

Original Article



Community-Based Pre-Hospital Electrocardiogram Transmission Program for Reducing Systemic Time Delay in Acute ST-Segment Elevation Myocardial Infarction

OPEN ACCESS

Received: Oct 9, 2019
Revised: Mar 29, 2020
Accepted: Apr 6, 2020

Correspondence to

Young-Dae Kim, MD, PhD

Cardiovascular Center, Busan Regional Cardio-cerebrovascular Center, Dong-A University Hospital and Division of Cardiology, Department of Internal Medicine, Dong-A University College of Medicine, 26, Daesingongwon-ro, Seo-gu, Busan 49201, Korea.
E-mail: kimyd@mail.donga.ac.kr

*The first two authors contributed equally to this work.

Copyright © 2020. The Korean Society of Cardiology





This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (<https://creativecommons.org/licenses/by-nc/4.0>) which permits unrestricted noncommercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

ORCID iDs

Kyungil Park 
<https://orcid.org/0000-0002-5212-2128>
Jong-Sung Park 
<https://orcid.org/0000-0001-6996-2476>
Moo-Hyun Kim 
<https://orcid.org/0000-0003-3468-6453>
Young-Dae Kim 
<https://orcid.org/0000-0002-8924-3695>

Conflict of Interest

The author has no financial conflicts of interest.

Kyungil Park , MD, PhD^{1,2,*}, **Jong-Sung Park** , MD^{1,2,*}, **Young-Rak Cho**, MD, PhD^{1,2}, **Tae-Ho Park**, MD, PhD^{1,2}, **Moo-Hyun Kim** , MD, PhD^{1,2}, **Tae-Hyun Yang**, MD, PhD³, **Doo-Il Kim**, MD, PhD⁴, **Jung-Hwan Kim**, MD⁵, **Yong-Hwan Lee**, MD⁶, **Dong-Won Lee**, MD⁷, **Jeongkee Seo**, MD⁸, **Geun-Young Lee**⁹, and **Young-Dae Kim** , MD, PhD^{1,2}

¹Department of Cardiology, Dong-A University Hospital, Dong-A University College of Medicine, Busan, Korea
²Cardiovascular Center, Busan Regional Cardio-cerebrovascular Center, Dong-A University Hospital, Busan, Korea
³Department of Inje University Baek Hospital, Inje University College of Medicine, Busan, Korea
⁴Department of Cardiology, Inje University Haeundae Baek Hospital, Inje University College of Medicine, Busan, Korea
⁵Department of Cardiology, Dong-Eui Medical Center, Busan, Korea
⁶Department of Cardiology, Dong Rae Bong Seng Hospital, Busan, Korea
⁷Department of Cardiology, Gupo Sunshim Hospital, Busan, Korea
⁸Department of Cardiology, BHS Hanseo Hospital, Busan, Korea
⁹Metropolitan City Fire and Safety Headquarters, Busan, Korea

ABSTRACT

Background and Objectives: In acute ST-segment elevation myocardial infarction (STEMI), on-site transmission of electrocardiogram (ECG) has been shown to reduce systemic time delay to reperfusion and improve outcomes. However, it has not been adopted in community-based emergency transport system in Korea.

Methods: Busan Regional Cardio-cerebrovascular Center and Busan Metropolitan City Fire and Safety Headquarters (BMFSH) jointly developed and conducted a pre-hospital ECG transmission program. Seven tertiary hospitals and 22 safety stations of BMFSH participated. Systemic time delay to reperfusion of STEMI patients in the program was compared with that of 95 patients transported by 119 emergency medical system (EMS) before the program was implemented.

Results: During the study period, 289 ECG transmissions were made by 119 EMS personnel, executed within 5 minutes in 88.1% of cases. Of these, 42 ECGs were interpreted as ST-segment elevation. Final diagnosis of STEMI was made in 20 patients who underwent primary percutaneous coronary intervention. With the program, systemic time delay to reperfusion was significantly reduced (median [interquartile range; IQR], 76.0 [62.2–98.7] vs. 90.0 [75.0–112.0], $p < 0.01$). Significant reduction of door-to-balloon time was also observed (median [IQR], 45.0 [34.0–69.5] vs. 58.0 [51.0–68.0], $p = 0.03$). The proportion of patients with systemic time delay shorter than 90 minutes rose (51.6% vs. 75.0%, $p = 0.08$) with pre-hospital ECG transmission.

Conclusions: We developed and implemented a community-based pre-hospital ECG

Author Contributions

Conceptualization: Kim YD; Data curation: Cho YR, Park TH, Kim MH, Yang TH, Kim DI, Kim JH, Lee YH, Lee DW, Seo J, Lee GY; Investigation: Kim YD; Project administration: Park JS; Supervision: Kim YD; Writing - original draft: Park K; Writing - review & editing: Park K, Kim YD.

transmission program for expeditious triage of STEMI patients. Significant reductions of systemic time delay and door-to-balloon time were observed. The expanded use of pre-hospital ECG transmission should be encouraged to realize the full potential of this program.

