



Access this article online

Quick Response Code:



Website:

www.turkjemergmed.org

DOI:

10.4103/2452-2473.276380

The effect of prehospital telecardiology on the mortality and morbidity of ST-segment elevated myocardial infarction patients undergoing primary percutaneous coronary intervention: A cross-sectional study

Peyman Saberian^{1,2}, Nader Tavakoli³, Parisa Hasani-Sharamin⁴,
Seyed Hashem Sezavar⁵, Fatemeh Dadashi⁴, Elnaz Vahidi^{1,6*}

¹Prehospital and Hospital Emergency Research Center, Tehran University of Medical Sciences, ²Department of Anesthesiology, Imam Khomeini Hospital Complex, Tehran University of Medical Sciences, ³Trauma and Injury Research Center, Iran University of Medical Sciences, ⁴Tehran Emergency Medical Service Center, ⁵Research Center for Prevention of Cardiovascular Disease, Institute of Endocrinology and Metabolism, Iran University of Medical Sciences, ⁶Department of Emergency Medicine, Shariati Hospital, Tehran University of Medical Sciences, Tehran, Iran

Received: 03-10-2019

Accepted: 03-11-2019

Published: 28-01-2020

ORCID:

0000-0003-1445-2756

0000-0002-5767-7771

0000-0003-2942-5275

0000-0003-3365-5129

0000-0001-6142-2328

0000-0002-4580-1456

Address for
correspondence:

Dr. Elnaz Vahidi,

Department of

Emergency Medicine,

Emergency Medicine

Research Center,

Shariati Hospital, Tehran

University of Medical

Sciences, Tehran, Iran.

E-mail: evahidi62@yahoo.

com

Abstract:

OBJECTIVES: The sooner the primary percutaneous coronary intervention (PPCI) is performed, the better prognosis is expected in patients with acute myocardial infarction. The objective is to evaluate the effect of prehospital triage based on electrocardiogram (ECG) and telecardiology on the mortality and morbidity of ST-segment elevated myocardial infarction (STEMI) patients undergoing PPCI.

METHODS: This cross-sectional study was conducted based on the data extracted from the hospital information system (HIS) of one general hospital, which had the capability of performing PPCI 24 h a day, 7 days a week. All patients with STEMI who undergone PPCI during 1 year, transferred by emergency medical service (EMS) and their data were registered in the HIS were eligible. Besides the baseline characteristics, first medical contact (FMC)-to-balloon time was recorded. Morbidity based on predischage left ventricular ejection fraction (LVEF) and mortality based on Global Registry of Acute Cardiac Events (GRACE) score were also recorded. Patients who were referred to the hospital by EMS with prehospital ECG and telecardiology were compared with those without prehospital ECG.

RESULTS: Totally, 298 patients with STEMI were enrolled, of whom 183 patients (61.4%) had prehospital ECG (telecardiology), and 115 patients (38.6%) had not. The means of predischage LVEF of the patients in the first and the second groups were 40.7 ± 10.4 and 40.6 ± 11.2 , respectively ($P = 0.946$). The mean of the probability of 6-month mortality based on GRACE score in the first group was significantly less than that of the second group ($P = 0.004$). Analyses of multivariable ordinal logistic regression showed that 6-month mortality severity risk in the second group was 1.5 times more than the first group (95% confidence interval 0.8–2.6), although this difference was not statistically significant ($P = 0.199$).

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

How to cite this article: Saberian P, Tavakoli N, Hasani-Sharamin P, Sezavar SH, Dadashi F, Vahidi E. The effect of prehospital telecardiology on the mortality and morbidity of ST-segment elevated myocardial infarction patients undergoing primary percutaneous coronary intervention: A cross-sectional study. Turk J Emerg Med 2020;20:28-34.

For reprints contact: reprints@medknow.com

CONCLUSIONS: It is likely that prehospital telecardiology, with shortening FMC to balloon time result in reducing probability 6-month mortality in STEMI patients who undergone PPCI. However, the process of telecardiology had no effect on predischarge LVEF in the current study.

