FULL LENGTH ARTICLE

A quality improvement project to reduce door-to-electrocardiogram time: A multicenter study

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Objective: **To improve compliance with a target door-to-electrocardiogram (EKG) time of 10 minutes or less in patients presenting with symptoms concerning for acute coronary syndrome.**

Methods: **A pre-post study was performed between January 2014 and May 2016 at five emergency departments (EDs) in Saudi Arabia. Patients who presented to ED with symptoms concerning for acute coronary syndrome were included in the study. The primary outcome of interest was whether EKG was completed within 10 minutes after the patient arrival to ED. Quality improvement interventions consisted of human resources adjustments, education, technological improvements, and improved interdepartmental collaboration. Multivariate analysis was used to model the percentage of EKGs that were completed within the targeted time.**

Results: **During the study period, 11,518 patients received EKGs. Prior to the intervention, compliance with a door-to-EKG time of 10 minutes or less was found to be 62.6%. Post intervention, compliance improved to 87.7%. On multivariate analysis, male patients were significantly more likely to receive EKG within 10 minutes than female patients (odds ratio = 1.231, 95% confidence interval = 1.113–1.361; $p < 0.001$).**

Conclusion: **A quality improvement project can successfully increase the percentage of patients receiving EKG within 10 minutes of presentation to ED. Further research is required to demonstrate the clinical significance of improved door-to-EKG times.**

Keywords: Electrocardiography, Emergency service, Hospital, Quality improvement

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Introduction

Ischemic heart disease is the leading cause of death worldwide, responsible for 14.86% of deaths in 2013 [1]. Early diagnosis is crucial because delays in the restoration of blood flow lead to a greater loss in the heart muscle [2]. The American Heart Association recommends that patients presenting to an emergency department (ED) with chest discomfort or pain should receive an electrocardiogram (EKG) within 10 minutes [3,4]. However, 33% of patients presenting with an acute myocardial infarction (MI) do not present with chest pain, and these patients have worse outcomes [5]. Primary percutaneous coronary intervention and thrombolytic therapy improve clinical outcomes following MI, although percutaneous coronary intervention has a survival benefit compared to thrombolytic therapy [6].

While the benchmark of 10 minutes for door-to-EKG (DTE) time was generated by expert opinion [7], some studies show that faster DTE times lead to reduced time to aspirin, or reduced door-to-balloon (DTB) time, which are crucial steps in the management pathway of acute MI [8–10]. A meta-analysis has revealed that DTB time of less than 90 minutes is associated with reduced in-hospital mortality [11]. The American Heart Association recommends that DTB time of less than 90 minutes is an acceptable management strategy, although they highly emphasize the importance of further minimizing DTB time [12].

Abbreviations

DTE	Door-to-EKG
DTB	Door-to-balloon
QI	Quality improvement
ED	Emergency Department

At our institution, we found that many patients did not receive EKGs within 10 minutes of arrival. Therefore, we believed that it was important to study this issue to develop ways for improving DTE time. Furthermore, DTE time was instituted as a key performance indicator at our institution, thereby providing further incentive and institutional buy-in for improving DTE time.

The primary objective of this study was to increase compliance to DTE time of 10 minutes or less for patients presenting with chest pain or other symptoms concerning for acute coronary syndrome (ACS). Quality improvement (QI) interventions were selected and implemented to achieve this goal. Our secondary objective was to