Keywords: ST elevation myocardial infarction; Percutaneous coronary intervention; Triage

INTRODUCTION

In acute ST-segment elevation myocardial infarction (STEMI), it is vital to reduce the time delay to reperfusion, which is delivered mostly by primary percutaneous coronary intervention (PCI), a preferred strategy over thrombolytic therapy.¹⁻³ Initial efforts were focused on the reduction of time delay in the hospital, the door-to-balloon (D-B) time, in part because it can be executed swiftly by mobilizing personnel and facilities within a medical institute. Indeed, D-B time has been substantially improved over the last decades in the developed countries, including Korea.^{4,5} Observational data demonstrated higher mortality among the patients with longer D-B time than mortality among those with shorter time.^{6,7} However, the association between D-B time and mortality has been inconsistent across the clinical studies,⁶⁻⁹ and recent data from a population based registry of United States, Taiwan, Korea has shown that clinical outcomes remained unchanged despite of the significant decline in D-B time during study period.^{5,10,11}

Effect of reducing D-B time may be limited because D-B time is just one fraction of total ischemic time. Systemic time delay, which is the time from first-medical contact (FMC) to reperfusion, is more relevant target because it constitutes to the total time to reperfusion modifiable by the health care system. In Danish registry,¹² systemic time delay was an independent determinant of mortality in patients with STEMI treated with primary PCI. Recognizing the importance of systemic time delay, latest guidelines set the goal of systemic time delay 90 minutes or less in patients with STEMI undergoing primary PCI.^{13,14} For this goal, collaborative effort with health care delivery system within a community is highly recommended.^{13,14}

One practical way to reduce systemic time delay is making STEMI diagnosis by on-site electrocardiogram (ECG) transmission via emergency medical system (EMS) in the pre-hospital setting, and immediately activating the catheterization laboratory of intervention center. Pre-hospital ECG transmission and interpretation has been shown to expedite the triage of STEMI patients, reduce the systemic time delay, and improve clinical outcomes.¹⁵⁻¹⁷ Therefore, performance of ECG at the site of FMC by EMS personnel earned high-level recommendation by contemporary guidelines for the management of STEMI.^{13,14} Pre-hospital triage network has been set up in various city or rural communities of different countries around world, and its beneficial effect has been demonstrated repeatedly.¹⁸⁻²² However, utilization of pre-hospital ECG is still low, and the potential benefit of the program is not fully materialized in the real world.²³ In Korea, pre-hospital ECG transmission has not been adopted in community-based emergency transport system, despite of the fact that pre-hospital time delay was not improved over the years among patients with STEMI.²⁴ To introduce the pre-hospital triage system into the community, a groundwork to identify the feasibility and efficacy of the pre-hospital ECG transmission was a necessary priority. Therefore, Busan Regional Cardiocerebrovascular Center (BRCC) and Busan Metropolitan City Fire and Safety Headquarters (BMFSH) jointly developed a pre-hospital ECG transmission program and conducted the program to set up a regional network for facilitating reperfusion in patients with STEMI.

METHODS

Preparation for pre-hospital ECG transmission program

BRCC at Dong-A University Hospital and BMFSH worked together to establish the infrastructure and software of the program. To conduct the 12-lead ECG examination and transmission, securing additional personnel (up to 3 EMS personnel per one 119 ambulance) and ECG equipment were essential requirement. After several conferences with municipal officers, these requirements were fulfilled by mid-2016 with the funding from Busan Metropolitan City. Additionally, BRCC and BMFSH jointly developed the ECG transmission protocol in ambulance and ECG education course for EMS personnel. Thus, 4 courses of lecture on the cardiovascular disease and 4 courses of intensified ECG lecture (each course consist of 6 hours) were provided to the 119 EMS personnel of Busan-Ulsan metropolitan region. The EMS personnel also received 4 courses of ECG transmission practice training. The education program was rated as satisfactory among 95% of trainees in 2016 survey.

Implementation of pre-hospital electrocardiogram transmission program and participants

Busan Metropolitan City is a second largest city in Korea, with population of 3.5 million and area of 770 km². In the city, PCI-capable hospitals in 24 hours/7 days basis are mainly concentrated in central part of the city, and such hospitals are sparse or non-existent in the large area of peripheral region (**Supplementary Figure 1**). Therefore, among the safety stations of Busan Metropolis, those in the peripheral area were first considered for program participation. BRCC and 6 tertiary hospitals capable of primary PCI in 24 hours/7 days basis, together with 22 safety stations belonging to 11 local headquarters of BMFSH participated in this program (**Figure 1**).

