Triage of Patients for a Rapid (5-Minute) Electrocardiogram: A Rule Based on Presenting Chief Complaints

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Study objective: A rule based on presenting chief complaints can identify patients for a rapid (5-minute) ECG and decrease delays in treatment of patients with acute myocardial infarction (MI).

Methods: The presenting chief complaint was electronically collected on all patients treated in a community teaching hospital emergency department. A rule for ordering ECG on patient presentation to the ED was developed from a model set of patients presenting from July through December 1994 (22,717 patients) and then tested on a validation set of patients from January through May 1995 (18,759 patients). Outcome measures (delay in performance of ECG and delay in administration of thrombolytic agents) were prospectively collected on written data sheets before (April 1993–May 1995, n=67) and after (June 1995–March 1997, n=128) implementation of the rule at the study hospital.

Results: On the model set, 193 patients had the final diagnosis of MI, with 5 chief complaints having the best performance in identifying patients with acute MI and comprising the rapid ECG rule: older than 30 years with chest pain (130 [67.4%] patients); older than 50 years with syncope (5 [1%] patients); weakness (12 [6.2%] patients); rapid heart beat (2 [1%] patients); and difficulty breathing or shortness of breath (20 [10.4%] patients). On the validation set, 142 patients had the final diagnosis of MI, with the rule performing better than chest pain in identifying patients for a "stat" ECG (sensitivity 93.7% versus 67.4% [95% confidence interval (CI) of the difference, 15.6% to 33.8%]), although a larger percentage of ED patients would receive a stat ECG (7.3% versus 6.3% [95% CI of the difference, 0.7% to 1.7%]). During the model and validation period, 44 (13.1%) of 335 patients with MI received thrombolytic agents. The rule had higher sensitivity on patients with MI treated with thrombolytic agents compared with patients with MI not treated with thrombolytic agents (sensitivity 100% versus 86.4% [95% CI of the difference, 1.7% to 20.3%] and speci-

ficity of 90.4% versus 93.8% [95% CI of the difference, 3.0% to 3.8%]). For the 4-year study period, outcome improved after the implementation of the rule: mean delay in performing ECGs in patients with MI who were administered thrombolytic agents decreased from 10.0 to 6.3 minutes (95% CI of the difference, 1.1 to 6.4), and mean delay in administering thrombolytic agents decreased from 36.9 to 26.1 minutes (95% CI of the difference, 3.5 to 17.7).

Conclusion: Use of a rule based on chief complaints can identify patients with MI for immediate ECG and decrease delays in performing ECGs and administration of thrombolytic agents.

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INTRODUCTION

A primary goal of triage in the emergency department is to reduce delays in the provision of patient care to seriously ill patients. The prompt administration of thrombolytic agents to patients with acute myocardial infarction (MI) is such a priority. Acute MI is a serious disease, with an 8% to 12% mortality rate if untreated.[1] Thrombolytic agents administered within 90 minutes of onset of symptoms can lower the mortality to 1.6% by "aborting the myocardial infarction."[1] The window of opportunity begins to close 1 hour after the symptoms of the patient with MI begin. Six hours after the symptoms of the patient with MI begin, most of the myocardium has died, and there is greatly reduced benefit from thrombolytic agents and other acute medical interventions. For every hour earlier that thrombolytic agents are administered, 24 per 1,000 patients with acute MI are saved.[2]

Hospital delays with thrombolytic administration are a significant issue.[3-7] EDs have attack programs to prevent delays in the administration of thrombolytic agents to patients with acute MI.[8] They try to meet the goal set by the National Heart Attack Alert Program of less than 30 minutes' mean delay on arriving at the hospital.[9] The 4 areas of delay addressed by an ED attack program are *door* (patient delay in seeking medical care), *data* (delay in procuring ECG), *decision* (delay in decision to treat), and *drug* (delay in administration of drug).[9] This study examines an approach to minimize the second component of delay, obtaining an ECG.

The study hypothesis was that a rule based on presenting chief complaints can identify patients for a rapid (5-minute) ECG and decrease delays in treatment of patients with acute MI.

MATERIALS AND METHODS

The study site was New Britain General Hospital, a community teaching hospital affiliated with the University of Connecticut Medical School. There are 44,000 ED visits per year, with 19% of ED patients admitted to the acute care hospital. Evaluation and management of patients are under the direct supervision of an emergency physician 24 hours per day, 7 days per week, including orders for diagnostic testing. Patients presenting to the ED are first assessed by a triage nurse, and those identified as having an emergency or critical problem (eg, chest pain) are triaged to be seen by the physician as a priority.

