Technical Feasibility of an Online Decision Support System for Acute Coronary Syndromes

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Wide variability presently exists in how patients are treated for suspected acute coronary syndromes (ACS) in the United States. Among the 6 million Americans presenting to the emergency department (ED) for evaluation of chest pain annually,1 of whom half are hospitalized,2 only 20% are found to have a heart attack.3 Moreover, 2% of ED patients actually having an acute myocardial infarction (MI) are mistakenly discharged home.4,5 Accordingly, 100 patients having chest pain must be evaluated in the ED, and 50 must be hospitalized, to diagnose the 10 who are having an acute MI, but this approach further fails to identify 1 additional patient discharged from the ED whose chest pain represented a heart attack. Thus, all patients reporting chest pain are treated as if they were at high risk, potentially resulting in overtreatment and higher costs.

Guidelines developed by the American College of Cardiology (ACC) and the American Heart Association (AHA)6,7 permit many patients reporting symptoms of chest pain to be classified as having a low risk for death or nonfatal MI. However, decision support tools that might reliably establish this classification are not presently incorporated into the clinical workflow of EDs and other treatment settings, including urgent care clinics and other outpatient settings. To address this issue, we developed a computerized database application to support telephone triage to patients reporting cardiovascular symptoms, we developed an online Decision Support System (DSS) that standardizes the initial evaluation of patients.

The system incorporates 2 key functions: (1) It assists physicians and other health care professionals to comprehensively and accurately elicit patients’ symptoms, irrespective of the patient’s location; and (2) it transforms patients’ symptoms of chest pain into a preliminary or “provisional” diagnosis linked to categories of high, moderate, and low risk for death or nonfatal MI based on the ACC/AHA guidelines. Previously, we had developed a computerized database application to support telephone triage to patients reporting cardiovascular symptoms.8,9 As part of the present project, we modified the application to incorporate decision support based on ACC/AHA and other published guidelines.

The present study is the first of a series of 3 planned studies designed to evaluate the technical feasibility of DSS in generating a preliminary or “provisional” diagnosis based on patients’ reports of symptoms. The aims of this, the first of these studies, were as follows: (1) to establish the reliability of DSS in generating a provisional diagnosis consistent with prespecified cardiovascular symptoms, (2) to determine the reliability of DSS in establishing a provisional diagnosis in a simulated clinical setting, (3) to document the time required by clinicians to acquire and enter the data into the database application, (4) to compare the accuracy of nurse clinicians and cardiologists in eliciting and recording patients’ symptoms in DSS, and (5) to evaluate the concordance between the provisional diagnoses generated by DSS and those established by the participating cardiologists. A second study will evaluate the clinical feasibility of DSS as a method of triage in a variety of representative medical settings. The third study is a multicenter, randomized controlled trial (RCT) evaluating the safety and cost-effectiveness of DSS as a method of triage for patients reporting chest pain in various clinical settings. Successful completion of the RCT would, for the first time, establish the safety and cost-effectiveness of alternatives to an ED visit for patients classified as low risk.

Design of the Initiative

To develop a standardized format for questioning patients, we identified the following symptoms commonly experienced by patients with coronary artery disease (CAD): (1) chest or epigastric pain, (2) shortness of breath, (3) dizziness or syncope, and (4) symptoms of stroke or transient ischemic attack (TIA), including weakness, numbness, or visual changes. We considered the features of each of these symptoms, including character, severity, type of onset, location, time course, radiation, and any associated symptoms and factors worsening or mitigating the symptoms, including physical activity, rest, breathing, body position, and response to medications. We then compiled a list of the provisional diagnoses that most commonly account for these symptoms (Table 1).

In any clinical evaluation, the patient’s report of symptoms is the initial step leading to a definitive diagnosis. The preliminary or “provisional” diagnosis based on patient’s symptoms guides the tempo and nature of subsequent diagnostic testing needed to establish a definitive diagnosis. DSS structures the questioning process to conform to the logic incorporated into published guidelines, ensuring that ques-
tions critical to the diagnostic process are not omitted. A single, comprehensive management guideline designed to establish a provisional diagnosis for the heterogeneous population of patients reporting symptoms of chest pain has not previously been developed.