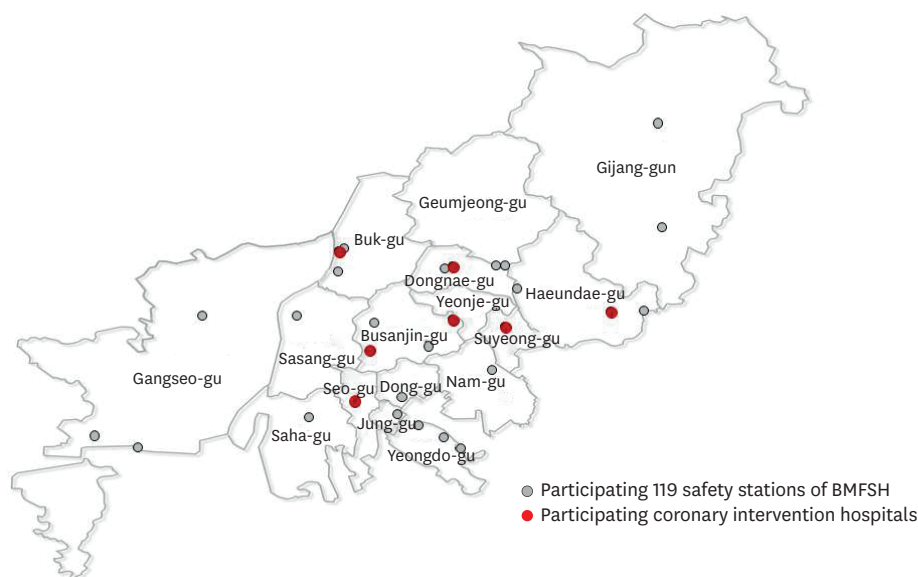


Figure 1. Location of 22 stations of BMFSH and 7 primary PCI-performing hospitals (6 regional hospitals and Busan Regional Cardio-Cerebrovascular Center), participating in the pre-hospital ECG transmission program. BMFSH = Busan Metropolitan City Fire and Safety Headquarters; ECG = electrocardiogram; PCI = percutaneous coronary intervention.

Patients living in the area under the jurisdiction of 22 participating BMFSH stations who required medical evacuation of 119 EMS for acute chest pain were eligible for inclusion from August 18, 2016 to January 31, 2017. Patients with 18 years or older who suffered anterior chest pain which is not caused by trauma and severe enough to call 119 EMS were included in the program. No other specific exclusion criteria was applied. ECG recording and transmission was conducted for all those subjects as directed in the protocol.

According to the protocol, the pre-hospital ECG transmission was conducted as follows. On contact with patient with severe precordial chest pain not caused by external injury, trained 119 EMS personnel performed a 12-lead ECG recording at a paper speed of 25 mm/s and amplitude of 10 mm/mV in the ambulance and transmitted acquired ECG images to the on-duty cardiologist in BRCC. To save the time, the ECG print-out of ECG was photographed by 119 EMS personnel and transmitted to mobile phone of the on-duty cardiologist. Transmitted ECG was promptly interpreted by on-duty cardiologist of BRCC. Once diagnosis of ST-segment elevation is made on the basis of the international criteria,²⁵⁾ the on-duty cardiologist directed the 119 EMS personnel to transport the patients to the nearest participating hospital, and alerted the emergency staff of the involved hospital in advance to immediately activate the cardiac catheterization laboratory and prepare for the primary PCI. Thus, primary PCI was performed in the nearest hospital from the FMC site, either Regional Center or other hospital participating in the program, depending on the distance of triage. Patients with ST elevation on the pre-hospital ECG were not sent directly to the cardiac catheterization laboratory, and underwent basic examination including ECG and laboratory test in the emergency room.

Study objectives and definitions

Primary objective of the study was reduction in the time delay to reperfusion in patients with STEMI undergoing primary PCI after implementation of the pre-hospital ECG program. Thus, systemic time delay to reperfusion (FMC to balloon time, FMC-B time) and in-hospital delay (D-B time) were compared between patients with STEMI transferred by EMS with prehospital ECG program and those transferred by EMS in conventional ways. Study group consisted of patients with STEMI treated with primary PCI who were included in the prehospital ECG transmission program. For indirect comparison, control group consisted of STEMI patients who were transported by 119 EMS and underwent primary PCI during previous 12 months (August 2015–July 2016) before the program was implemented. Control group included patients transferred directly to PCI centers by 119 EMS as well as those who were redirected from PCI-incapable hospitals to which initial transport by 119 EMS was made. Inclusion of the latter cases was necessary because it represents the common practice of STEMI patients triage in the Korean communities. Aside from time interval, proportion of patients who had FMC-B time within 90 minutes and D-B time within 60 minutes, as recommended by guidelines,¹³⁾¹⁴⁾ were also compared between two groups. Secondary objective was efficacy of ECG transmission by 119 EMS, so the time taken for ECG transmission and quality of transmitted ECG image were examined. Time taken for ECG transmission was measured by 119 EMS personnel, and grouped into 3 time groups (transmission within 3, 5, and 7 minutes). Quality of ECG images was rated as high (sharp and clear), moderate (not high but interpretable), and low (difficult to interpret) by the on-duty cardiologist. The study protocol was approved by an institutional review board of the Dong-A University Hospital.