Keywords:

Mortality, percutaneous coronary intervention, prehospital emergency services, ST elevation myocardial infarction, telemedicine

Introduction

Coronary reperfusion therapy through primary percutaneous coronary intervention (PPCI) is nowadays the standard treatment in patients with ST-segment elevation myocardial infarction (STEMI).^[1] Most recent guidelines have recommended that PCI should be best performed within 90 min of patients' arrival at hospitals (door-to-balloon time <90 min).^[2] The European Society of Cardiology (ESC) latest guideline (2017) defines new target times such as a "time to diagnosis to wire crossing," and it is recommended to be <120 min.^[1]

The importance of prompt recognition of STEMI and early definite intervention has been studied and confirmed in many studies both in preserving cardiac function and improving mortality. It has been showed that every 30-min delay in PCI will, unfortunately, increase 1-year mortality by 7.5%. Evidence also shows that early PCI is related to less mortality and morbidity, less re-infarction, and less intracranial hemorrhage compared to thrombolytic therapy.^[3-7]

Unfortunately, not all hospitals have the capability of performing PCI 24 h a day, 7 days a week and the process of transferring patients to other centers, can cause delay in reperfusion.^[4] Hence, prehospital phase has a critical role in decreasing the delay of reperfusion from the time of the first contact to emergency medical service (EMS) and also in STEMI recognition.^[8] Thus, it seems necessary to design and execute protocols related to faster patients' transfer by EMS to centers with 24 h active PCI and promote the prehospital service to take electrocardiogram (ECG) and report it. Recording 12-lead ECG by EMS in STEMI is one of the class I recommendations of American College of Cardiology Foundation, American Heart Association Task Force, and ESC.^[1,2,9] Applying this recommendation leads to faster transfer of patients to a PCI capable center and less mortality.^[10] Different strategies have been held in different countries to report ECG.^[11-13] Some are based on ECG machine reporting, some are reported by EMS paramedics, and some are done by cardiologists.^[14,15] The first two reporting systems are useful yet, weak in best decision-making choice.^[16] Most guidelines nowadays emphasized the necessity of ECG reviewing and confirmation by a physician.^[17] They concluded that

this strategy makes the time of life-saving reperfusion shorter.^[1]

The protocol of performing 24-h PCI has been developed by the ministry of health in most central hospitals in Iran since 2015. This protocol has been held across the country with the aim of decreasing door-to-balloon time to <90 min. This study decided to evaluate the mortality and morbidity rates of STEMI patients undergoing PPCI who had prehospital ECG and transferred by EMS following telecardiology comparing to those without prehospital ECG. This study was designed to investigate whether there was any significant effect on the mortality and morbidity of these populations by applying telecardiology.

Methods

Study design

This was a cross-sectional study approved by the Ethics Committee of Iran University of Medical Sciences. We selected our cases from six general hospitals in Tehran, which had the official announcement of performing primary PCI 24 h a day, 7 days a week. We extracted our patients' data from files and information registered in a hospital information system (HIS). We enrolled our cases since March 21, 2017–April 20, 2018. All information was used unnamed, and therefore, the confidentiality of information was respected.

Study population

All patients who were referred to the mentioned hospital by EMS and undergone PPCI were eligible. Patients referred from other hospitals, patients with the time of symptom onset longer than 12 h before PCI, patients with undetermined time of symptom onset or PCI, STEMI disapproval of cardiologists, misdiagnosis of STEMI, cases with out of hospital cardiac arrest, and patients whose data were registered incorrectly or incompletely in HIS were excluded from the study.

After reviewing their prehospital and hospital records, they were divided into two groups. Group A include patients whose ECG was taken by EMS and sent to a cardiologist. After the cardiologist's confirmation of STEMI, the emergency department (ED) was bypassed and the patient was directly transferred to

the catheterization laboratory. Group B include patients who did not have prehospital ECG and were routinely referred to the ED where they were diagnosed with STEMI and then sent to the catheterization laboratory. Patients were happened to be in either group and we did not select them to be in which group. We mentioned this limitation in the specified section.

Data gathering

Patients' data were recorded in predesigned checklists containing three main parts: the first part consisted of demographic data and baseline characteristics of the patients. Times, including symptom onset, first medical contact (FMC), and first ECG taken whether in an ambulance or at the hospital, arrival at catheterization laboratory, admission at hospital, STEMI diagnosis, and PCI performance, were recorded in the second part. The third part included ultimate outcomes, including in-hospital mortality and 6-month mortality by the Global Registry of Acute Cardiac Events (GRACE) score^[18] and morbidity based on the left ventricular ejection fraction (LVEF) on discharge from the hospital.