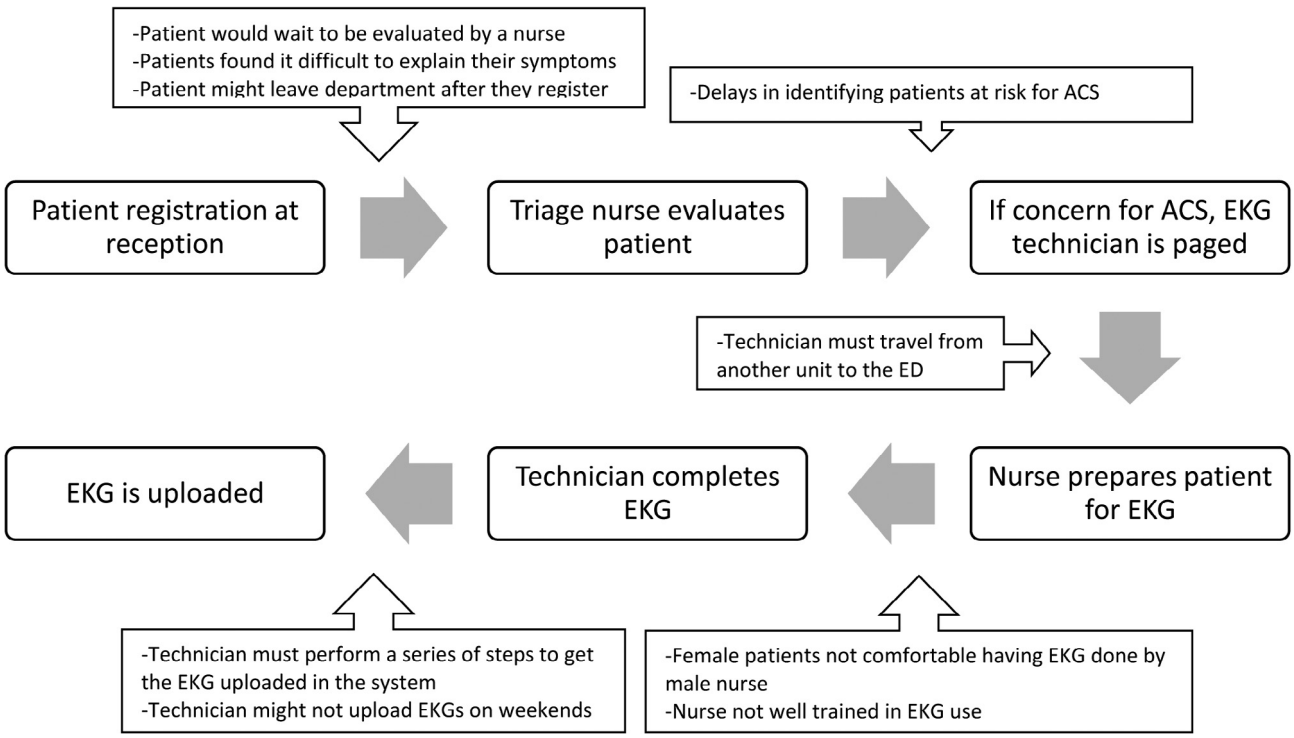

Figure 1. Simplified process map for performing an electrocardiogram with associated barriers prior to intervention. ACS = acute coronary syndrome; ED = emergency department; EKG = electrocardiogram.

identify factors that were associated with increased delays as potential targets for future interventions.

Materials and methods

Study design

This study was approved by the institutional review board at Johns Hopkins Aramco Healthcare and was conducted according to the published guidelines for QI research [13]. This is a pre-post interventional study that compared the time to obtaining an EKG prior to and following the bundle of interventions.

Study setting and population

This study was conducted at five EDs in different cities. These EDs are affiliated with the same private hospital system in Saudi Arabia. These criteria were selected after reviewing the presenting symptoms of patients with MI at our institution.

Interventions

The steps for an EKG to be performed upon initial presentation to the ED at all study locations were examined in detail. An interdisciplinary team generated a process map and brainstormed the barriers that prevent EKGs from being completed in a timely manner (Fig. 1). Based on this initial assessment, a bundle of interventions was selected that would be applicable to all study sites to improve compliance with a DTE time of 10 minutes. The bundle included the following six interventions: (1) improving the patient registration process by having a primary triage nurse at the reception desk, displaying information asking patients to alert the nurse if they have certain symptoms (e.g., chest pain), and installing a bell to alert the nurse if the patient is presenting with symptoms concerning for ACS in EDs without a primary triage nurse; (2) ensuring that a sufficient proportion of the nurses in triage are female; (3) training of triage nurses to expedite EKG if a patient presents with warning signs for ACS and to perform the EKG themselves if the technician does not arrive promptly; (4) training of technicians to rapidly perform EKGs and to optimize the settings on the EKG machines; (5) improving collaboration with the information technology department so that technical issues are resolved promptly; and (6) ensuring that the equipment is properly maintained (e.g., old electrodes are replaced). In addition, technical improvements were made to the system to allow EKGs to be uploaded from each EKG machine to the electronic medical record, which prevents delays in the EKGs becoming available for viewing and improved workflow. These interventions were implemented starting in December, 2014.