Criteria of ST-segment elevation in 12-lead ECG in the present study was adopted from the Third Universal Definition of Myocardial Infarction as new ST-segment elevation at the J point of at least

two contiguous leads of ≥ 2 mm (≥ 0.2 mV) in men or ≥ 1.5 mm (0.15 mV) in women in leads V2 and V3 or ≥ 1 mm in any other contiguous precordial leads or the limb leads for either gender.²⁵⁾ In order to monitor the interpretation of transmitted ECG, cardiologists in Regional Cardiocerebrovascular Center have met regularly to evaluate ST-segment changes on ECG and to discuss cases. First Medical Contact was defined as described in European guideline, i.e., the time point when the patient is either initially assessed by a physician, paramedic, or nurse or other trained EMS personnel who can obtain and interpret the ECG, and deliver initial interventions.¹⁴⁾ Door time was defined as the time of hospital arrival, and balloon time as first coronary balloon inflation time. Final diagnosis of STEMI was registered from the discharge record of participating hospitals.

Statistical analysis

Categorical variables were described as frequencies and percentages and were analyzed with chi-square tests. Continuous variables were presented with mean \pm standard deviation or median and interquartile range (IQR), and they were compared by Student's t-test or Mann-Whitney U test respectively, depending on the normality test of variables. Analyses were conducted with the use of SPSS version 20.0. A p value of 0.05 or less was considered to indicate statistical significance.

RESULTS

Between August 18, 2016 to January 31, 2017, a total of 289 on-site ECG transmissions were made by 119 EMS personnel. Of these, 42 ECGs were interpreted as ST-segment elevation in the leads. Final diagnosis of STEMI was made in 20 patients who underwent primary PCI. Those patients comprised the study group. Of 22 patients without STEMI, three patients had non-ST-segment elevation acute coronary syndrome and 3 had aortic aneurysm. Three of the 22 patients were diagnosed with variant angina and 7 patients were finally diagnosed with various disease (**Table 1**). Six patients refused coronary angiography, so the investigators could not determine whether they were actually STEMI or other diseases with resembling STEMI ECG, such as acute myopericarditis or stress induced cardiomyopathy. For control group, 95 STEMI patients who were transported by 119 EMS and underwent primary PCI from August 2015 to July 2016, prior to implementation of prehospital ECG program, were enrolled. When compared with 95 patients in control group, baseline characteristics were similar in 20 patients involved in pre-hospital ECG transmission program (**Table 2**).

Table 1. Cases of pre-hospital ECG transmission with results of ECG interpretation and clinical diagnosis after triage

Pre-hospital ECG Transmission	289
Interpretation of ST-segment elevation: No	247
Interpretation of ST-segment elevation: Yes	42
Diagnosis	
ST-segment elevation myocardial infarction	20
Non-ST-segment elevation acute coronary syndrome	3
Variant angina	3
Aortic dissection/Aneurysm	3
Congestive heart failure	2
Gastrointestinal tract bleeding	1
Colitis	1
Pneumonia	1
Syncope	1
Acute pyelonephritis	1
Not specified	6

ECG = electrocardiogram.

Table 2. Baseline characteristics of study subjects

Variables	Study group (n=20)	Control group (n=95)	Total (n=115)	p value
Male	18 (90.0)	74 (77.9)	92 (80.0)	0.22
Age (years)	64.24±13.58	62.7±13.3	63.0±13.3	0.54
SBP (mm/Hg)	128.4±28.5	118.2±35.7	119.9±34.7	0.24
DBP (mm/Hg)	80.0±13.3	72.2±19.5	73.5±18.8	0.11
Pulse rate (/minute)	76.6±24.0	75.8±21.4	75.7±21.6	0.88

Data was expressed as means±SD or number (%).

