Factors Influencing Time-dependent Quality Indicators for Suspected Acute Coronary Syndrome Patients

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Abstract

Objectives—Rapid risk stratification and timely treatment are critical to favorable outcomes for acute coronary syndrome (ACS) patients. Our objective was to identify patient and system factors that influence time-dependent quality indicators (QIs) for unstable angina (UA)/non-ST elevation Myocardial Infarction (NSTEMI) patients in the emergency department (ED).

Methods—A retrospective, cohort study was conducted over a 42-month period of all patients aged 24 years or older suspected of having ACS as defined by receiving an electrocardiogram (ECG) and at least one cardiac biomarker test. Cox regression was used to model the effects of patient characteristics, ancillary service utilization, staffing provisions, equipment availability and ED and hospital crowding on ACS QIs.

Results—ED adherence rates to national standards for ECG read out time and biomarker turn-around-time were 42% and 37%, respectively. Cox regression models revealed that chief complaints without chest pain and the timing of stress testing and medication administration were associated with the most significant delays.

Conclusions—Patient and system factors both significantly influenced QI times in this UA/NSTEMI cohort. These results illustrate both the complexity of diagnosing NSTEMI patients and the competing effects of clinical and system factors on patient flow through the ED.

Keywords

Acute Coronary Syndrome; Emergency Department; Delays; Systems Engineering

1.0 INTRODUCTION

1.1 Background

Chest pain prompts over 5.5 million emergency department (ED) visits. There are more than 1 million hospitalizations annually for acute myocardial infarction (AMI), the leading cause of death in the U.S [1]. Acute coronary syndrome (ACS) - an umbrella term that includes all clinical findings consistent with acute myocardial ischemia - is a strong predictor of future AMI. Clinical research has shown that rapid risk stratification and timely treatment are critical to favorable outcomes in ACS patients. However, the majority of this research has focused on ST-Elevated Myocardial Infarction (STEMI). Randomized clinical trials of ACS management during the 1990s yielded numerous diagnostic tools and treatment strategies. Based on these data, the American College of Cardiology (ACC), the American Heart Association (AHA), and others developed clinical practice guidelines for the diagnosis and treatment of ACS using an evidence-based framework for clinical decision making [2, 3].

Results from the “Can Rapid Risk Stratification of Unstable Angina Patients Suppress Adverse Outcomes with Early Implementation of the ACC/AHA Guidelines” (CRUSADE) study demonstrated a significant relationship between adherence to recommended guidelines in the ED and hospital and inhospital mortality. The CRUSADE study did not evaluate the association between the adherence to recommended time-based guidelines, such as time to electrocardiogram, and in-hospital mortality. For every 10% increase in composite guideline adherence score at a hospital, there was a 10% decrease in ACS patients’ likelihood of in-hospital mortality [4]. Despite the evidence favoring the adoption and adherence to these AHA/ACC guidelines, many EDs struggle to meet these criteria.

For many components of cardiac care, the timeliness of care delivery is nearly as important for safety outcomes as the care itself [2, 4–9]. Timely identification of very low risk patients could benefit ED quality by reducing the ED length of stay (LOS) for this population that generates a particularly high volume of clinical workload. The impact of early and accurate triage decisions is significant in light of mounting evidence that ED crowding adversely affects quality of care [10–15]. Quality indicators (QI) that emphasize the temporal dimension of care have been adopted for ED ACS patients.

In this study, we analyzed natural and artificial variability in completion times of diagnostic and therapeutic care events for suspected ACS patients presenting to a large tertiary care center accredited as a Chest Pain Center by the Society of Chest Pain Centers. We hypothesized that time-based ACS QIs are significantly influenced by ED and hospital system factors adjusted for patient factors (i.e., patient disease process and time of ED arrival). To test this hypothesis, we used multivariable regression modeling to assess the independent contributions of patient, ED, and hospital system factors on ED performance on five time-based QIs for UA/NSTEMI: (1) ECG readout time; (2) laboratory turnaround time (TAT); (3) therapeutic turn-around time (TTAT); (4) ED boarding time; and (5) ED LOS.

2.0 METHODS

2.1 Study Design and Methods

This was a retrospective cohort study of all patients presenting to an urban, academic, tertiary care hospital with suspected ACS between February 1, 2006 and August 31, 2009. We included all patients aged 24 years or older on whom an electrocardiogram (ECG) and at least one cardiac biomarker test was performed and documented in the hospital's adult ED (see Table 1). Twenty-four years of age was selected as the cut-off age because it serves as a demarcation line for Vanderbilt's adult and children's hospitals. The 45-bed ED has 55,000 patient visits per year, a 29% admission rate, and is accredited as a Chest Pain Center by the Society of Chest Pain Centers. The study was approved by the Vanderbilt University Institutional Review Board.