Measurements

DTE time was defined as time from registration in the ED until the time that EKG was completed. Registration time at the hospital and EKG completion time were recorded electronically and monitored by the hospital's data management team. If the time from registration to the time of EKG completion was 10 minutes or less, then compliance was demonstrated. If EKG was performed in time but was not uploaded to the hospital system, then non-compliance was reported. Data validation was conducted monthly by the data analytics team and the QI team by reviewing a representative patient sample and ensuring that the reported times were accurate. Due to the high accuracy of the data that was being collected, the data was subsequently validated quarterly instead of monthly. Demographic data, including age and sex, were also recorded along with chief presenting symptom and triage level as measured by the Emergency Severity Index. The Emergency Severity Index is a five-level triage scoring system that is based on patient acuity and the resources needed, with lower scores indicating higher acuity and higher expected resource requirements [14–16].

Outcome measures

The primary outcome for the analysis was percent compliance with DTE cutoff time of 10 minutes. A secondary outcome was the time difference between registration and EKG completion time, or DTE time. If EKG was not uploaded, then the data was identified as missing for the DTE time analysis.

Data analysis

Statistical analysis was performed using STATA version 12 (StataCorp, College Station, Texas, USA). Statistical significance was set at $\alpha \leq 0.05$. Statistical tests, including the Student *t* test, Chi-square test, and Wilcoxon-Mann-Whitney test, were used to compare age, sex, chief presenting symptom, triage category, and presenting ED before and after the intervention. The Chi-square test was used to compare compliance with DTE time of 10 minutes before and after the intervention. The Student *t* test was employed to evaluate the mean DTE time before and after the intervention.

Univariate logistic regression was performed to examine the association between compliance to the 10-minute threshold and several predictor variables, including patient age, sex, month of presentation, chief presenting symptom, triage category, and presenting ED. All predictor variables were included in the multivariate logistic regression analysis model as they were all deemed to be relevant. The model was checked for excessive collinearity and goodness-of-fit.

Results

Characteristics of study patients

During the 29-month study period, EKGs were performed on 11,518 patients presenting with symptoms concerning for MI. Patient characteristics are shown in Table 1. Two patients had missing data on triage level. Overall, the mean age of patients was 56.5 years, 55.1% of patients were male, and the mean Emergency Severity Index was 2.8. Most patients who met the inclusion criteria were from ED 2 (63.5%), followed by ED 3 (15.6%), ED 4 (9.4%), ED 1 (9.1%), and ED 5 (2.5%). Chest pain was the most common presenting symptom (84.2%), followed by abdominal pain (12.6%) and dizziness/weakness (3.2%).

Main results

There was a statistically significant improvement in compliance with DTE time of 10 minutes from 62.6% pre-intervention to 85.7% post-intervention ($p < 0.001$). Table 2 illustrates the proportion of patients who received EKG within 10 minutes before and after the intervention. There was a statistically significant improvement in compliance following the intervention in all categories, except for in patients that were triaged as level 5. While a higher percentage of compliance was achieved among men following the intervention (87.4% vs. 82.4%), compliance improved more for females from the pre-intervention to the post-intervention period (24.3% vs. 21.2%). Following the intervention, compliance was greatest among patients aged 40–65 years (91.3%) and lowest for patients aged >of 65 years (77.1%). All patients that were triaged as level 1 received EKG within 10 minutes compared with only 66.7% prior to the intervention. The worst performing ED (ED 3) experienced the greatest improvement in compliance (22.8% to 72.9%).

Data were presented as mean ± standard deviation. The mean DTE time pre-intervention was 9.0 ± 8.7 minutes, and the mean DTE time post-intervention was 5.6 ± 5.2 minutes ($p < 0.001$). The median time decreased from 6.6 minutes to 4.4 minutes.

Table 1. Baseline characteristics.