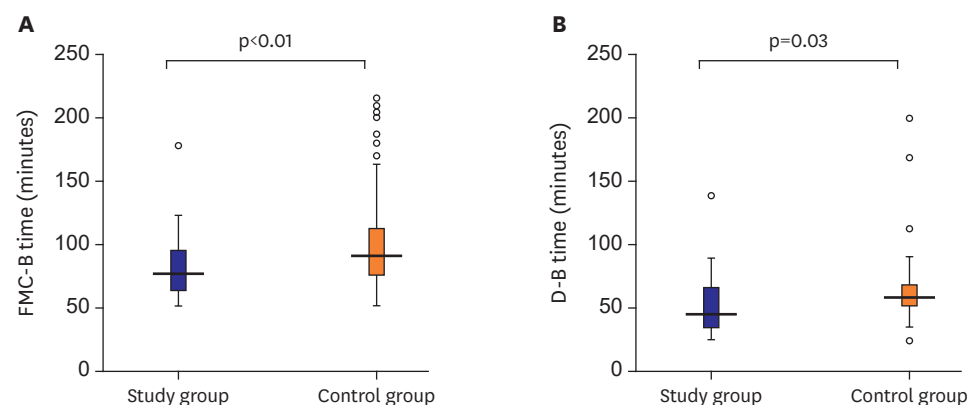
DBP = diastolic blood pressure; SBP = systolic blood pressure; SD = standard deviation.

Table 3. Comparison of the time delay to reperfusion between the study and control groups

Time delay	Study group (n=20)		Control group (n=95)		p value
	Median	IQR	Median	IQR	
FMC-D time	29.0	21.0–34.0	25.0	20.0–40.0	0.96
D-B time	45.0	34.0–69.5	58.0	51.0–68.0	0.03
FMC-B time	76.0	62.2–98.7	90.0	75.0–112.0	<0.01

D-B = door to balloon; FMC-B = first-medical contact to balloon; FMC-D = first-medical contact to door.

The time delay to reperfusion in the study and control groups are shown in **Table 3**. The details of the distribution of variables and used statistical methods were presented in the **Supplementary Table 1** in the supplement. The time delay to reperfusion was reduced with the implementation of pre-hospital ECG transmission program. **Figure 2** presents box-whiskers graph of FMC-B and D-B times for the two groups of patients. FMC-B time was significantly reduced in the study group than in the control group (median [IQR], 76.0 [62.2–98.7] versus 90.0 [75.0–112.0], $p<0.01$) by non-parametric analysis. D-B time was significantly different (median [IQR], 45.0 [34.0–69.5] versus 58.0 [51.0–68.0], $p=0.03$) between the two groups. The proportion of the patients with FMC-B time shorter than 90 minutes rose after implementation of pre-hospital ECG transmission (75.0% in the study group vs. 51.6% in the control group, $p=0.08$). The proportion of the patients with D-B time less than 60 minutes also tended to increase (75.0% in the study group versus 61.1% in the control group, $p=0.31$) (**Figure 3**). All patients in the study group was transported directly to the PCI-capable hospital without visiting PCI-incapable hospitals en route. In contrast, 11 out of 95 patients (11.6%) in the control group were transferred to PCI-capable hospitals via PCI-incapable hospitals along the way.

**Figure 2.** Box plots showing median levels of the time delay to reperfusion of the patients in the study group compared with the control group. (A) shows FMC-B time between the study and control groups, and (B) shows D-B time. Boxes show interquartile ranges.

D-B = door to balloon; FMC-B = first medical contact to balloon.

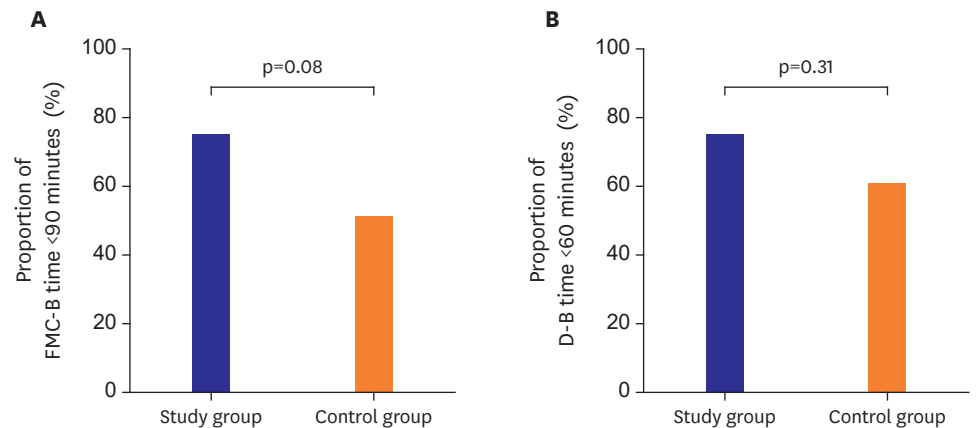


Figure 3. Proportion of patients with FMC-B time less than 90 minutes (A), and proportion of patients with D-B time less than 60 minutes (B).

D-B = door to balloon; FMC-B = first medical contact to balloon.