Statistical analysis

We presented frequency, percentage, mean \pm standard deviation, and median with inter-quartile range (IQR) (quartile 1 [Q1] to quartile 3 [Q3]). The Chi-square and Fisher's exact tests were used to compare the proportions of qualitative variables. We checked normality with the Kolmogorov-Smirnov test. We used independent *t*-test and Mann-Whitney U test to compare the numeric variables in the two groups. Furthermore, we omitted the confounding factor of some variables (age and sex) with ANCOVA analysis to compare the mean of GRACE score in two study groups.

We used univariable and multivariable ordinal logistic regression model for assessing the predictive factor of the probability of 6-month mortality based on GRACE score. The level of statistical significance was 0.05. Data were analyzed using the SPSS version 22 software IBM corp., USA.

Results

In this study, all patients underwent PCI. Fifty-six cases had STEMI, but they had no severe coronary artery narrowing or they had normal arteries in PCI. Cardiologist did not approve STEMI in 49 cases based on prehospital ECG. All these cases were excluded from our study. Finally, 298 patients with STEMI diagnosis were enrolled and analyzed; of whom, 183 cases (61.4%) were referred by EMS, and they had prehospital ECG and telecardiology (Group A), while 115 cases (38.6%) were referred either by EMS, but they did not have any prehospital ECG (Group B). The mean age of the patients

in Groups A and B was 58.2 ± 11.8 and 60.2 ± 12.6 years, respectively ($P = 0.172$). Comparison of patients' demographic data and their underlying diseases is shown in Table 1. Eleven patients (6.0%) in Group A and 5 patients in Group B (4.3%) deceased, but this difference was not statistically significant ($P = 0.535$).

In Groups A and B, we evaluated 169 and 111 patients, respectively, for GRACE score. We could not calculate GRACE score in 14 cases in Group A and in 4 cases in Group B because their data in their medical records were not enough. The mean of GRACE score in Group A (101.6 ± 26.8) was significantly less than that of Group B (111.6 ± 29.6) ($P = 0.004$). The mean of GRACE score in females was significantly more than males (118.4 ± 24.8 vs. 102.8 ± 28.3) ($P < 0.001$). Furthermore, the correlation of age and GRACE score was statistically significant ($r = 0.848$) ($P < 0.001$). Hence, after controlling for age and sex, as covariates, the result of analysis of variance of GRACE score mean in Group A was significantly less than that of Group B ($P = 0.027$).

Distribution of probability of 6-month mortality (GRACE score) is also shown in Table 1. Probability of 6-month mortality with overall intermediate and high risks in Groups A and B was 64.9% and 75.0%. Although 6-month mortality with high-risk score in Group B was more prevalent than in Group A (36.6% vs. 26.9%), no statistically significant difference was observed ($P = 0.117$).

Ordinal regression model showed that probability of

Table 1: Demographic data, comorbidities, and comparison of probability of 6-month mortality based on global registry of acute coronary events score in two groups

Variable	Group A, n (%)	Group B, n (%)	P
Gender			
Male	156 (85.2)	90 (78.3)	0.158
Female	27 (14.8)	25 (21.7)	
Past medical history			
Congestive heart failure	3 (1.6)	5 (4.3)	0.268
Coronary artery disease	2 (1.1)	2 (1.7)	0.641
Ischemic heart disease	32 (17.5)	26 (22.6)	0.295
Diabetes mellitus	34 (18.6)	34 (29.6)	0.033
Hyperlipidemia	26 (14.2)	17 (14.8)	0.891
Chronic kidney disease	3 (1.6)	7 (6.1)	0.049
Cerebrovascular disease	0 (0.0)	1 (0.9)	0.386
Hypertension	66 (36.1)	46 (40.0)	0.540
Chronic pulmonary disease	8 (4.4)	4 (3.5)	0.772
GRACE score level			
Low (<88)	58 (34.3)	31 (28.0)	0.117
Intermediate (89-118)	66 (39.0)	41 (36.9)	
High (>118)	45 (26.7)	39 (35.1)	

Group A=With prehospital ECG taken by EMS, Group B=Without prehospital ECG (control group). GRACE=Global Registry of Acute Coronary Events, ECG=Electrocardiogram, EMS=Emergency medical service

6-month mortality severity risk in Group B was 1.6 times more than that of Group A (95% confidence interval 1.0–2.5) ($P = 0.039$), but adjusted odds ratio was not statistically significant ($P = 0.199$) [Table 2]. The type of transferring patients to the hospital (whether by EMS or not) is actually one of the involving factors in mortality. However, as it is shown, the role of this factor is not that much significant alone.

