision to send home a patient from the ED who presents with ACS or to hospitalize a patient who does not prove to be experiencing ACS to the CCU, and errors in treatment, such as the failure to promptly use reperfusion therapy for patients with ST-elevation AMI. ECG-based ACI-TIPI and TPI predictive instruments, with a linked TIPI-IS, provide real-time, concurrent, and retrospective decision support tools and feedback for the prevention of medical errors in the care of patients who present with ACS. In real-time, ACI-TIPI probabilities printed on the ECG header for the ED physician, provide an additional piece of information for triage decision making, and the ACI-TIPI risk management form reduces liability risk by prompting consideration and documentation of key clinical factors in the diagnosis of ACI. Also in real-time, the TPI increases overall coronary reperfusion therapy use. Concurrent flagging by TIPI-IS uses electronically acquired ECG and hospital data to provide concurrent alerts about potential misdiagnosis or mis-triage of patients with ACS. Retrospectively TIPI-IS–based feedback reports allow performance improvement. These examples of information technology tools, integrated into ECG equipment already used in hospitals to deliver patient care, demonstrate the potential to adapt other existing equipment or other patient care activities to enhance patient safety and error reduction.

References


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