In the survey to estimate the efficacy of pre-hospital ECG transmission program, ECG examination and transmission was executed by paramedics within 3 minutes in 31.0%, within 5 minutes in 88.1%, and within 7 minutes in 99.2% of the cases. Quality of ECG image was rated as high in 29.5%, moderate in 63.6%, and low in 6.9% of 289 ECGs transmitted.

DISCUSSION

In recent years, pre-hospital delay is increasingly important determinant of total ischemic time in STEMI, because it became clear that shortening of in-hospital delay, D-B time, alone is not enough to further reduce mortality.¹⁰⁾ Thus, emphasis has been shifted to minimizing the time delay covering the pre-hospital phase, and time from the FMC to reperfusion, the systemic time delay, is the new target for reducing ischemic time in STEMI guidelines.¹³⁾¹⁴⁾ On-site diagnosis and triage of STEMI patients by pre-hospital ECG transmission is a practical strategy proven to reduce the systemic delay and patient mortality.¹⁵⁻¹⁷⁾ However, pre-hospital ECG transmission program has never been adopted in community-based emergency patient transport system in Korea despite the fact that pre-hospital time delay remain unchanged, with median symptom-to-hospital arrival 150 minutes in recent survey.²⁴⁾

This project was the first attempt in Korea to develop and implement a community-based pre-hospital ECG transmission program by collaborative effort from regional health care center, emergency medical system, and municipal office. After the period of preparations which include securing the personnel, equipment in the emergency vehicle and delivering dedicated educational programs for the EMS personnel, BRCC and BMFSH jointly produced pre-hospital ECG transmission protocol. As a measure of efficacy of the protocol, on-site ECG transmission was completed within 5 minutes by trained EMS personnel in the majority of the cases in this study. New technology of sending ECG directly to a mobile phone of duty cardiologist in this study also allowed prompt review of ECG irrespective of physician's location within or outside the hospital. Quality of ECG image was less satisfactory, resulting in over-interpretation of ST-segment elevation in the study.

After implementing the pre-hospital ECG program in the metropolitan community, we could observe the significant reduction of time to reperfusion in patients who underwent primary

PCI. In addition, pre-hospital ECG transmission was also associated with a higher proportion of patients treated within the targeted time windows of guidelines, FMC-B time less than 90 minutes and D-B time less than 60 minutes. The results of the present study are concordant with previous data of other countries which demonstrated reduced treatment delay in both in-hospital and pre-hospital phases with the triage strategy based on-site diagnosis of STEMI using pre-hospital ECG.¹⁵⁾¹⁸⁻²⁰⁾²²⁾²⁶⁾²⁷⁾ Every constitute of time delay has been shown to be affected by pre-hospital ECG program, which includes time from symptom to hospital arrival, time from FMC to balloon, and time from symptom to balloon inflation.¹⁵⁾¹⁸⁻²⁰⁾²²⁾²⁶⁾²⁷⁾ On-site diagnosis of STEMI can reduce pre-hospital time delay by direct transport to the PCI-capable hospital and bypassing the PCI-incapable hospital,¹⁵⁾ which was also exhibited in this study. Further, it has been shown that safety of patients was not compromised during direct transport of patient to the intervention center despite skipping the primary care of nearby hospital.²⁶⁾ In addition, the D-B time has been consistently reduced in previous studies,¹⁵⁾¹⁸⁻²⁰⁾²¹⁾²³⁾²⁶⁾²⁷⁾ indicating that pre-hospital notification to the intervention center facilitate the in-hospital process of preparation for primary PCI. By reducing both the pre- and in-hospital time delay, pre-hospital ECG transmission program in the present study and others provide sufficient evidence that it can achieve the goal of minimizing the systemic time delay, a total ischemic time targeted by health care system, in the triage of STEMI patients. The expanded use of pre-hospital ECG should be encouraged to realize the full potential of this program in wider regions of community, and at nationwide level.