Patients diagnosed with ST-elevation MI (STEMI) or non-STEMI/unstable angina represent approximately 25% of patients presenting to the ED with chest pain. Patients classified as having angina who do not meet the criteria for ACS comprise an additional 25%. Many of the remaining patients harbor conditions that simulate ACS, such as pericarditis, and those that accompany ACS, such as heart failure and stroke/TIA. Accordingly, we structured the questioning process of DSS to accommodate a broad range of conditions associated with cardiovascular symptoms.

We defined “ischemic” chest pain as tight, crushing, pressing, squeezing, aching, or dull in character. To establish the general relationship between patient symptoms and their risk for subsequent cardiovascular events, including death and nonfatal MI, we used the descriptions of ischemic chest pain appearing Table 8 of the guidelines for unstable angina initially established by Braunwald et al in 1994 for the Agency for Healthcare Policy and Research, now termed the Agency for Healthcare Research and Quality, and in Table 7 of the 2007 ACC/AHA guidelines. These guidelines are the most widely used source of expert knowledge for the management of suspected ACS. As shown in the Figure, the guidelines stratify patients into high-, moderate-, and low-risk groups, representing the 8 discrete categories described below.

A patient reporting ischemic chest pain that occurred at rest, lasted 20 minutes or more, and was still present at the time of the patient’s report was categorized as ACS: high risk, as shown in the top box of the Figure. Patients reporting chest pain of similar character that (1) occurred at rest during the past 3 days, lasted 20 minutes or more, and had resolved by the time of the patient’s report, (2) occurred at night (nocturnal angina) during the past 3 days, or (3) appeared for the first time during the last 2 weeks and restricted physical activity to walking 1 to 2 blocks or 1 flight of stairs were categorized as ACS: moderate risk, as shown in the middle box of the Figure. Patients reporting angina that (1) increased in frequency, severity, or duration during the past 2 weeks, (2) occurred at a lower threshold of physical activity during the past 2 weeks, or (3) appeared for the first time during the past 2 weeks but did not restrict physical activity to walking 1 to

![Decision Support for Acute Coronary Syndromes](http://circoutcomes.ahajournals.org/)

**Figure.** Triage of patients with suspected ACS.
2 blocks or 1 flight of stairs were categorized as angina: non-ACS, as shown in the bottom box of the Figure. Patients with angina who did not meet these criteria were also categorized as angina: non-ACS. These patients were considered to have a low risk of death or nonfatal MI.

Provisional diagnoses corresponding to nonischemic chest pain, heart failure, syncope, and stroke/TIA were based on the constellation of symptoms specified by the Medline Plus website of the National Library of Medicine (www.nlm.nih.gov). Pleuritic chest pain (piercing, stabbing, sticking, tearing, sharp, or ripping in character) was represented by 6 provisional diagnoses representing aortic dissection, chest wall pain, pericarditis, panic attack, pneumonia, and pulmonary embolus/infarction, respectively. Burning chest or epigastric discomfort was represented by 2 provisional diagnoses, esophagitis and gall bladder attack. Patients with chest or epigastric pain who did not meet the criteria for any of the defined chest pain syndromes were categorized as “nondiagnostic” and considered as low risk.

Implementation of the Initiative
We performed β testing to establish that the variables input by the investigators consistently returned a provisional diagnosis consistent with prespecified symptoms. We then tested the technical feasibility of DSS in rendering a provisional diagnosis when the symptoms elicited from patients were input by cardiologists and nurses new to the system.

We developed 28 clinical cases representing patient symptoms associated with the 14 provisional diagnoses. Chest or epigastric pain accounted for 17 cases, heart failure for 4 cases, syncope for 4 cases, and stroke/TIA for 3 cases. Each of the 28 cases was repeated at least twice, accounting for 100 cases.

We recruited a convenience sample of 20 local, healthy, well-educated, middle-aged individuals, 10 men and 10 women, to serve as “patients” during a single telephone interaction with clinicians. We identified 8 current Stanford University School of Medicine cardiology fellows and 12 local cardiovascular nurses with a minimum of 10 years’ clinical experience. Each of the 20 “patients” was provided with 5 case report forms, or scripts describing symptoms corresponding to a provisional diagnosis. Each patient was asked to initiate a single telephone contact with 1 of the 20 clinicians to review a total of 5 cases. The clinicians were provided with written instruction on how to navigate the DSS and were requested to practice using the DSS online before the study patient’s call to report symptoms. We did not test clinicians’ proficiency in using DSS before their telephone sessions with patients.