In 1992, the ED continuous quality improvement committee began initiatives to decrease delays in the administration of thrombolytic agents. Published research and the National Heart Attack Alert Program had shown there were 3 major causes of delays: obtaining the data, making the decision, and administering the drug. Internal audits at the study hospital showed a 20- to 30-minute delay for each component (total delay, 60 to 90 minutes). Delays in making the decision to administer the thrombolytic agent were addressed with a checklist of exclusion and inclusion criteria for thrombolytic agent use. Delays in administering the drug once the decision was made were addressed with a cart in the ED to hold the thrombolytic drug and relevant equipment. Addressing issues that lead to delay in performing ECGs was the focus of this study and initiative. A rule was derived for when to perform a rapid ECG and then validated on a separate data set. Then the rule was implemented in the study hospital's ED.

Much of the data for development and validation of the 5-minute ECG rule were from an electronic ED database. Data elements were entered into the hospital mainframe computer during rendering of patient services or immediately after service. The patient's chief complaint is a mandatory field on the patient registration screen and must be filled in by the registration clerk for every patient who presents to the ED. It is recorded as expressed in the patient's own words (no data dictionary in the field). For the 45,239 patients in part 1 and part 2 of this study, the data elements collected included patient demographics, chief complaint, final diagnosis, and final disposition. The patient's final diagnosis after hospitalization or after the ED visit (if there was no hospitalization) was obtained from hospital billing data. Patients with acute MI on initial presentation were identified by using *International*

Classification of Diseases, ninth revision, Clinical Modification (ICD-9-CM) codes (410.01, 410.11, 410.21, 410.31, 410.41, 410.51, 410.61, 410.71, 410.81, and 410.91).

Data for development of the rule were analyzed and collated on a personal computer on a monthly basis. Chief complaints, as expressed by the patient, were reviewed by the chief investigator. These were sorted in an Excel (Microsoft, Redmond, WA) spreadsheet and then grouped into categories. For example, the chest pain category included all similar complaints (eg, substernal pain, tightness chest, chest tightness, left chest pain, right chest pain, heaviness chest, and burning chest). Because the chief complaint was recorded by the registration clerk in the patient's own words, some patients had a single complaint, and some had multiple complaints. Patients with chest pain were sorted and categorized by their associated chief complaint (eg, chest pain with shortness of breath versus chest pain with vomiting). Chest pain with non–chest pain chief complaints (eg, weakness) were sorted and categorized only by the first chief complaint. After patients were grouped into chief complaint categories, then the presence or absence of acute MI was identified from *ICD-9* codes.

A rule predictive of acute MI was developed by using an analytic approach similar to that of Marton et al[10] and Lowe et al.[11] Two-by-two contingency tables were created for individual variables to analyze their performance in identifying MI (sensitivity, specificity, and likelihood ratio). The likelihood ratio was chosen as the best means to rank the clinical criteria because the test with the highest likelihood ratio is the most efficient in detecting as many true-positive results with as few false-positive results as possible. After the criteria with the highest likelihood ratio was selected, combinations of variables were examined for best performance, as measured by likelihood ratios. An age cutoff that improved specificity without lowering sensitivity was examined for each chief complaint's performance in identifying MI.

The rapid ECG rule was implemented in June 1995. It was distributed to the department, posted in the triage station, and used for in-service training of nurses on their triage procedure. If a patient had a chief complaint listed in the 5-minute ECG rule, the nurse would bypass the usual full nursing assessment, escort the patient into the ED, obtain an ECG on the patient, and show it to an emergency physician. Because the rule was implemented as a continuous quality improvement initiative for the ED, the institutional review board judged that this did not require board review and approval.

Data for evaluation of the effectiveness of the rule (part 3 of the study) were prospectively collected on written checklists. Outcome measures (ie, time delay to obtain an ECG and time delay to administer thrombolytic agents) were measured before (April 1993–May 1995) and after (June 1995–March 1997) implementation of the rule. At the time of patient care, the patient care nurse entered on the study sheet the time the patient arrived in the department (printed on the registration sheet), the time the ECG was performed (printed on the computerized ECG), and the time the thrombolytic agents were administered. On a monthly basis, the checklists were collected, checked for completeness (99.5% of checklists were complete), cross-checked with the pharmacy to ensure all thrombolytic patients were identified (96.5% of thrombolytic patients had checklists), and collated for mean delays in performing ECGs and administering thrombolytic agents. When there was no checklist, the study nurse reviewed the chart for time of ECG performance and time of administration of thrombolytic agents.