Characteristic	Pre-intervention	Post-intervention	*p*
Number	4,268 (37.1)	7,250 (62.9)	—
Age (y)	55.1 ± 18.3	57.4 ± 18.0	0.001*
Male sex	2,336 (54.7)	4,105 (55.4)	0.501**
Chief presenting symptom			0.001**
Chest pain	3,832 (89.8)	5,869 (81.0)	—
Abdominal pain	330 (7.7)	1,122 (15.5)	—
Dizziness/weakness	106 (2.5)	259 (3.6)	—
Triage category			0.5778***
1	12 (0.3)	16 (0.2)	—
2	1,182 (27.7)	1,975 (27.3)	—
3	2,824 (66.2)	4,933 (68.1)	—
4	247 (5.8)	322 (4.4)	—
5	3 (0.1)	2 (0.0)	—
Emergency department			0.001**
1	345 (8.1)	702 (9.7)	—
2	2,699 (63.2)	4,615 (63.7)	—
3	839 (19.7)	956 (13.2)	—
4	290 (6.8)	787 (10.9)	—
5	95 (2.2)	190 (2.6)	—

Data are presented as *n* (%) or mean ± SD.
* Student *t* test.
** Chi-square test.
*** Wilcoxon-Mann-Whitney test.

Table 2. Proportion of patients meeting door-to-electrocardiogram time of less than 10 minutes.

Characteristic	Pre-intervention	Post-intervention	*p*
Overall	2,670 (62.6)	6,174 (85.2)	0.001
Age (y)			
18–39	562 (65.7)	1,087 (87.2)	0.001
40–64	1,429 (71.2)	2,945 (91.3)	0.001
>65	679 (48.3)	2,142 (77.1)	0.001
Sex			
Male	1,547 (66.2)	3,509 (87.4)	0.001
Female	1,123 (58.1)	2,665 (82.4)	0.001
Chief presenting symptom			
Chest pain	2,562 (66.9)	5,311 (90.5)	0.001
Abdominal pain	56 (17.0)	700 (62.4)	0.001
Dizziness/weakness	52 (49.1)	163 (62.9)	0.014
Triage category			
1	8 (66.7)	16 (100.0)	0.013
2	702 (59.4)	1,649 (83.5)	0.001
3	1,846 (65.4)	4,282 (86.8)	0.001
4	113 (45.8)	227 (70.5)	0.001
5	1 (33.3)	0 (0.0)	0.361
Emergency department			
1	206 (59.7)	626 (89.2)	0.001
2	2,040 (75.6)	3,997 (86.6)	0.001
3	191 (22.8)	697 (72.9)	0.001
4	171 (59.0)	676 (85.9)	0.001
5	62 (65.3)	178 (93.7)	0.001

Data are presented as *n* (%).

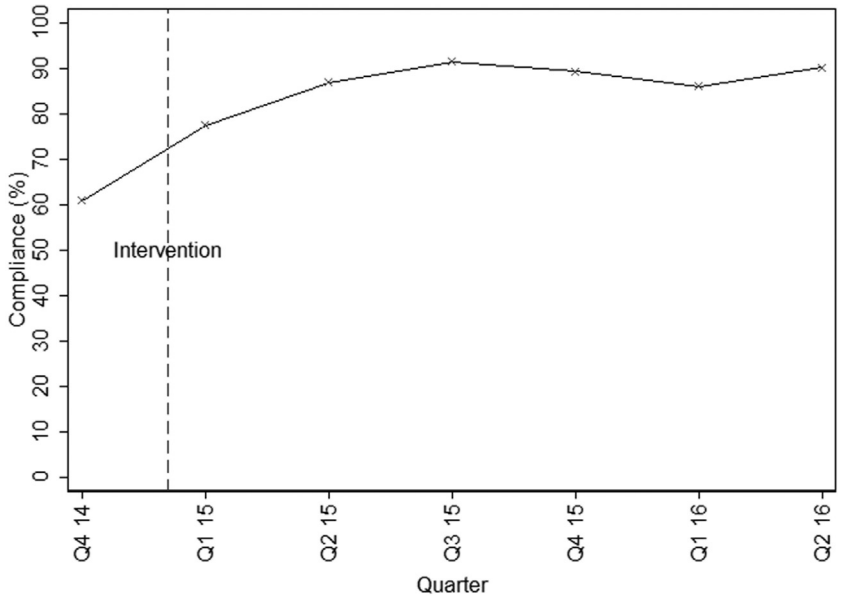

Figure 2. The evolution of the proportion of patients receiving an electrocardiogram within 10 minutes over the study period.