By prearrangement, the 20 volunteers telephoned the clinicians, who were logged on to DSS during the telephone interaction. Patient responses to the clinician’s questions were prespecified on a script provided to the patient before his or her telephone call. Once the patient reported a prespecified symptom such as chest pain, the clinician led the patient through the series of questions that appeared on the clinician’s screen in the form of an inbound call. Clinicians were not allowed to skip any of the questions appearing on the inbound call screen. DSS tabulated the time required for completion of each of the 5 consecutive cases.

At the conclusion of each case, DSS displayed a list of the 14 provisional diagnoses but did not specify a preferred choice among them. The provisional diagnoses and treatment recommendations provided to patients by the clinicians were based on clinicians’ perception of the patient’s risk of death or serious morbidity. To avoid biasing clinicians’ advice, the computer-generated provisional diagnoses and associated treatment recommendations were not provided to the clinicians during their interactions with patients. After the telephone session, cardiologists were presented with a printed narrative summary of patient symptoms reported during each of the 5 cases. Provisional diagnoses and treatment recommendations specified by the cardiologists were compared with those generated by DSS. Because of the differences in physicians’ and nurses’ training and clinical prerogatives, no similar comparison was made for the participating nurses.

The treatment recommendations associated with 70 of the high-risk or moderate-risk cases were to “call 911 immediately for transport to the ED,” “visit the ED immediately,” or “visit the urgent care clinic today.” In 30 of the low-risk cases, the treatment recommendation was to undergo outpatient evaluation within 24 to 72 hours, at the discretion of the patient’s physician(s). These cases included “angina: non-ACS,” chest wall pain, esophagitis, panic attack, and heart failure unassociated with pulmonary edema.

Success of the Initiative
The goal of establishing the technical feasibility of DSS in providing decision support to clinicians was fulfilled by the present study. DSS structured the questions needed to establish a provisional diagnosis for a heterogeneous population of patients reporting cardiovascular symptoms. Six of the 8 participating cardiologists and 11 of the 12 participating nurses successfully navigated the online DSS, completing a total of 85 clinical scenarios. Data obtained by the 3 individuals who failed to navigate DSS were excluded from the analysis. Nurse clinicians’ performance in eliciting and recording patients’ symptoms was equivalent to that of their cardiologist counterparts.

Among the 85 provisional diagnoses corresponding to these clinical scenarios, we identified 5 “data entry” errors in which patients did not render the response specified by the script, or in which clinicians failed to enter it correctly. We identified 2 instances in which the logic correctly specified in DSS was misrepresented in the script provided to the patient. These clinical scenarios represented “panic attack” and “angina: non-ACS,” respectively. A 1-word change from “yes” to “no” in a single question corrected the error in both cases.

The time required to elicit and record the responses of patients regarding the 4 categories of symptoms was similar for cardiologists and nurses. It was 4.8±2.6 minutes for 48 responses representing chest pain, 2.4±0.6 minutes for 17 responses representing heart failure, 3.5±1.3 minutes for 20 responses representing syncope, and 1.5±0.6 minutes for 8 variables representing stroke/TIA.

Among the 9 cases representing ischemic chest pain syndromes, agreement between the provisional diagnoses
generated by the computer and those rendered by the cardiologists was noted in 4, or 44%, whereas disagreement was noted in 5, or 56%, as shown in Table 2. Two of the 3 cases categorized by the computer as “ACS: moderate risk” were categorized by the cardiologists as “ACS: high risk.” Of the 6 clinical scenarios categorized by the computer as “angina: non-ACS,” 2 were categorized by the cardiologists as “ACS: moderate risk” and 1 was categorized as “ACS: high risk.”

