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

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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 predischarge 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 predischarge 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).

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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). 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). 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.

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.

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. 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. 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. Applying this recommendation leads to faster transfer of patients to a PCI capable center and less mortality. Different strategies have been held in different countries to report ECG. Some are based on ECG machine reporting, some are reported by EMS paramedics, and some are done by cardiologists. The first two reporting systems are useful yet, weak in best decision-making choice. Most guidelines nowadays emphasized the necessity of ECG reviewing and confirmation by a physician. They concluded that this strategy makes the time of life-saving reperfusion shorter.

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 ± 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 (1.8)       | 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 \((P = 0.056 \text{ and } 0.066, \text{ respectively})\).

**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 (1-2.5) | 0.039 | 1.5 (0.82-2.6) | 0.199 |

Type of transferring=Group B with prehospital ECG taken by EMS and Group A 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

**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 predischarge LVEF showed no significant difference between the two groups. We observed that...
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 predischarge 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.[20]

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 predischarge 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 predischarge LVEF in the current study.

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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
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Conflicts of interest
None.

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