The mean of on-discharge LVEF was 40.7 ± 10.4 in Group A and 40.6 ± 11.2 in Group B. This factor of morbidity showed no statistically significant difference between the two groups ($P = 0.903$).

The studied median times within the two groups are shown in Table 3. The median time of hospital arrival to PCI and also the median time of FMC to PCI showed statistically significant differences between the two groups.

Table 4 shows the relationship between all studied median times within the two groups in GRACE score level strata. All probability of 6-month mortality strata showed that the median times in Group A were lower than that of Group B. This difference was statistically significant for door-to-balloon time (min)

in intermediate (15.0 [IQR: 14.0–25.0] vs. 46.5 [IQR: 15.0–68.8] [$P = 0.001$]) and high (15.0 [IQR: 10.0–25.0] vs. 42.5 [IQR: 20.8–69.5] [$P = 0.001$]) mortality probability of 6 months. The median of FMC-to-balloon time (min) in Group A was significantly lower than that of Group B in intermediate (59.0 [IQR: 48.0–75.8] vs. 79.0 [IQR: 61.0–105.0] [$P = 0.001$]) and high (64.0 [IQR: 46.0–83.0] vs. 91.0 [IQR: 60.8–120.3] [$P = 0.002$]) mortality probability of 6 months. Furthermore, door-to-balloon and FMC-to-balloon times in low probability of 6-month mortality strata were lower in Group A, yet not statistically significant ($P = 0.056$ and 0.066 , respectively).

Discussion

In this study, mortality and morbidity of STEMI patients underwent PPCI following prehospital telecardiology compared to those without telecardiology. It was found that the probability of 6-month mortality in those patients referred following telecardiology was significantly lower than those managed without prehospital telecardiology. However, in-hospital mortality rate itself and predischage LVEF showed no significant difference between the two groups. We observed that

Table 2: Ordinal logistic regression of three severity level of global registry of acute coronary events score in probability of 6-month mortality risk adjusted for age, sex, and type of transferring

	Univariable		Multivariable	
	Crude OR (95% CI)	P	Adjusted OR (95% CI)	P
Age (years)	1.3 (1.2-1.4)	<0.001	1.3 (1.2-1.4)	<0.001
Sex; female	3.4 (1.9-6.1)	<0.001	0.88 (0.41-1.9)	0.756
Type of transferring; Group B	1.6 (1.0-2.5)	0.039	1.5 (0.82-2.6)	0.199

Type of transferring=Group A with prehospital ECG taken by EMS and Group B without prehospital ECG (control group). OR=Odds ratio; CI=Confidence interval

Table 3: Comparison of the median times (interquartile range) between the two groups

Time interval (min)	Group A	Group B	P
Symptom onset-to-balloon	150.0 (95.0-236.3)	165.0 (129.0-267.5)	0.946
Door-to-balloon	18.5 (13.5-30.0)	42.5 (19.3-68.0)	<0.001
First medical contact-to-balloon	58.0 (45.3-75.8)	79.0 (55.0-110.0)	<0.001

Group A=With prehospital ECG taken by EMS, Group B=Without prehospital ECG (control group). IQR=Interquartile range, Q1=Quartile 1, Q3=Quartile 3, ECG=Electrocardiogram, EMS=Emergency medical service

Table 4: Relationship of median times (interquartile range) studied with different strata of the global registry of acute coronary events score

Time intervals (min)	GRACE score	Group A	Group B	P
Symptom onset-to-balloon	Low	150.0 (105.0-210.0)	150.0 (99.5-200.0)	0.853
	Intermediate	150.0 (85.0-240.0)	170.0 (140.0-270.0)	0.325
	High	150.0 (92.5-260.0)	177.5 (123.8-345.0)	0.487
Door-to-balloon	Low	20.0 (14.0-35.0)	35.5 (15.0-72.8)	0.056
	Intermediate	15.0 (14.0-25.0)	46.5 (15.0-68.8)	0.001
	High	15.0 (10.0-25.0)	42.5 (20.8-69.5)	<0.001
First medical contact-to-balloon	Low	56.0 (45.0-72.0)	72.5 (47.3-111.8)	0.066
	Intermediate	59.0 (48.0-75.8)	79.0 (61.0-105.0)	0.001
	High	64.0 (46.0-83.0)	91.0 (60.8-120.3)	0.002