Time-stamped diagnostic and therapeutic care event data were obtained from the hospital's clinical information systems to recreate the time course of care for each suspected ACS patient presenting to the ED during the study period. Data were obtained from the following systems and sources: provider computerized order entry (CPOE); ED Information Systems (EDIS); ED Nursing documentation; Laboratory information system (LIS); Admission, Transfer, Discharge (ADT) system; Perioperative Information Management System; the National Cardiovascular Data Registry (NCDR) ACTION Registry – Get With the Guidelines (GWTG); and the NCDR CATH PCI Registry. Patient socioeconomic and clinical data, ED and hospital resource utilization data, and concurrent staffing data were obtained. System queuing metrics, designed to capture system workload and ancillary resource congestion, were calculated from the hospital's clinical and operational data systems. Patient variable, staffing levels, work process factors and system queuing metrics were used as potential independent variables for the multivariable analyses.

2.2 Outcome Measures

Table II shows the five ED process QI time intervals for UA/MSTEMI used as the dependent variables for all analyses. The ACC/AHA have adopted formal standards for ECG read out time and lab turn-around time. Standards have not been adopted for therapeutic turn-around-time, boarding time, or ED length of stay, however, as of January 2012, the Centers for Medicare and Medicaid Services requires hospitals to report hospital performance on the ED throughput measures for admitted patients. The adoption of formal standards is anticipated as a result of these new requirements.

2.3 Primary Data Analysis

Chi-square tests and analysis of variance (ANOVA), respectively, were used to compare categorical and continuous variables characterizing the socioeconomic and clinical characteristics of the study cohort. The median interval time, interquartile range (IQR), and the percentage adherence to defined ACS standards were computed for each QI (Table II). Cox proportional hazard regression modeling was used to test our hypothesis that system factors influence ACS QIs when adjusted for patient factors. For all tests, a 2-tailed probability of less than 5% was used for statistical significance. We modeled the statistical relationships between selected independent variables and care process interval times (i.e.,

dependent variables) that define the time-based QIs for UA/STEMI patients. For the dependent variables door-to-ECG readout, door-to-biomarker readout, and biomarker order-to-treatment, only the time to first event was used for patients who received serial biomarkers, cardiac enzyme tests, or treatments. Independent variables included in the analysis were measures of: ED, ancillary, and hospital operations, as well as patient characteristics (see Table II) hypothesized to influence the timeliness of cardiac care. ED operational variables measured ED workload, resource demands, and staffing levels. Ancillary operational variables measured the workload, resource demands (e.g., ECG), staffing levels and shift patterns of radiology and the clinical laboratory. Hospital operational variables reflected workload demand, resource availability (e.g., inpatient beds) and staffing levels of cardiology, the catheterization laboratory and the operating rooms. QIs that were the sum of multiple, serially correlated clinical processes were partitioned such that one regression model was created for each process. The assumption that each process time interval was independent of the previous interval (i.e., renewal process) was accounted for by including the previous time interval as a predictor variable.

Predictor variables were selected by first identifying a sub-set of operational, clinical, and patient demographic predictors that were hypothesized to influence each process time interval. A penalized likelihood approach was used to determine which predictor variables to include in the final models [16, 17].

The proportional hazard assumption was tested by examining plots of scaled Schoenfeld residuals and using the proportional hazard test described by Grambsch [18]. None of the predictor variables used in the final models had a non-proportional effect over time. Bootstrapping was used to assess model bias [19, 20].

Applying Cox regression within this framework raises several analytical issues. Our dataset had very little missing data (<1%) so bias from our complete-case analyses was negligible. We also included only one (i.e., the first) visit per patient (<5% had more than one visit) excluding data from subsequent repeat visits to simplify the handling of correlation within a patient over repeat visits. Correlated survival times for patients treated by the same provider during the same shift were expected. If correlated survival times follow a proportional hazards model then treating correlated survival times as independent gives *consistent* estimates of relative risk parameters, but may yield inconsistent estimates of asymptotic variance [21–23]. These effects were examined by creating clusters around ED provider and shift. The clusters included all cohort patients with the same ED attending (i.e., attending physician responsible for care upon patient arrival) during the same attending shift. Robust variance estimates [21–23] were compared to original variance estimates and were found to be consistent.