Cardiologists’ treatment recommendations tended to reflect their perception of higher risk, as follows: Two of the 3 patients specified by the computer as “ACS: moderate risk” were advised by the cardiologists to seek ED care and 1 was advised to seek urgent care, whereas the computer specified an urgent care clinic visit in all 3. Similarly, 5 of the 6 patients specified by the computer as “angina: non-ACS” were advised to visit the ED (3 cases) or urgent care clinic (2 cases), whereas the computer specified that the patient could undergo outpatient evaluation within 24 to 72 hours, at the discretion of the patient’s physician.

As shown in Table 2, agreement between the cardiologists’ diagnoses and treatment recommendations was higher for the 11 patients with “other chest pain” than among the 9 with “ischemic chest pain.” Cardiologists’ treatment recommendations were concordant with those rendered by the computer in 8 of 11 patients. There was complete agreement between cardiologists’ provisional diagnoses and treatment recommendations and those rendered by the computer for the 10 patients reporting heart failure, syncope, or stroke/TIA.

### Local Challenges in Implementation

The greatest challenge was the novelty of DSS as a method for triage of patients reporting cardiovascular symptoms. Clinicians are generally unfamiliar with customized clinical applications focused on a single purpose such as triage. DSS establishes the primacy of symptoms as the basis for triage, whereas decision-making in the ED is largely based on the results of cardiac biomarkers and the ECG. In this study, clinicians’ interaction with patients was mediated by telephone rather than the face-to-face contact that is typical of the ED. Decision support tools have generally relied on the ED physician to interpret a set of relatively simple rules. Physicians are not accustomed to entering prespecified or structured sets of data as part of the clinical encounter. Even clinicians who successfully navigated DSS were challenged by the requirement to enter a response for each and every variable appearing on the computer screen. The failure of 2 cardiologists and 1 nurse to navigate DSS successfully highlights the need for an online tutorial to establish the clinical rationale for DSS and to better enable its execution.

### Previous Experience With Decision Support for Suspected ACS

Virtually all of the decision support tools developed for triage of patients reporting chest pain have been intended for use in the ED. The decision support rule developed and validated by Goldman et al focused largely on the prediction of cardiac complications within 72 hours among patients hospitalized with acute MI. Goldman’s decision support rule was based on ECG findings and the presence or absence of 3 clinical predictors. The clinical impact of this rule on the treatment of patients with suspected ACS was subsequently evaluated by Reilly et al in a study of patients undergoing ED evaluation. The rule stratified patients into high-, moderate-, low-, and very low-risk categories representing 23%, 34%, 30%, and 14% of patients, respectively. Physicians’ use of the rule increased the efficiency of decisions, defined as the proportion of patients without major complications who were triaged to an ED observation unit or an unmonitored ward. After introduction of the rule, efficiency increased significantly, from 21% to 36%. The safety of decision-making, defined as the proportion of patients having major cardiac complications who were admitted to inpatient cardiac beds, increased nonsignificantly from 89% to 94% during the same period. Use of the rule increased the proportion of very low-risk patients triaged to the observation unit and decreased the proportion of patients in the other 3 risk categories who were triaged to inpatient monitored beds.

Among the 300 patients discharged home from the ED who completed follow-up, there were no deaths or complications. Physicians used the decision rule in 83% of intervention-group patients and ascribed high value to its impact on patient care and on the decision-making process. This study demonstrated not only the willingness of physicians to use decision support tools for triage of patients with suspected ACS but the favorable clinical impact of these tools, especially in patients classified as very low risk.

Selker et al developed a decision support tool, the Acute Cardiac Ischemia Time-Insensitive Predictive Instrument, which used a logistic regression formula to calculate a patient’s probability of having acute cardiac ischemia on the basis of ECG abnormalities or adverse clinical features. After its introduction in the ED, the decision tool significantly reduced coronary care unit admissions from 14% to 10% and telemetry admissions from 39% to 31%, while increasing discharges home from 45% to 56%. The effect of the tool was greatest among patients without cardiac ischemia or stable angina.
Katz et al\textsuperscript{14} evaluated the clinical impact of guidelines for unstable angina developed by the Agency for Health Care Policy and Research.\textsuperscript{9} This 1-page guideline, based on variables from the history, physical examination, and ECG findings, was evaluated in 2 EDs over a 5-month intervention period, after a 5-month baseline period. The main finding of this nonrandomized study was that physicians’ triage decisions were not significantly influenced by the guidelines. Physicians did not adhere strictly to guideline criteria in their risk stratification of patients. The clinical appropriateness of triage did not compromise patient outcomes, although adverse clinical events were too infrequent to permit statistical analysis.