Group A=With prehospital ECG taken by EMS, Group B=Without prehospital ECG (control group). IQR=Interquartile range, Q1=Quartile 1, Q3=Quartile 3, ECG=Electrocardiogram, EMS=Emergency medical service, GRACE=Global Registry of Acute Coronary Events

in-hospital mortality was fewer in Group B than that of Group A (6% vs. 4.3%). As mentioned, there was no statistical difference; however, this difference should be considered very important in clinical situations. This might be due to a small sample size and single-center study.

Bagai *et al.* studied 12581 patients with STEMI and they reported that just 10.5% of the cases had prehospital ECG and undergone PPCI. They found that the patients who bypassed ED were faster referred for PCI and had lower heart failure and mortality.^[19]

Even in the study by Kahlon *et al.*, most of the studied patients (63.4%) had not undergone prehospital ECG.^[20] However, in the current study, the rate of conducted telecardiology was more than 60% that could be considered as a valuable index in terms of STEMI patients' management. However, in contrast with the result of Bagai *et al.*, we cannot find any significant effect on heart failure rate, while we just assessed the predischage LVEF.

The time intervals, including symptom onset-to-balloon and also FMC-to-balloon, in those referred following prehospital telecardiology, were significantly less than the other groups. In comparison with the results of Saberian *et al.*, in which FMC-to-device in those with telecardiology and without telecardiology were 110 and 120 min, respectively, in the current study, this time interval was 58 and 79 in those with and without telecardiology in turn.^[8] It is a respectful progress in terms of decreasing delay for conducting PPCI which was seen in almost same study population.

Quinn *et al.* evaluated 288,990 patients with the diagnosis of STEMI between 2005 and 2009 and found that cases with prehospital ECG had a significantly lower 30-day mortality rate (8.6%).^[21] In the current survey, although mortality rate was not differed in two studied groups, but probability of 6-month mortality was significantly lower in telecardiology patients than those who had not prehospital telecardiology.

The benefits of implementation of prehospital ECG in patients suspected of having STEMI have been elucidated in different studies. It has been reported that prehospital ECG could reduce an approximately 10 min in door-to-drug time and 15–20 min in door-to-balloon time; thus, it could lead to less mortality and morbidity and treatment reduced delay for performing PPCI and adjusted 1-year mortality in them.^[22-27] Afolabi *et al.* evaluated 167 patients with STEMI and found that 78% of the cases met the recommended door-to-balloon time <90 min. They also reported that patients who had a higher mortality rate were presented during the off-hours.^[28]

All in all, same as the previous studies declared, by performing prehospital ECG and applying telecardiology patients' management and mortality in STEMI patients could be improved.

Limitations

In the current study, in terms of morbidity, we just calculated the data regarding predischage LVEF, and the data of postdischarge follow-up were not considered. Therefore, the comparison of data regarding morbidity in the current study with previous ones should be performed with caution. It was a single-center uncontrolled study design. Prehospital personnel might not diagnose STEMI in some atypical cases. In our region, EMS takes ECG from all suspected cases of STEMI. The model and type of transferring patients to the hospital are actually one of the involving factors in mortality. However, as we mentioned the role of this factor is not that much significant alone. We did not choose our patients to be in which group, they happened to be in either group.

We did not evaluate other risk factors such as the size of infarcted area, the numbers of ECG derivation, and odds of patients who underwent surgery. Further studies considering multiple variables involved in mortality are recommended. All suspected cases who were referred by EMS in our region should have ECG taken from them, but different issues such as ECG machine malfunction, inappropriate Internet connection, difficulties in sending ECG for cardiologist, and sometimes atypical presentations of acute coronary syndrome can lead to misdiagnosis. For this reason, some of our patients had to be first admitted in the ED and then be referred to PCI ward.

Conclusions

It is likely that prehospital telecardiology, with shortening FMC-to-balloon time result in reducing probability 6-month mortality in STEMI patients who undergone PPCI. We observed fewer mortality rate in Group B, although this difference was not statistically significant. The process of telecardiology had no effect on predischage LVEF in the current study.

Acknowledgments

We would like to express our obligations to the prehospital and hospital emergency research center affiliated to the Tehran University of Medical Sciences.