There are some limitations to mention in this study. First, the number of the study subjects was too small to conduct full analysis such as influence of diverse practice among different PCI centers. Although we observed a significant reduction in the time to reperfusion with the implementation of pre-hospital ECG program, further study with large numbers of population will be necessary to clarify the impact of the program. The results of this study just show the prehospital ECG transmission can be as feasible and effective in Korean community as demonstrated previously in other countries. Second, there might be systemic bias related to time course. We used the data obtained before the program as control, and the comparative analysis between “before” and “after” could be affected by the changes in other processes that might occur within the study period. However, the control group data was obtained during the 12 months immediately before the study period, and the changes of device, technologies, pharmacotherapy, etc. between two time period could be minimal. Third, the rate of false-positive interpretation of ECG was high in this study, resulting in unnecessary activation of cardiac catheterization laboratory. Of the 42 subjects transferred to PCI facilities based on the of ST-segment elevation on transmitted ECG, only 20 subjects were confirmed as STEMI. This was primarily due to poor image of ECG picture sent to mobile phone of duty cardiologist who chose worse diagnosis in the presence of ambiguous ECG rather than missing STEMI patients. Because of absence of built-in software in ECG equipment for transmitting the ECG directly to mobile phone, the EMS personnel had to take a picture of ECG print-out in the ambulance. This drawback needs improvement, and we are developing an application program which allows transmitting of high-quality ECG image directly to mobile, either Android or iOS system. Another reason for the false-positive interpretation may be the inherent limitations of standard 12-lead ECG to diagnose STEMI accurately. In addition, various conditions may present with ST-segment elevation on surface ECG, mimicking STEMI. Fourth, the nature of the study did not allow the evaluation of clinical outcomes. Because this project was not designed as a clinical trial, only limited access to the patients' data was permitted. Only time intervals, basic demographic data, and initial vital signs were available. Thus, the time interval to reperfusion was the primary objective of this study. Lastly, symptom to FMC time, the patient delay, was

not covered in the program. Although this is another important determinant of ischemic time in STEMI, it is the most difficult factor to control, and not modifiable by health care system. Reducing the patient delay would require nationwide effort to enhance public awareness of symptom of STEMI and necessary steps in response to symptoms. At the present time, it is practical to focus on the time constitute amenable to medical transport system, which is the systemic time delay, i.e., time from FMC to reperfusion. Reducing the prehospital phase of the systemic delay is the novel target in STEMI triage. Implementation of pre-hospital ECG transmission in larger population of broader area will be necessary to identify the clinical benefit conferred by this program among the patients with STEMI in Korea.

In conclusion, we developed and conducted a pre-hospital ECG transmission program for expeditious triage of patients with STEMI for primary PCI in the metropolitan community. Prompt on-site ECG transmission and diagnosis were feasible in most cases. Statistically significant reductions of systemic time delay and door-to-balloon time were observed with pre-hospital ECG transmission program. Proportion of patients treated within the targeted time window also increased. These encouraging results suggest that use of pre-hospital ECG should be expanded to realize the full potential of this program in wider community regions and at nationwide level.

ACKNOWLEDGEMENTS

We would like to deliver special thanks to Busan Metropolitan City for the generous funding for the program. Thanks to the fund, the personnel and ECG equipment could be secured, and pre-hospital ECG program could be launched in substance. We also feel much indebted to ex-chief of BMFSH, Mr. Haewoon Ryu, who made a great contribution to this program through his passion and leadership.

SUPPLEMENTARY MATERIALS

Supplementary Table 1

Distribution of variables and used statistical methods

[Click here to view](#)

Supplementary Figure 1

Distribution of hospitals capable of primary PCI in 24 hour/7 days basis in Busan Metropolitan City. Most of these hospitals are located in the central region of the city. Vast area of peripheral region is devoid of primary PCI-capable hospitals.

[Click here to view](#)

REFERENCES

1. Denktas AE, Anderson HV, McCarthy J, Smalling RW. Total ischemic time: the correct focus of attention for optimal ST-segment elevation myocardial infarction care. *JACC Cardiovasc Interv* 2011;4:599-604.

[PUBMED](#) | [CROSSREF](#)