3.0 RESULTS

During the 42-month study period, 12,544 (6%) patient visits met the inclusion criteria for suspected ACS. A consort diagram of the study cohort is displayed in Figure 1. The socioeconomic and clinical characteristics of the final cohort are displayed in Table 1. Most patients meeting the inclusion criteria received a chest x-ray (N = 11,354; 91%) in the ED

before a treatment or disposition decision was made. Overall, 48% (N=6,021) of cohort visits resulted in admission to the hospital as compared to a 19% rate (N = 37,136) for all other ED patients not meeting inclusion criteria. Of the admitted patients, 2,401 (40%) received anti-ischemic, anti-platelet, and/or anti-thrombin therapy during their ED stay.

Table II presents the calculated median interval time, IQR and the percent adherence measured for each ACS QI. Performance standards have been defined for time-to-ECG readout 10 minutes [24–26] and laboratory TAT 60 minutes [3, 27, 28]. The ED adhered to these performance standards in less than 50% of visits comprising the cohort which is consistent with previously published adherence rates [29–31]. The median TTAT was much faster for anti-thrombin therapy than anti-platelet therapy. The median ED LOS was approximately 4 hours and the median boarding time was nearly 3.5 hours for patients admitted to the hospital in the cohort.

Cox proportional hazards regression models were created for each defined ACS interval (See Table III for Hazard Ratios (HR) and 95% Confidence Intervals). Predictor variable HRs greater than one are associated with shorter time intervals. HRs less than one are associated with longer time intervals. Table III also shows the influence of the independent variables on the baseline median interval for each QI model.

Forty-two percent of ECG TATs met the national guideline of 10 minutes or less. Performance on this QI was primarily influenced by patient factors. Patients who presented to the ED with chief complaints inconsistent with ACS, especially those without chest pain, experienced the longest delays. Conversely, median ECG TATS were 2.4 minutes shorter for patients stratified into the Emergency Severity Index (ESI) Level 1 at triage than for lower acuity patients. Age<65, female gender, and non-English language were all statistically significant in our multivariable model. Trauma activations (i.e., ED Trauma load in our models) did not influence ECG acquisition time. ED waiting room count and arrival by ambulance were associated with very small ECG acquisition delays, while having a dedicated cardiologist in ED was associated with small reductions in ECG TATs.

Cardiac biomarker results were reported within 60 minutes of the physician's order in 37% of patients in the ACS cohort. The regression model for biomarker TAT indicates that ED performance was influenced by female gender, presenting with chief complaint not related to chest pain or any cardiovascular disease, evening or night arrival, and ED occupancy. The presence of a cardiologist in the ED at the time of admission was associated with an 8 minute increase in median lab TAT, whereas ambulance arrival, physician triage, and point-of-care testing were associated with faster TATs.

The median therapeutic TAT was 65 minutes. More than half of the patients in our cohort received anti-ischemic, anti-thrombin, or anti-platelet therapies before the biomarker test results were available. Patients presenting with non ACS-related chief complaints and/or received a stress test before receiving medication therapy experienced the longest TTAT. Reduced ED physician staffing levels were also contributed to TTAT delays. The use of portable X-ray machines was associated with the greatest (i.e., 30 minutes) reduction in median TTAT.

Boarding time increased over the study period as ED visits increased. Female gender and insurance type (Self pay, Medicaid, and Medicare) were associated with longer boarding times, while high patient acuity and non-English language was associated with shorter boarding times. Temporal factors also influenced boarding times: weekends and holidays had shorter boarding times whereas evenings or nights had longer boarding times. Receiving medication therapy before disposition decision and increased census in the catheterization laboratory, cardiovascular intensive care unit (CVICU), and cardiac telemetry unit were also independently and significantly associated with increased ED of ACS patients boarding. Access and use of critical resources such portable X-ray machines and cardiology consults shortened ED boarding times.

The median ED LOS of 247 minutes was also influenced by numerous patient, ED, and clinical factors. Patient age (<65 years) and chief complaint (i.e., non cardiovascular, non chest pain-related) were associated with increased ED LOS. Female gender was also associated with increased LOS but the effect was small. Influential ED operational factors included point-of care testing, the use of portable x-rays machines, and the presence of a cardiologist in the ED. ED LOS increased each year of the study as ED volume increased. ED crowding factors significantly influenced ED LOS but hospital crowding factors did not. Factors affecting ED crowding and demand included: ED occupancy; the number of ED beds occupied by suspected ACS and neurology patients; and demand for ECGs. Year and evening or night admissions were the only temporal factors of significance in the model. Patients who received a stress test before disposition decision experienced the longest ED LOS, while patient admitted to the hospital had the shortest LOS.