Author contribution statement

PS: concepts, design, definition of intellectual content NT: clinical studies, experimental studies, data acquisition PH-S: definition of intellectual content, literature search, clinical studies SHS: data analysis, statistical analysis, data acquisition FD: manuscript editing, and manuscript review, data acquisition EV: data analysis, statistical analysis, manuscript preparation, manuscript editing, and manuscript review

Funding

This study was financially supported by a grant received from Tehran EMS Center.

Conflicts of interest

None.

References

- Ibanez B, James S, Agewall S, Antunes MJ, Bucciarelli-Ducci C, Bueno H, et al. 2017 ESC guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation: The task force for the management of acute myocardial infarction in patients presenting with ST-segment elevation of the European Society of Cardiology (ESC). *Eur Heart J* 2018;39:119-77.
- O'Gara PT, Kushner FG, Ascheim DD, Casey DE Jr., Chung MK, de Lemos JA, et al. 2013 ACCF/AHA guideline for the management of ST-elevation myocardial infarction: Executive summary: A report of the American College of Cardiology Foundation/American Heart Association task force on practice guidelines: Developed in collaboration with the American College of Emergency Physicians and Society for Cardiovascular Angiography and Interventions. *Catheter Cardiovasc Interv* 2013;82:E1-27.
- De Luca G, Suryapranata H, Ottervanger JP, Antman EM. Time delay to treatment and mortality in primary angioplasty for acute myocardial infarction: Every minute of delay counts. *Circulation* 2004;109:1223-5.
- Boersma E; Primary Coronary Angioplasty vs. Thrombolysis Group. Does time matter? A pooled analysis of randomized clinical trials comparing primary percutaneous coronary intervention and in-hospital fibrinolysis in acute myocardial infarction patients. *Eur Heart J* 2006;27:779-88.
- Arhami Dolatabadi A, Kashani P, Hatamabadi H, Baratloo A. Using risk factors to help in the diagnosis of acute myocardial infarction in patients with non-diagnostic electrocardiogram changes in emergency department. *J Emerg Pract Trauma* 2015;1:3-6.
- Nallamotheu B, Fox KA, Kennelly BM, Van de Werf F, Gore JM, Steg PG, et al. Relationship of treatment delays and mortality in patients undergoing fibrinolysis and primary percutaneous coronary intervention. The global registry of acute coronary events. *Heart* 2007;93:1552-5.
- McNamara RL, Wang Y, Herrin J, Curtis JP, Bradley EH, Magid DJ, et al. Effect of door-to-balloon time on mortality in patients with ST-segment elevation myocardial infarction. *J Am Coll Cardiol* 2006;47:2180-6.
- Saberian P, Tavakoli N, Ramim T, Hasani-Sharamin P, Shams E, Baratloo A, et al. The role of pre-hospital telecardiology in reducing the coronary reperfusion time; a brief report. *Arch Acad Emerg Med* 2019;7:e15.
- Welsh RC, Travers A, Huynh T, Cantor WJ; Canadian Cardiovascular Society Working Group. Canadian Cardiovascular Society Working Group: Providing a perspective on the 2007 focused update of the American College of Cardiology and American Heart Association 2004 guidelines for the management of ST elevation myocardial infarction. *Can J Cardiol* 2009;25:25-32.
- Le May MR, Wells GA, So DY, Glover CA, Froeschl M, Maloney J, et al. Reduction in mortality as a result of direct transport from the field to a receiving center for primary percutaneous coronary intervention. *J Am Coll Cardiol* 2012;60:1223-30.
- Bradley EH, Herrin J, Wang Y, Barton BA, Webster TR, Mattern JA, et al. Strategies for reducing the door-to-balloon time in acute myocardial infarction. *N Engl J Med* 2006;355:2308-20.
- Welsh RC, Armstrong PW. It's a matter of time: Contemporary pre-hospital management of acute ST elevation myocardial infarction. *Heart* 2005;91:1524-6.
- Giugliano RP, Braunwald E; TIMI Study Group. Selecting the best reperfusion strategy in ST-elevation myocardial infarction: It's all a matter of time. *Circulation* 2003;108:2828-30.