Spreadsheet analysis was performed with the Quatro Pro 6.0 for Windows program (Novell, Inc, Orem, UT), and statistical calculations were done with SigmaStat 2.0 for Windows (SPSS Inc, Chicago, IL) and SPSS for Windows (version 9.0; SPSS Inc, Chicago, IL). Sample size calculations for mean time to ECG showed that the study needed 100 patients to demonstrate a 20% decrease in time delays (2 minutes) if the SD is 5, power is 0.80, and α value is .05. Sample size calculations for mean time to thrombolytic agents showed that the study needed 130 patients to demonstrate a 20% decrease in time delay (7 minutes) if the SD is 20, power is 0.80, and α value is .05. There are approximately 320 patients with acute MI each year at the study hospital. If 15% receive thrombolytic agents, then there will be 48 patients with acute MI for the study each year. Thus in a 2-year study period, there should be approximately 96 patients with acute MI receiving ECGs and then thrombolytic agents enrolled. For proportions, the *z* test for proportions with Yates correction was used for independent observations.[12] When observations were not independent, significance was determined by using the McNemar test. The unpaired Student *t* test was used to compare means for continuous data with the Mann-Whitney *U* test for data not normally distributed. Ninety-five percent confidence intervals (CIs) for difference of means were reported where appropriate. Statistical significance was defined as a *P* value of less than .05.

RESULTS

The rule for ordering rapid ECGs was developed on 22,717 patients presenting to the study ED from July 1994 to

December 1994 (model set of patients). One hundred ninety-three patients had the final diagnosis of acute MI, with 22 (11.4%) administered thrombolytic agents. Chest pain was the most common chief complaint, encompassing 67.4% of all patients with MI, with all over the age of 30 years (Table 1). For 10% of these patients with MI, a chief complaint in addition to chest pain was given by the patient. Only 1 patient with MI with chest pain had an additional chief complaint of respiratory infection (cough, asthma, wheezing, congestion, fever, chills, sore throat, or cold) or trauma. Patients in this category had very low likelihood ratios, and excluding these patients did not substantially worsen sensitivity but improved specificity. Patients with acute MI presented with 22 chief complaints other than chest pain. Rapid heart beat, weakness, syncope, and difficulty breathing (shortness of breath) had the highest likelihood ratios, indicating best correlation with the final diagnosis of acute MI (Table 1). Limiting to an age limit of older than 50 years did not substantially worsen the indicators' performance in identifying patients with acute MI. Combination of these 4 chief complaints with chest pain (excluding respiratory infections or trauma) gave the highest sensitivity. Specificity and the false-positive rate increased as expected, but the likelihood ratio remained high (13.5), indicating high overall diagnostic performance (changes in sensitivity compared with changes in the false-positive rate; Table 1). This comprised the rule for ordering 5-minute ECGs. Patients should have an immediate ECG if they are older than 30 years with chest pain (excluding respiratory infection or trauma) or older than 50 years with a rapid heart beat, weakness, syncope, or difficulty breathing. The likelihood ratios (13.8 versus 12.7) and sensitivity (87.6% versus 67.4%, 95% CI for difference 11.8% to 28.6%) were better for the rule than chest pain as an indicator for performing an ECG (Table 1).

The rule was validated on all 18,759 patients treated in the ED from January 1995 through May 1995 (validation set of patients). One hundred forty-two patients during that time period had the final diagnosis of acute MI, with 22 (15.5%) administered thrombolytic agents. One thousand fifty-two of all study patients had chest pain, with 98 having the final diagnosis of acute MI. As in the model set of data, the rule performed better than chest pain as an indication for stat ECG. There was lower specificity and a larger percentage of ED patients receiving a rapid ECG with the rule than with chest pain as the indication for a rapid ECG (Table 2).