4.0 DISCUSSION

Systems-based research and quality improvement have primarily focused on decreasing the time to interventions in patients with STEMI. The diagnosis or rule-out of UA/NSTEMI is equally important, especially in this era of ED crowding. With a more subtle presentation and more gradual clinical manifestation, clinical evaluation can be prolonged due to diagnostic uncertainty and complexity. Systems-based improvements are more difficult to design and implement for UA/NSTEMI because the evaluation period of these patients is longer, more resource intensive, and more dependent on intra-hospital factors. The duration of ED evaluation can be problematic because it makes the diagnosis and treatment of UA/NSTEMI patients more susceptible to fluctuations in ED and hospital occupancy, provider handovers, and time-varying demands on ED and hospital resources. This study measured and characterized variability in ACS care processes at an accredited chest pain center and used multivariable regression modeling to isolate the contributory effects of specific patient, ED, and hospital factors.

The results of the Cox regression models show that six classes of factors affected the timeliness of emergency ACS care in our cohort: (1) patient socioeconomic factors; (2) clinical factors; (3) ED and hospital process factors; (4) temporal factors; and (6) crowding and resource demand factors. The following socioeconomic factors significantly influenced each of our QIs: Age<65, female gender, non-English language, and insurance type. Female gender was significantly associated with delay in ECG TAT, biomarker TAT, boarding time,

and ED LOS. Non-English language was the only patient factor associated with shorter QI intervals. Insurance type only influenced boarding time in our cohort. The results of previous studies on the effects of patient socioeconomic factors on ECG TATS have been largely inconclusive, although female gender has been consistently associated with delayed ECG TAT [30, 32–34]. By comparison, Diercks' analysis of data from patients enrolled in the CRUSADE initiative found female gender, nonwhite race, insurance type, and off-hour presentation to be significantly associated with delayed ECG acquisition [30]. Research has shown that patient socioeconomic factors can affect care quality perhaps due to conscious or subconscious biases of healthcare providers [35].

Clinical factors associated with ACS QI intervals included ESI level, chief complaint, disposition decision, and the use of ancillary services. Patients triaged to ESI level I or II experienced significantly shorter QI intervals; the highest acuity patients were appropriately attended first. Yoon found that patients in intermediate triage levels III and IV had the longest wait times for physicians and nurses, and the longest ED LOS [36]. Our finding that ACS patients with non chest pain-related and non cardiovascular-related chief complaints had the longest QI intervals is a logical result since discordant chief complaints can lead clinicians down the wrong diagnostic pathway [37]. From a systems improvement perspective, the most interesting clinical factors were those involving ancillary services. Previous research has shown that diagnostic imaging, laboratory tests, and specialty consultations are associated with longer LOS [36]. Our results suggest that efficient resource management and the creative navigation of constraints related to ancillary services can facilitate timely, but not always optimal, ACS care. For example, patients received the fastest TTAT when physicians began medication therapy before biomarker tests were reported by the laboratory. TTAT, boarding times, and ED LOS were shorter for patients who received a chest x-ray in the ED via a portable device. However, patients receiving stress tests had among the longest QI intervals because the service was not available after-hours. Cardiology consults were associated with a 49 minute reduction in median boarding time in our study compared to a 2.5 hour (150 minute) mean prolongation in Yoon's study [36]. Increasing access to cardiac stress testing, provided via 24-hour stress testing services, will likely reduce delays in TTAT and improve patient flow in high throughput EDs.

ED and hospital process factors included strategies designed to improve the quality of emergency ACS care. Our study period overlapped with the implementation of three QI interventions: (1) inclusion of a physician on the triage team; (2) point-of-care testing; and (3) placement of cardiologist in the ED. The physician triage system was initiated in January of 2006 but its hours of operation were modified substantially four times between January 2006 and July 2007. The effect of physician triage in the Cox models was likely muted since the majority of patients during our study period were evaluated under this system. Previously published research performed in our ED showed physician triage reduced ED LOS by 37 minutes [38]. The new STEMI response system (i.e., "One Call system") uses a single call to the hospital's LifeFlight team (i.e., air rescue) to activate the STEMI team and the catheterization laboratory. Since the One Call system emphasized urgency in obtaining an ECG in less than 10 minutes for suspected ACS patients, it has benefited all patients even those ruled out for STEMI.