- Youngquist ST, Kaji AH, Lipsky AM, Koenig WJ, Niemann JT. A bayesian sensitivity analysis of out-of-hospital 12-lead electrocardiograms: Implications for regionalization of cardiac care. *Acad Emerg Med* 2007;14:1165-71.
- Brown JP, Mahmud E, Dunford JV, Ben-Yehuda O. Effect of prehospital 12-lead electrocardiogram on activation of the cardiac catheterization laboratory and door-to-balloon time in ST-segment elevation acute myocardial infarction. *Am J Cardiol* 2008;101:158-61.
- Camp-Rogers T, Dante S, Kontos MC, Roberts CS, Kreisa L, Kurz MC, et al. The impact of prehospital activation of the cardiac catheterization team on time to treatment for patients presenting with ST-segment-elevation myocardial infarction. *Am J Emerg Med* 2011;29:1117-24.
- Kligfield P, Gettes LS, Bailey JJ, Childers R, Deal BJ, Hancock EW, et al. Recommendations for the standardization and interpretation of the electrocardiogram: Part I: The electrocardiogram and its technology: A scientific statement from the American Heart Association Electrocardiography and Arrhythmias Committee, CoNuncil on Clinical Cardiology; the American College of Cardiology Foundation; and the Heart Rhythm Society: Endorsed by the International Society for Computerized Electrocardiology. *Circulation* 2007;115:1306-24.
- Granger CB, Goldberg RJ, Dabbous O, Pieper KS, Eagle KA, Cannon CP, et al. Predictors of hospital mortality in the global registry of acute coronary events. *Arch Intern Med* 2003;163:2345-53.
- Bagai A, Jollis JG, Dauerman HL, Peng SA, Rokos IC, Bates ER, et al. Emergency department bypass for ST-segment-elevation myocardial infarction patients identified with a prehospital electrocardiogram: A report from the American Heart Association mission: Lifeline program. *Circulation* 2013;128:352-9.
- Kahlon TS, Barn K, Akram MM, Blankenship JC, Bower-Stout C, Carey DJ, et al. Impact of pre-hospital electrocardiograms on time to treatment and one year outcome in a rural regional ST-segment elevation myocardial infarction network. *Catheter Cardiovasc Interv* 2017;89:245-51.
- Quinn T, Johnsen S, Gale CP, Snooks H, McLean S, Woollard M, et al. Effects of prehospital 12-lead ECG on processes of care and mortality in acute coronary syndrome: A linked cohort study from the myocardial ischaemia national audit project. *Heart* 2014;100:944-50.
- Curtis JP, Portnay EL, Wang Y, McNamara RL, Herrin J, Bradley EH, et al. The pre-hospital electrocardiogram and time to reperfusion in patients with acute myocardial infarction, 2000-2002: Findings from the national registry of myocardial infarction-4. *J Am Coll Cardiol* 2006;47:1544-52.
- Ferguson JD, Brady WJ, Perron AD, Kielar ND, Benner JP, Currance SB, et al. The prehospital 12-lead electrocardiogram: Impact on management of the out-of-hospital acute coronary syndrome patient. *Am J Emerg Med* 2003;21:136-42.
- Pedley DK, Bissett K, Connolly EM, Goodman CG, Golding I, Pringle TH, et al. Prospective observational cohort study of time saved by prehospital thrombolysis for ST elevation myocardial infarction delivered by paramedics. *BMJ* 2003;327:22-6.
- Terkelsen CJ, Lassen JF, Nørgaard BL, Gerdes JC, Poulsen SH, Bendix K, et al. Reduction of treatment delay in patients with ST-elevation myocardial infarction: Impact of pre-hospital diagnosis and direct referral to primary percutaneous coronary intervention. *Eur Heart J* 2005;26:770-7.
- Björklund E, Stenström U, Lindbäck J, Svensson L, Wallentin L, Lindahl B, et al. Prehospital diagnosis and start of treatment reduces time delay and mortality in real-life patients with STEMI. *J Electrocardiol* 2005;38:186.
- Brainard AH, Raynovich W, Tandberg D, Bedrick EJ. The

prehospital 12-lead electrocardiogram's effect on time to initiation of reperfusion therapy: A systematic review and meta-analysis of existing literature. *Am J Emerg Med* 2005;23:351-6.

28. Afolabi BA, Novaro GM, Pinski SL, Fromkin KR, Bush HS. Use of the prehospital ECG improves door-to-balloon times in ST segment elevation myocardial infarction irrespective of time of day or day of week. *Emerg Med J* 2007;24:588-91.