There was no significant difference between the model and validation data set in patient mode of arrival at the ED. The percentage of patients with MI presenting by ambulance was similar (50.4% versus 52.5%). The percentage of patients by chief complaint that presented by ambulance was also similar: chest pain, 33.7% versus 34.7%; weakness, 80.0% versus 76.6%; syncope, 77.1% versus 76.1%; rapid heart beat, 24.2% versus 29.8%; and shortness of breath or difficulty breathing, 51.2% versus 52.0%.

Table 1.
Model set: predictive properties of chief complaints in identifying acute MI.

Chief Complaint*	No.	Sensitivity (%)	False-Positive (%)	LR
All chest pain	1,324	67.4	5.3	12.7
Chest pain as sole complaint	737	60.6	2.8	21.6
Chest pain and other symptoms	227	6.3	2.1	3.0
All chest pain (>30 y), except URI† or trauma	1,241	66.8	4.9	13.8
Rapid heart beat (>50 y)	21	1.0	0.08	12.5
Weakness (>50 y)	153	6.2	0.6	10.3
Syncope (>50 y)	78	2.7	0.3	9.0
Shortness of breath (>50 y)	493	10.4	2.1	5.0
Dizziness (>50 y)	188	1.0	0.8	1.3
Vomiting (>50 y)	490	1.0	2.2	0.5
Abdominal pain (>50 y)	1,377	2.7	6.1	0.4
Back pain (>50 y)	398	0.5	1.8	0.3
Cough (>50 y)	434	0.5	1.9	0.3
Asthma (>50 y)	444	0.5	2.0	0.3
Fall (>50 y)	1,087	0.5	4.8	0.1
Rule for 5-min ECG	1,986	87.1	6.5	13.5

LR, Likelihood ratio; **URI,** upper respiratory tract infection.
*Not listed: diabetes, flu, flutter, neck pain, rectal pain, pulmonary embolism, foot pain, numb leg, swollen lip, disoriented, and diarrhea.
†Cough, asthma, wheezing, congestion, fever, chills, sore throat, or cold.

Table 2.
Performance of the 5-minute ECG rule in identifying patients with acute MI: model set of data versus validation set of data.

Set	Chest Pain	Rule	95% CI of Difference	Change With Rule
Model set				
Sensitivity (%)	67.4	87.6	11.9–28.5	30 improved
Specificity (%)	94.7	91.9	2.3–3.3	3 worsened
ED patients with ECG (%)	5.8	8.7	2.4–3.4	50 increased
Validation set				
Sensitivity (%)	69.0	93.7	15.6–33.8	36 improved
Specificity (%)	96.8	93.3	3.1–3.9	0.6 worsened
ED patients with ECG (%)	6.1	7.3	0.7–1.7	16 increased

In the model and validation series of patients with MI, thrombolytic agents were administered to 44 (13.1%) of 335 patients with MI. In those patients with MI administered thrombolytic agents, chest pain was the chief complaint in 86.4%, weakness in 2.3%, and shortness of breath in 11.3%. Chest pain was a more frequent chief complaint in patients with MI administered thrombolytic agents than in patients with MI not administered thrombolytic agents (86.4% versus 65.3%, 95% CI of the difference 6.3% to 35.9%). The rapid ECG rule performed better in patients with MI administered thrombolytic agents than in patients with MI not administered thrombolytic agents (sensitivity of 100% versus 86.4%, 95% CI of the difference 1.7% to 20.3%; and specificity of 90.4% versus 93.8%, 95% CI of the difference 3.0% to 3.8%, respectively).

The rapid ECG rule was implemented at the study hospital in May 1995. Outcome measures of performance from April 1993 through May 1995 (n=67) were compared with outcome measures of performance from June 1995 through March 1997 (n=128). The ED delay in performance of an ECG on patients with MI who received thrombolytic agents decreased from a mean of 10.0 minutes (95% CI 6.6 to 13.4) to 6.3 minutes (95% CI 5.4 to 7.2, 95% CI of the difference 1.1 to 6.4; Figure 1). The median of the delay decreased from 8 minutes (25% to 75% quartiles, 3.3 to 12.0) to 5 minutes (25% to 75% quartiles, 2.5 to 9.8). At the same time, the delay until administration of thrombolytic agents decreased from a mean of 36.9 minutes (95% CI 29.3 to 43.5) to 26.1 minutes (95% CI 23.3 to 30.1; 95% CI of the difference 3.5 to 17.7; Figure 2). The median of the delay decreased from 30 minutes (25% to 75% quartiles, 18.0 to 48.8) to 21 minutes (25% to 75% quartiles, 16.0 to 30.5).