Our ED implemented a variation of true point-of-care testing that uses a dedicated pneumatic tube system to deliver specimens to an ED-dedicated (i.e., 24/7/365) laboratory technician in the central laboratory. Time-of-day effects, which were significant in our model, persisted under the new point-of-care testing model. A recent multi-center cost-benefit study of true point-of-care testing in the ED found that its use increased the proportion of patients successfully discharged home and reduced the median hospital LOS but did not reduce costs [39]. These results contradict recent projected benefits of point of care testing in the ED [40]. Further research will be required to determine if our variant of point-of-care testing is clinically effective and cost-effective.

The presence of an in residence ED cardiologist was not associated with a systematic improvement UA/NSTEMI QI intervals. However, conclusions regarding this intervention must be made cautiously because the dichotomous variable used in our models represented whether or not a cardiologist was present at the time of patient admission and not whether the cardiologist personally evaluated that patient. Future research should evaluate how the cardiologist's direct interaction with suspected ACS patients affects care quality.

Factors characterizing ED and hospital crowding were significantly associated with delays in ACS care. ED crowding and/or increasing demands on critical resources prolonged all QI intervals. Our finding that ED occupancy contributed to biomarker TAT delays is consistent with, although less pronounced, than the results of Hwang and colleagues [41–43] but contradict those of Hulstad et al. or Pines et al. [41–43]. Similar to McCarthy et al. [44], we found hospital crowding, rather than ED crowding, was associated with prolonged boarding times. Instead, high occupancy in the catheterization lab, telemetry unit, and CVICU delayed ACS care processes, consistent with previously published research by our team [45]. Increasing occupancy in the catheterization laboratory is a major driver of ED boarding for cardiac patients. However, neither expanding the catheterization lab from 16 to 19 beds in 2008 nor extending its hours of operation to include Saturday morning influenced any of our ACS QI intervals. Interestingly, concurrent (i.e., with ED admissions) cardiac surgery volume was not associated with QI intervals. This may reflect limitations of our models' variables to measure accurately variation over time. For example, our 'cardiac surgery load' variable was simply a count (i.e., a snapshot) of cardiac surgical procedures occurring within a 1 hour period of the ACS care event being analyzed. In a previously published study, we demonstrated that variability in elective surgery schedules had more significant adverse effects on ED boarding times than sources of natural or random variability [46].

While individual patient visits to the ED are naturally (i.e., random) occurring, ED arrival patterns at the population level are not. In fact, ED visit patterns are fairly predictable by time of day, day of week, and season of year [46]. Nationally, ED occupancy typically increases from early afternoon until night, and it spikes on Friday and Saturday night and annually during influenza season [47]. Consistent with national findings, year and time of day were the most significant temporal factors in our ACS QI models. Year was a proxy for ED volume which increased steadily over the study period as is occurring nationwide. As ED volume increased QI intervals lengthened. Evening and night time ED admissions were associated with delays in ECG acquisition and biomarker TAT, and longer boarding time. Night time admission increased median boarding time by 45 minutes. Conversely, holiday

admissions decreased median boarding by 51 minutes. Winter was associated with slower lab processing of cardiac biomarker tests. Knowledge of temporal patterns of ED utilization should be used to inform quality improvement strategies. For example, Bucheli added one additional physician during nights shifts to reduce mean ED LOS by approximately 35 minutes [48].

4.1 Limitations

This study has limitations. Since the data are from a single academic medical center, the results may not be applicable to other hospitals and chest pain centers. Secondly, the statistical models were developed from retrospective data collected from clinical information systems. The reliability of these data can be highly variable, especially when electronic documentation is influenced by many of the very factors we analyzed, including staffing levels and crowding. However, prior to our study we conducted over 200 hours of direct observations of ED physician and nurse work practices and workflow [49–51]. Through this work we were able to accurately measure the variability in clinical information system variables and used this information to guide subsequent data usage. The third limitation was that we limited our analysis to initial care events. The diagnosis of UA/NSTEMI often requires extended clinical evaluation and serial diagnostic tests so by ignoring the iterative processes of diagnosing complex ACS cases we missed an opportunity to explore the effects of clinical uncertainty on ED response. This study did not include physiological data (i.e., vitals sign data) which are certain to influence care processes (but are naturally occurring variables). Finally, we were unable to acquire reliable pre-hospital (i.e., EMS data) that would have potentially provided important insights on pre-hospital delays and clinical practices (i.e., ECG, administration of aspirin, etc.). Therefore, patients who received an ECG by EMS were excluded from our analysis if the test was not repeated and documented in the ED.