Fig. 2 illustrates the improvement in compliance that occurred over the study period. Compliance improved rapidly at first, reaching a peak of 90% in quarter 3 of 2015, which was subsequently followed by a plateau.

Univariate and multivariate analyses results are presented in Table 3. On multivariate analysis, we found that the odds of compliance being achieved increased over time. The odds of compliance were lower in the older patients and female patients.

Table 3. Univariate and multivariate analysis of compliance with a door-to-electrocardiogram target time of 10 minutes.

Characteristic	Univariate analysis (n = 11,518)		Multivariate analysis (n = 11,516)	
	OR (95% CI)	p	OR (95% CI)	p
Age (y)	0.985 (0.983–0.987)	0.001	0.995 (0.992–0.998)	0.003
Male sex	1.421 (1.303–1.550)	0.001	1.231 (1.113–1.361)	0.001
Month	1.088 (1.082–1.095)	0.001	1.114 (1.106–1.122)	0.001
Chief presenting symptom				
Chest pain	Ref	—	Ref	—
Abdominal pain	3.965 (3.535–4.448)	0.001	5.712 (4.880–6.686)	0.001
Dizziness/weakness	1.320 (1.046–1.665)	0.019	0.806 (0.597–1.087)	0.158
Triage category				
1	Ref	—	Ref	—
2	0.486 (0.168–1.405)	0.183	1.293 (0.395–4.227)	0.671
3	0.627 (0.217–1.810)	0.388	0.861 (0.265–2.805)	0.804
4	0.247 (0.085–0.723)	0.011	0.345 (0.104–1.141)	0.081
5	0.042 (0.004–0.475)	0.010	0.029 (0.002–0.394)	0.008
Emergency department				
1	0.819 (0.696–0.962)	0.015	0.841 (0.704–1.006)	0.058
2	Ref	—	Ref	—
3	0.207 (0.185–0.231)	0.001	0.170 (0.148–0.197)	0.001
4	0.779 (0.665–0.912)	0.002	0.641 (0.538–0.763)	0.001
5	1.128 (0.816–1.560)	0.466	0.773 (0.542–1.103)	0.155

*Hosmer–Lemenshow test: $p < 0.001$.
Data are presented as n (%).
CI = confidence interval; OR = odds ratio; Ref = Reference.

Compliance was greater in patients presenting with abdominal pain than in those presenting with chest pain. A triage level score of 5 was associated with significantly lower odds of compliance than a triage score of 1. Additionally, compliance was significantly worse in ED 3 and ED 4 than in the primary ED (ED 2).

Discussion

Following the intervention, compliance with DTE time of ≤10 minutes significantly improved. Prior to the intervention, compliance was 62.6%, which increased to 87.7% after the intervention. Similarly, the median DTE time was significantly reduced from 6.6 minutes to 4.4 minutes. This compares favorably to median DTE times that have been reported in the literature [8,9].

Several other studies have examined the issue of DTE time [9,17,18]. However, these studies were all conducted in the United States, and as such, it was not evident that their results were generalizable to Saudi Arabia. For example, in our study population, we found it much more difficult to obtain EKGs in a timely manner in female patients due to privacy concerns. We addressed this by ensuring that adequate numbers of female staff members were present in the triage area. In addition, we often found it difficult to track down patients after they checked in at the triage desk because they would leave to smoke tobacco. This was countered by instructing patients in need of an EKG not to leave prior to receiving their EKG.

Our study demonstrated sustained improvements because of interventions to improve DTE time. We achieved a 25.1% point increase in compliance in the months that followed the intervention. Purim-Shev-Tom et al. [17] in 2007 demonstrated that having an ED greeter resulted in a significant reduction in DTE time over a period of 3 weeks, although it is unclear whether this improvement was sustained in the long term. Ballard et al. [19] demonstrated small reductions in DTE time following a nursing education intervention; however, the reductions were not statistically significant.