An evaluation of 3 clinical trials reported by Katz et al\textsuperscript{15} showed that low-risk patients discharged home from the ED after evaluation for chest pain had a similarly low rate of adverse clinical events, whether their care was concordant or discordant with Agency for Health Care Policy and Research guidelines.\textsuperscript{15} These studies underscore the variability that presently exists among physicians in translating guidelines-based risk assessments of chest pain into clinical practice. It also highlights the need for an RCT designed to document physicians’ decisional practices, the care that is provided to patients in various treatment settings throughout the episode of illness, and the clinical outcomes that occur during a follow-up period of 6 months or more.

Decision support models implemented in the ED have focused largely on the identification of high-risk patients with acute MI who require hospitalization rather than on the identification of low-risk patients with ACS who are suitable for ED discharge. In their critique of new methods to improve evaluation of patients presenting to the ED with suspected ACS, Ekelund et al\textsuperscript{16} emphasized the need to expand the present focus on acute MI to include the broader category of ACS. However, despite the favorable influence of prediction rules on the care provided to patients presenting to the ED with chest pain,\textsuperscript{11–13} formal approaches to the triage of such patients have yet to be systematically implemented in clinical practice.\textsuperscript{14} Katz et al\textsuperscript{14} have suggested that better integration of guidelines into the clinical work flow, including the use of health information technology tools, could increase ED physicians’ use of the ACC/AHA guidelines.

Innovations in the Treatment of Patients With Suspected ACS

All patients having symptoms of a possible heart attack are presently advised to seek immediate evaluation in an ED, where specialized testing can be performed.\textsuperscript{17} However, the ACC/AHA guidelines for suspected ACS specify that an outpatient evaluation may be appropriate for patients classified as low risk, based on symptoms.\textsuperscript{5–7} For example, a systematic and thorough assessment of patient symptoms with DSS could permit low risk patients to undergo expedited outpatient evaluation, including performance of specialized testing, 24 to 72 hours later, at the discretion of their physician(s). The concept of a 2-stage evaluation for patients initially classified as low risk is not new: many medical care organizations presently provide immediate telephone triage followed by an expedited outpatient evaluation. In one study, a health care team composed of physicians and nurses provided telephone triage to previously enrolled patients with CAD.\textsuperscript{18} Computerized medical files were continuously updated, permitting immediate clinical decision-making. The triage decisions made by physicians were indistinguishable from those made by nurses. The short-term clinical outcomes observed in patients were similar for the 2 groups of clinicians. Among the telephone contacts initiated by patients with CAD, approximately 80% were managed without dispatch of a special cardiac ambulance. The role of formal decision support in this study was not reported.\textsuperscript{18}