5.0 CONCLUSIONS

Wait time distributions associated with ACS QIs were significantly influenced by both artificial variability in ED and hospital work processes and by natural variability in ED patient arrivals and clinical factors. Clinical improvement strategies designed to enhance the management and coordination of resources between the ED and hospital showed the most potential for improving ACS care delivery.

The analysis and modeling of temporal patterns of ED utilization and process flow can make emergency departments more adaptive to time-varying demands on clinical resources. Systems modeling provides a valuable methodology for understanding clinical uncertainty and the factors affecting care quality. Good models facilitate evidence-based decisions about quality improvement interventions.

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Figure 1.
Emergency Department ACS Pathway Analyzed for Study Cohort

Table 1
Socioeconomic and clinical characteristics of the study cohort and exclusion cohorts

Variable	Study Cohort* Age ≥24; ECG and Biomarker (N=12,544)		Exclusion Cohort with one ACS-related Test†		Exclusion Cohort with No ACS-related Testing†† (N=173,646)	
	N	%	N	%	N	%
Age (yr.)						
Median(IQR)	56.8(46.0, 70.1)		52.7(40.8, 66.7)		35.1 (24.8, 49.6)	
Mean/SD	58.1/16.2		54.0/17.5		39.5/18.5	
English speaking	11,264	90%	21,655	85%	150,451	87%
Gender (Female)*	6,040	48%	13,962	55%	96,720	56%
RACE*						
White	9,138	73%	17,067	67%	109,509	63%
Black	2,747	22%	7,300	29%	49,888	29%
Others	502	4%	945	4%	12,263	7%
Insurance Type*						
Commercial	4,608	37%	7,573	36%	58,354	43%
Medicaid	1,567	12%	3,209	15%	35,346	26%
Medicare	5,119	41%	8,178	39%	19,754	14%
Self Pay	1,236	10%	2,102	10%	23,797	17%
ESI Level*						
1	141	1%	297	1%	3,113	2%
2	10,128	81%	17,831	70%	55,240	36%
3–5	2,220	18%	7,318	29%	94,903	62%
Chief Complaint						
Chest pain NOS (786.5)	5,202	41%	1,484	6%	19,364	11%
Shortness of Breath (786.05)	1,915	15%	6,490	25%	3,082	2%
Other Malaise & Fatigue (780.79)	931	7%	2,317	9%	6,168	4%
Syncope and Collapse (780.2)	508	4%	2,998	12%	2,792	2%
Abdominal Pain-Site NES (789.09)	404	3%	1,035	4%	872	1%
Musculoskeletal (710–739)	477	4%	725	3%	408	0%
Digestive (520–579)	388	3%	687	3%	1,008	1%

Variable	Study Cohort [*] Age >=24; ECG and Biomarker (N=12,544)		Exclusion Cohort with one ACS-related Test [†] (N=25,564)		Exclusion Cohort with No ACS-related Testing ^{††} (N=173,646)	
	N	%	N	%	N	%
Other Cardiovascular(785)	367	3%	1,303	5%	11,846	7%
Circulatory (390–459)	314	3%	1,296	5%	28,363	16%
Skin (680–709)	310	2%	706	3%	8,556	5%
Injury (800–999)	275	2%	1,431	6%	23,769	14%
Respiratory (460–519)	264	2%	599	2%	11,260	6%
Nervous (320–459)	179	1%	905	4%	7,049	4%
Mental (290–319)	159	1%	832	3%	10,297	6%
General (all other ICD9)	851	7%	2,756	11%	38,812	22%
Admission to hospital	6,021	48%	7,554	30%	29,582	17%

^{*} Less than 1% missing value in study cohort.

[†] Patients had either an ECG or cardiac enzyme tests but not both.

^{††} Patients had neither an ECG nor cardiac enzyme tests.