DISCUSSION

This study developed a rule for ordering rapid ECGs for patients with possible acute MI. This rule creates a process by which ECGs are performed on appropriate patients immediately on their arrival in the ED. We used nonprocessed chief complaints that were stated by the patient during the initial interaction between the patient and a clerk or nurse. This bypasses the usual delay during the nursing triage assessment and the queuing that occurs for patients waiting to see the triage nurse. The goal is to meet the national standard of overall less than 30 minutes of delay in the administration of thrombolytic agents.[9]

Without such a rule, the delays are significant in obtaining an initial ECG. Sharkey et al,[13] in 1989, found that the mean delay until ECG was performed in patients with acute MI administered thrombolytic agents was 19.9

Figure 1.
Histogram of the delay in performing ECG on patients with acute MI before (mean, 10.0 minutes; n=67) and after (mean, 6.3 minutes; n=128) implementation of the rule.

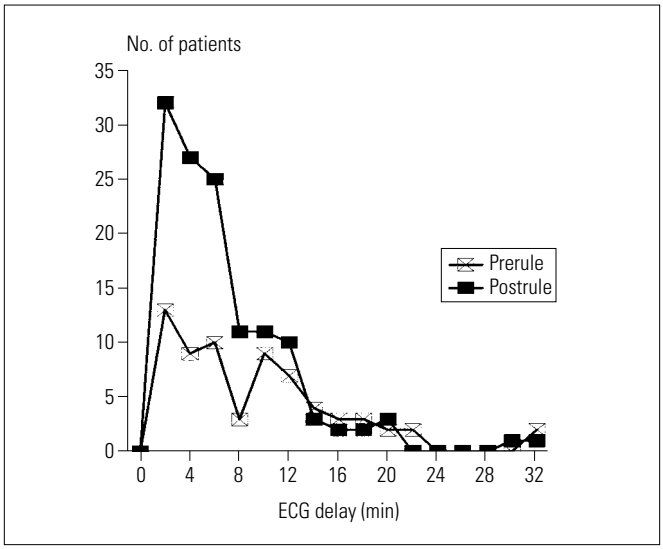
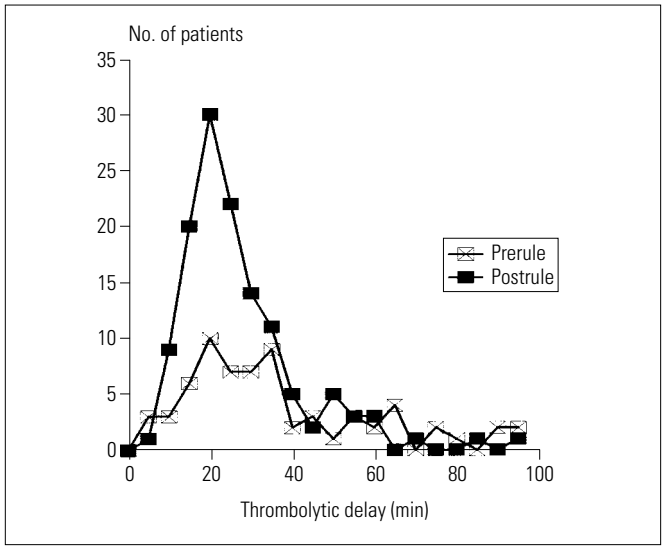


Figure 2.
Histogram of the delay in administration of thrombolytic agents to patients with acute MI before (mean, 37.0 minutes; n=67) and after (mean, 26.4 minutes; n=128) implementation of the rule.



minutes. In 1991, Nemhauser et al[14] found the mean delay until ECG for thrombolytic patients was still prolonged at 13.3 minutes. In 1992, Kline et al[15] found an 11-minute mean delay in obtaining an ECG in thrombolytic patients. Jackson et al[16] studied 2 hospitals in 1996 and found that mean delays until ECG of thrombolytic patients were 17 and 25 minutes, respectively. If the total delay in administering thrombolytic agents is to be less than 30 minutes, the mean delay in obtaining the initial ECG needs to be significantly less than in these studies.