In our study, we did not measure clinical outcomes; therefore, we cannot report that improvements in DTE time resulted in better clinical outcomes for patients. However, it has been shown that faster DTE times can result in substantially faster DTB times [8,9], which reportedly result in better patient outcomes [11]. Additionally, the American Heart Association recommends DTE time of less than 10 minutes because delays in restoration of blood flow leads to a greater loss in the heart muscle.

Our results also suggest several trends that may shed some important insights for clinical practice. The older patients took longer to receive their EKG potentially because they tend to be less agile. Male patients had 1.23 times higher odds of

receiving their EKG within 10 minutes than female patients. To date, the literature has been unclear as to whether women receive EKGs in the ED significantly slower than men [20]. Our study provides definitive evidence that, in our study population, after controlling for confounding factors, female patients received EKGs slower than male patients. Reasons for this could be that women need extra privacy when EKG is performed or that they need permission from their husbands before the EKG is performed, which may take extra time. However, our intervention of assigning more female nurses to triage appears to have been successful in reducing the difference. The odds of compliance being achieved were 5.7 times higher for patients presenting with abdominal pain than for those presenting with chest pain on multivariate analysis. Part of the intervention was increasing awareness of atypical presentations of MIs; however, the reason for higher compliance with abdominal pain than with chest pain is unknown. Patients presenting with an Emergency Severity Index of 5 had lower odds of receiving EKG within 10 minutes possibly because staff members tend to react quicker when the patient appears to be more sick.

All the EDs (except for one) reached compliance above 85% following the intervention. The one department that was struggling the most had a higher patient load for its size and had recently relocated to a new building; however, despite these barriers, it achieved substantial improvement in compliance. In the other four EDs, compliance rates plateaued at around 90% compliance. We believe that the main reasons for this are patient-related. For example, a patient may register in the ED and then leave the department for various reasons, such as to smoke, pray, eat, or go to the bathroom. As such, we suggest that setting a target of 90% compliance is reasonable and achievable, but higher rates of compliance may not be feasible.

Some of the key factors that contributed to the success of the project included establishing a multidisciplinary team and walking the processes with all five ED teams, which helped to identify specific issues pertinent to each unit. By applying a structured problem-solving, team-based approach, the QI team utilized Lean Six Sigma methodologies to identify, define, and delineate factors contributing to the issue. Education on the management of the ACS patients, improved technical support, enhanced interdisciplinary teamwork, and standardization of the EKG clinical process also played pivotal roles. Finally, departmental buy-in was critical to the sustainability of the project, allowing most of the responsibility for the project to be transitioned from the QI department to the individual EDs.

One of the main challenges of the project was working with five different EDs that were geographically separated and had distinct procedures in place for triaging patients. In addition, larger departments tended to have greater technical support from information technology and had more technicians that could assist than the smaller departments. This meant that delays were more common and that the nurses were required to assume more of the responsibility in some of the smaller departments.

A primary limitation of our study was that we were not able to determine which patients were diagnosed with ST-segment elevation myocardial infarction (STEMI) due to insufficient resources. Additionally, the relationship between DTE time and other outcomes, such as time to supportive treatment, time to definitive treatment (percutaneous coronary intervention), or incidence of complications or mortality in patients diagnosed with STEMI could not be evaluated due to insufficient resources. For instance, the mean DTB time at our institution was found to be 55 minutes; however, we could not determine if DTB time was faster in patients who received their EKG in a shorter time.

Second, the study was performed within the context of a single health system, which limits the generalizability of our study. Furthermore, most of the patients in our study were from a single ED. Third, we did not measure the time from symptom onset, which others have suggested is more important than measuring the time from presentation to ED [21].

Another important area for improvement is the time that is taken from onset of symptoms to patient arrival at ED. In our study population, education was lacking regarding the importance of rapidly presenting to the hospital after the onset of chest pain. There remains a huge need to increase public awareness about the dangers of and adequate response to chest pain.

Conclusion

Overall, we found that a QI project with a target DTE time of less than 10 minutes was successful in improving compliance to close to 90% and that these gains were sustainable. Patient factors that influenced the compliance with DTE time of 10 minutes were age, sex, presenting symptom, and

triage category. An area for further study would include demonstrating clinical significance of improving DTE time.

Conflicts of interest

The authors have no conflicts of interest.

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