Table 2

Time-dependent Quality Indicators for UA/NSTEMI patients (N=12,544)

Quality Indicator	Definition	Performance Standard	Time: Median (IQR) min	Percent Adherence
1. ECG read out time	Arrival time to ECG read out time	10 min ²⁴⁻²⁶	13 (7 – 32)	42%
2. Lab turn-around-time	Physician biomarker order to lab report time	60 min ^{3, 27, 28}	70 (53 – 96)	37%
3. Therapeutic turn-around-time (overall)	Physician biomarker order to first anti- ischemic medication administration	Not defined	65 (14 – 66)	--
3b. Therapeutic turn-around-time (Anti-platelet)	Physician biomarker order to first anti- platelet medication administration	Not defined	173 (71 – 317)	--
3c. Therapeutic turn-around-time (Anti-thrombin)	Physician biomarker order to first anti- thrombin medication administration	Not defined	30 (14 – 65)	--
4. Boarding time	Disposition decision time to inpatient admit time for admitted patients	Not defined	198 (97 – 496)	--
5. ED length of stay	Arrival time to discharge (disposition decision for inpatients)	Not defined	247 (156 – 392)	--

Table 3

Cox Regression Models for Critical ACS Intervals

Outcome	Variable	Hazard Ratio (95% CI)	Median in Minutes
ECG Readout Time			Baseline = 9.1
	Age: >64	Reference	-
	Age: 24–34	0.89 (0.79, 0.96)	0.8
	Age: 35–44	0.96 (0.89, 1.01)	0.3
	Age: 45–54	0.94 (0.88, 0.99)	0.4
	Age: 55–64	0.96 (0.90, 1.10)	0.3
	Gender: Male	Reference	-
	Gender: Female	0.94 (0.90, 0.98)	0.4
	Language: English	Reference	-
	Language: non English	1.16 (1.10, 1.22)	-0.7
	Mode of Arrival: Walk-in	Reference	-
	Mode of Arrival: Ambulance	0.94 (0.90, 0.99)	0.4
	Mode of Arrival: Missing	1.00 (0.87, 1.12)	-1.1
	Emergency Severity Index (ESI): Level 3–5	Reference	-
	ESI Level 1	1.83 (1.70, 2.10)	-2.4
	ESI Level 2	1.36 (1.31, 1.42)	-1.3
	Chief Complaint: Cardiovascular (CV) with Chest Pain	Reference	-
	Chief Complaint: CV without chest pain	0.58 (0.53, 0.63)	4.8
	Chief Complaint: non CV-related	0.35 (0.30, 0.50)	16.3
	Season: Summer	Reference	-
	Season: Winter	0.95 (0.90, 0.99)	0.3
	Physician Triage*: Yes compared to No	0.95 (0.90, 0.99)	0.3
	Cardiologist in ED*: Yes compared No	1.16 (1.11, 1.20)	-0.7
	ED ACS/Stroke load: Number of chest pain and neurological patients admitted to ED within one hour of patient admission to ED	0.99 (0.98, 1.00)	0.2
	Wait Room Count at Time of Admission	0.99 (0.98, 0.99)	0.4
Biomarker Readout Time			Baseline = 66.3
	Gender: Female	0.91 (0.87, 0.95)	2.5
	Mode of Arrival: Ambulance	1.06 (1.02, 1.10)	-1.3
	Mode of Arrival: Missing	1.22 (1.11, 1.31)	-14.2
	Chief Complaint: CV without chest pain	0.89 (0.84, 0.94)	3.0
	Chief Complaint: Non- CV-related	0.88 (0.83, 0.91)	3.6
	Time of Day: Afternoon	Reference	-
	Time of Day: Evening	0.89 (0.84, 0.94)	3.1
	Time of Day: Night	0.84 (0.77, 0.90)	4.8
	ED Trauma Load	0.95 (0.91, 0.99)	1.4
	Cardiologist in ED*: Yes compared to No	0.74 (0.69, 0.80)	8.0
	Physician Triage*: Yes/No	1.12 (0.08, 1.16)	-2.5