These delays in obtaining an initial ECG contributes to the delays in administering thrombolytic agents to patients with possible acute MI. The above authors found total mean delays in administering thrombolytic agents of 70 minutes,[13] 84 minutes,[14] 70 minutes,[15] 62 minutes,[16] and 127 minutes,[16] respectively. Larger studies have found similar delays. Meehan et al[17] found that the mean delay was 70 minutes in 35 acute care hospitals in the state of Connecticut, studying 1,202 patients with acute MI. Ellerbeck et al[18] examined mean delays in administration of thrombolytic agents on 16,869 patients with acute MI in 4 states and found a 1.2-hour mean delay. Addressing delays in obtaining an ECG is an important initial step in decreasing total delays and meeting the national goal of less than 30 minutes of hospital delay.

These delays are present because the routine process for evaluating patients in the ED has significant delays. An ED, such as the study hospital, with 44,000 patient visits per year has 5 to 10 patients arriving each hour. Each patient needs to be registered and evaluated with a nursing assessment. During triage, the nurse categorizes patients as critical, emergency, urgent, or nonurgent, with patients in the more unstable category to be seen by the physician first. This nurse triage significantly decreases the delay until the physician sees the sicker patients.[19] Yet many patients with acute MI will not have clear evidence of their condition on presentation, except for symptoms such as weakness or shortness of breath.[20] For these patients with acute MI who are not clearly identified initially, there will be delays of 30 to 60 minutes until the physician sees the patient. Thus, the mean delay until administration of thrombolytic agents is prolonged, as described in the studies discussed above.[13-18]

Implementation of a rule for ordering immediate ECGs facilitates the creation of a focused clinical path for rapid treatment of patients with acute MI with thrombolytic agents. It goes beyond the traditional assessment process and defines an imperative for treatment without delay. With the rapid ECG rule, the physician's first interaction with the patients with acute MI who may require thrombolytic agents is review of the patient's ECG. If the ECG shows ST-segment elevation, then the physician's next step is to quickly clarify whether the patient's clinical findings are consistent with an acute MI. In contrast, the usual approach in the ED is for the physician to review the written nursing assessment and then perform the physician's own evaluation. This is a measured process that is proper for many patients where the patient's clinical condition is not so time-sensitive that delays of minutes result in serious adverse outcome. Our study illustrates the time savings possible by redesigning the clinical process to first focus on whether there is a need for thrombolysis and then perform the detailed medical evaluation.

A surprising finding in this study was the rapid ECG rule performed better in patients with MI requiring thrombolytic agents than in patients with MI not requiring thrombolytic agents. Patients with MI treated with thrombolytic agents had chest pain as their chief complaint more frequently than patients with MI not treated with thrombolytic agents. Every patient with MI treated with thrombolytic agents had one of the 5 chief complaints in the rapid ECG rule. Previous research has similarly shown that patients with MI who are, as determined by ECG, candidates for thrombolytic agents (ST-segment elevation) have more typical clinical findings.[20] Further research is needed to examine the relationship between the symptoms of patients with MI (chief complaint), initial ECG findings, and need for acute interventions.

This study has several potential limitations. We did not evaluate the performance of the chief complaint as evaluated by the nurse or the physician. Our study used the patient's stated chief complaint. This has the advantage of being immediately available on patient presentation but may not be as accurate in reflecting the patient's condition. This may limit the generalizability of our findings. The study hospital did not have emergency angioplasty, which complicates the emergency physician's decision on use of thrombolytic agents. *ICD-9* codes were used to identify patients with acute MI, and the coding accuracy was not reviewed. There was no follow-up to examine for patients with MI whose diagnosis may have been missed during the ED visit. Acute coronary syndrome is a spectrum from acute MI to unstable angina, and future research should examine the performance of the rule on all patients with acute coronary syndrome. This study used only a single hospital site with a historical control. Randomization of patients in a multicenter clinical trial would be preferred, although not clearly feasible or ethical. Patients randomly assigned to complete initial nurs-

ing assessment rather than immediate ECG would by study design have longer delays because they are being provided an additional service before the ECG is performed. Randomization could also address the issue of how much of the improvement in this study was due to the Hawthorne effect on outliers. In addition, a competing technology was not examined in this study, the out-of-hospital 12-lead ECG.[1,21,22] Cost-effectiveness studies need to be performed comparing these 2 technologies to examine whether delays are decreased in administration of thrombolytic agents and whether benefits justify the increases in direct and indirect costs with implementation of this technology in the out-of-hospital arena.

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