The perceived need for a same-day evaluation of patients reporting chest pain reflects concern about the risks of delaying treatment. However, results from the CRUSADE Initiative suggest that this concern may be exaggerated. Among patients hospitalized for treatment of non–ST-elevation–MI, Pollack et al\textsuperscript{19} found that the 56% of those presenting to the ED after hours had a higher risk profile than the 44% of those presenting during usual hours. Despite an 8-hour delay in receiving coronary angiography and a 5-hour delay in receiving percutaneous coronary intervention, clinical outcomes during hospitalization were no worse among late-arriving patients.\textsuperscript{19} In contrast, studies of patients hospitalized with STEMI—the highest-risk category of patients—have found that delayed treatment worsened clinical outcomes.\textsuperscript{20} A multicenter RCT could establish whether patients classified as low risk by DSS, who underwent outpatient evaluation within 24 to 72 hours after their initial telephone report of symptoms, have a rate of adverse clinical events different from that of comparable patients undergoing ED evaluation. Moreover, such a study would permit evaluation of death and nonfatal MI, the adverse clinical events presently specified by the ACC/AHA guidelines. It could also address an expanded set of adverse clinical events accounting for much of the morbidity and cost associated with suspected ACS. These events include repeated visits to the ED or urgent care clinic for chest pain, repeated hospitalizations for chest pain, and the performance of coronary revascularization performed on an emergency as opposed to an elective basis. Standardized decision support tools are also needed for the evaluation of chest pain in outpatient settings. Sequist et al\textsuperscript{21} found that more than one fourth of patients hospitalized with acute MI without a previous diagnosis of coronary artery disease had reported chest pain during primary care visits in the preceding month. Among these patients, nearly half were not referred for hospital care. DSS fits these authors’ definition of a “structured evaluation and triage protocol” that could diminish the rates of missed opportunities to identify outpatients at risk for ACS. Rapid access chest pain clinics have been used in the United Kingdom to provide expedited outpatient evaluation to patients reporting new-onset chest pain.\textsuperscript{22} Patients referred by their general practitioners were screened by a clinic coordinator to identify high-risk subsets reporting severe chest pain, rest pain, or symptoms of unstable angina. The method used for telephone triage was not described in this study. A visit to the rapid access chest pain clinic that included an option for treadmill testing was provided to low-risk patients within 2 to 3 working days.\textsuperscript{22}
Decision support tools that reduce the effort of the physician may be more widely implemented than those that increase it. At present, the responsibility for eliciting and recording patient symptoms falls largely, if not exclusively, on the physician. In contrast, nurses and other nonphysician health care providers located in a variety of settings could use DSS to elicit and record the patient’s symptoms and generate a narrative summary for review by the physicians before their contact with patients in the ED or outpatient clinic.

Summary of the Experience: Future Challenges in the Implementation of DSS

Decision support tools were effective in identifying low-risk patients eligible for discharge from the ED. This suggests that DSS might achieve comparable success in identifying low-risk patients reporting chest pain by telephone who are eligible for outpatient evaluation. Indeed, the 50% of patients discharged home from the ED after evaluation of chest pain subsequently have a low rate of adverse clinical events. Systematic follow-up of such patients might lower this rate still further.

Factors influencing the future adoption of DSS for triage of patients reporting chest pain are both conceptual and practical in nature. One of the greatest conceptual challenges to the adoption of decision support based on patients’ reports of chest pain is that symptoms are considered less reliable than cardiac biomarkers and ECG findings in the triage of patients reporting chest pain. Cardiac biomarkers are readily obtained and are generally less susceptible to interpretation than ECG findings or symptoms. Accordingly, most ED physicians rely largely on cardiac biomarkers to distinguish patients requiring hospitalization from those who can be discharged home.

However, physicians who are focused on a single category of diagnosis such as ischemic heart disease are susceptible to a cognitive error known as premature closure. This error occurs when a satisfactory explanation of the patient’s symptoms short-circuits a broader search for the correct diagnosis. This error is especially likely in the treatment of patients with established CAD who have had multiple previous ED visits for chest pain. The value of symptoms in the triage process reflects the quality of the questioning process itself. A unique contribution of DSS is that it permits systematic, comprehensive questioning of patients regarding the symptoms associated with a broad spectrum of provisional diagnoses, not only ACS.

Arguably, the most important single practical consideration in the adoption of DSS is whether it is in the self-interest of health care providers and medical institutions to systematize the treatment of patients reporting chest pain. The ED is the entry point for nearly half of all hospitalizations in the United States annually, including the 3 million patients who have undergone ED evaluation for suspected ACS. Selker et al estimated that widespread use of decision support tools might avoid 204,000 hospitalizations and 112,000 coronary care unit admissions annually. Most of the savings would accrue from avoidance of hospitalization in patients without cardiac ischemia, whose risk of subsequent cardiac events is low. The potential of decision support tools to reduce ED visits by patients reporting chest pain in urgent care clinics or by telephone may be even greater. The prospect of forgoing ED and hospital revenues may temper the enthusiasm of hospitals to use decision support tools, yet establishing the safety and cost-effectiveness of alternatives to the present management of suspected ACS is a national priority. The American health care system is presently confronting the need to coordinate the care provided to patients not only in traditional delivery sites such as hospitals but in nontraditional sites, including the home, where symptoms of heart attack begin in most cases. Decision support tools and health care teams trained to use them will be critical to the provision of high-quality, cost-effective care to these patients in the future.

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Disclosures

None.

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