Outcome	Variable	Hazard Ratio (95% CI)	Median in Minutes
Therapeutic TAT	ED Bed Occupancy (%) at Time of Biomarker Test Ordered	0.99 (0.99, 0.99)	2.3
	Point-of-Care Testing: Yes compared to No	1.15 (1.08, 1.22)	-3.1
	ED ACS Lab Load: Number of biomarker tests sent to lab from ED within one hour of order	0.97 (0.95, 0.98)	0.9
			Baseline = 61.7
	Chief Complaint: CV without chest pain	0.73 (0.66, 0.80)	35.3
	Chief Complaint: Non CV-related	0.61 (0.53, 0.68)	64.3
	ED Bed Occupancy (%) at Time of Biomarker Test Ordered	0.99 (0.99, 1.00)	3.8
	Medication received before biomarker test	2.51 (2.31, 2.66)	-17.4
	Stress Test Prior to* Treatment: Yes/No	0.40 (0.20, 0.61)	160.1
	Portable Chest X*-Ray prior to treatment: Yes compared to No	1.23 (1.11, 1.36)	-30.0
ED Boarding Time			Baseline = 218.2
	Year Admitted: 2009	Reference	-
	Year Admitted: 2006	1.07 (0.96, 1.17)	-0.7
	Year Admitted: 2007	1.18 (1.11, 1.29)	-22.7
	Year Admitted: 2008	1.03 (0.94, 1.11)	7.3
	Gender: Female	0.94 (0.88, 0.99)	13.9
	Language: Non English	1.20 (1.11, 1.29)	-33.1
	Insurance: Private	Reference	-
	Insurance: Medicaid	0.80 (0.71, 0.89)	39.9
	Insurance: Medicare	0.88 (0.82, 0.93)	30.3
	Insurance: Self Pay	0.84 (0.74, 0.95)	53.8
	ESI Level 1	3.78 (3.57, 3.99)	-142.1
	ESI Level 2	1.15 (1.07, 1.23)	-25.9
	Day of Week: Weekday	Reference	-
	Day of Week: Weekend	1.37 (1.29, 1.45)	0.0
	Time of Day: Evening	0.97 (0.90, 1.03)	6.9
	Time of Day: Night	0.82 (0.73, 0.92)	45.4
	Holiday: Yes compared to No	1.36 (1.17, 1.56)	-51.3
	ED LOS: Minutes to Disposition Decision	1.00 (1.00, 1.01)	-11.8
	Treatment before Disposition Decision	0.75 (0.66, 0.85)	71.4
	Cath Lab Open: Yes compared to No	0.87 (0.77, 0.97)	17.8
	Telemetry Bed Occupancy (%)	0.31 (0.03, 0.60)	17.9
	CVICU Bed Occupancy (%)	0.65 (0.43, 0.88)	6.3
	Cardiology consult: Yes compared to No	1.37 (1.13, 1.43)	-51.9
	Portable Chest X- Ray*prior to disposition Decision	1.18 (1.13, 1.23)	-30.2
ED LOS			Baseline = 231.3
	Year Admitted: 2009	Reference	-
	Year Admitted: 2006	1.23 (1.11, 1.36)	0.81
	Year Admitted: 2007	1.30 (1.22, 1.38)	-5.1
	Year Admitted: 2008	1.16 (1.12, 1.20)	7.0

Outcome	Variable	Hazard Ratio (95% CI)	Median in Minutes
	Age: 24–34	0.91 (0.82, 0.99)	11.4
	Age: 35–44	0.80 (0.73, 0.86)	26.3
	Age: 45–54	0.80 (0.74, 0.86)	26.0
	Age: 55–64	0.91 (0.86, 0.97)	10.4
	Gender: Female	0.95 (0.91, 0.99)	5.6
	Mode of Arrival: Ambulance	0.92 (0.87, 0.97)	9.9
	Mode of Arrival: Missing	2.12 (2.02, 2.31)	–28.0
	Chief Complaint: CV without chest pain	1.12 (1.06, 1.17)	–10.7
	Chief Complaint: Not CV-related	0.87 (0.81, 0.92)	16.9
	Time of Day: Evening	0.89 (0.86, 0.96)	13.1
	Time of Day: Night	0.94 (0.86, 1.01)	7.4
	Cardiologist in ED*: Yes compared to No	0.97 (0.91, 1.03)	3.3
	Point-of-Care Testing*: Yes compared to No	0.93 (0.82, 1.02)	9.4
	ED ECG Load: Number of ECG performed in ED within one hour of admission	1.02 (1.01, 1.03)	–1.7
	ED ACS/Neuro Load: Number of chest pain and neurological patients admitted to ED within one hour of patient admission to ED	1.01 (1.00, 1.02)	–2.1
	ED OCCUPANCY (%) at ED Admission	0.99 (0.99, 1.00)	0.8
	Admitted to Hospital: Yes compared to No	1.72 (1.68, 1.77)	–50.8
	Anti-platelet. Anti- ischemic, or anti- thrombin therapy provided: Yes/No	0.95 (0.90, 0.99)	6.3
	Stress Test Prior to* Disposition Decision: Yes compared to No	0.35 (0.28, 0.42)	169.7
	Portable Chest X*-Ray before disposition decision	1.16 (1.12, 1.20)	–29.0