2. Francone M, Bucciarelli-Ducci C, Carbone I, et al. Impact of primary coronary angioplasty delay on myocardial salvage, infarct size, and microvascular damage in patients with ST-segment elevation myocardial infarction: insight from cardiovascular magnetic resonance. *J Am Coll Cardiol* 2009;54:2145-53. [PUBMED](#) | [CROSSREF](#)
3. 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. [PUBMED](#) | [CROSSREF](#)
4. Bradley EH, Nallamothu BK, Stern AF, et al. The door-to-balloon alliance for quality: who joins national collaborative efforts and why? *Jt Comm J Qual Patient Saf* 2009;35:93-9. [PUBMED](#) | [CROSSREF](#)
5. Kim HK, Jeong MH, Ahn Y, et al. Relationship between time to treatment and mortality among patients undergoing primary percutaneous coronary intervention according to Korea Acute Myocardial Infarction Registry. *J Cardiol* 2017;69:377-82. [PUBMED](#) | [CROSSREF](#)
6. McNamara RL, Wang Y, Herrin J, 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. [PUBMED](#) | [CROSSREF](#)
7. Berger PB, Ellis SG, Holmes DR Jr, et al. Relationship between delay in performing direct coronary angioplasty and early clinical outcome in patients with acute myocardial infarction: results from the global use of strategies to open occluded arteries in Acute Coronary Syndromes (GUSTO-IIb) trial. *Circulation* 1999;100:14-20. [PUBMED](#) | [CROSSREF](#)
8. Brodie BR, Stone GW, Morice MC, et al. Importance of time to reperfusion on outcomes with primary coronary angioplasty for acute myocardial infarction (results from the Stent Primary Angioplasty in Myocardial Infarction Trial). *Am J Cardiol* 2001;88:1085-90. [PUBMED](#) | [CROSSREF](#)
9. Zijlstra F, Patel A, Jones M, et al. Clinical characteristics and outcome of patients with early (<2 h), intermediate (2-4 h) and late (>4 h) presentation treated by primary coronary angioplasty or thrombolytic therapy for acute myocardial infarction. *Eur Heart J* 2002;23:550-7. [PUBMED](#) | [CROSSREF](#)
10. Menees DS, Peterson ED, Wang Y, et al. Door-to-balloon time and mortality among patients undergoing primary PCI. *N Engl J Med* 2013;369:901-9. [PUBMED](#) | [CROSSREF](#)
11. Lee WC, Fang HY, Chen HC, et al. Effect of improved door-to-balloon time on clinical outcomes in patients with ST segment elevation myocardial infarction. *Int J Cardiol* 2017;240:66-71. [PUBMED](#) | [CROSSREF](#)
12. Terkelsen CJ, Sørensen JT, Maeng M, et al. System delay and mortality among patients with STEMI treated with primary percutaneous coronary intervention. *JAMA* 2010;304:763-71. [PUBMED](#) | [CROSSREF](#)
13. O'Gara PT, Kushner FG, Ascheim DD, et al. 2013 ACCF/AHA guideline for the management of ST-elevation myocardial infarction: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. *Circulation* 2013;127:e362-425. [PUBMED](#) | [CROSSREF](#)
14. Ibanez B, James S, Agewall S, 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. [PUBMED](#) | [CROSSREF](#)
15. Pedersen SH, Galatius S, Hansen PR, et al. Field triage reduces treatment delay and improves long-term clinical outcome in patients with acute ST-segment elevation myocardial infarction treated with primary percutaneous coronary intervention. *J Am Coll Cardiol* 2009;54:2296-302. [PUBMED](#) | [CROSSREF](#)
16. Le May MR, Wells GA, So DY, 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. [PUBMED](#) | [CROSSREF](#)
17. Ducas RA, Labos C, Allen D, et al. Association of pre-hospital ECG administration with clinical outcomes in ST-segment myocardial infarction: a systematic review and meta-analysis. *Can J Cardiol* 2016;32:1531-41. [PUBMED](#) | [CROSSREF](#)

18. Le May MR, So DY, Dionne R, et al. A citywide protocol for primary PCI in ST-segment elevation myocardial infarction. *N Engl J Med* 2008;358:231-40.
[PUBMED](#) | [CROSSREF](#)
19. Brunetti ND, Di Pietro G, Aquilino A, et al. Pre-hospital electrocardiogram triage with tele-cardiology support is associated with shorter time-to-balloon and higher rates of timely reperfusion even in rural areas: data from the Bari-Barletta/Andria/Trani public emergency medical service 118 registry on primary angioplasty in ST-elevation myocardial infarction. *Eur Heart J Acute Cardiovasc Care* 2014;3:204-13.
[PUBMED](#) | [CROSSREF](#)
20. Kawakami S, Tahara Y, Noguchi T, et al. Time to reperfusion in ST-segment elevation myocardial infarction patients with vs. without pre-hospital mobile telemedicine 12-lead electrocardiogram transmission. *Circ J* 2016;80:1624-33.
[PUBMED](#) | [CROSSREF](#)
21. Ong ME, Wong AS, Seet CM, et al. Nationwide improvement of door-to-balloon times in patients with acute ST-segment elevation myocardial infarction requiring primary percutaneous coronary intervention with out-of-hospital 12-lead ECG recording and transmission. *Ann Emerg Med* 2013;61:339-47.
[PUBMED](#) | [CROSSREF](#)
22. Kahlon TS, Barn K, Akram MM, 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.
[PUBMED](#) | [CROSSREF](#)
23. Diercks DB, Kontos MC, Chen AY, et al. Utilization and impact of pre-hospital electrocardiograms for patients with acute ST-segment elevation myocardial infarction: data from the NCDR (National Cardiovascular Data Registry) ACTION (Acute Coronary Treatment and Intervention Outcomes Network) Registry. *J Am Coll Cardiol* 2009;53:161-6.
[PUBMED](#) | [CROSSREF](#)
24. Park YH, Kang GH, Song BG, et al. Factors related to prehospital time delay in acute ST-segment elevation myocardial infarction. *J Korean Med Sci* 2012;27:864-9.
[PUBMED](#) | [CROSSREF](#)
25. Thygesen K, Alpert JS, Jaffe AS, et al. Third universal definition of myocardial infarction. *J Am Coll Cardiol* 2012;60:1581-98.
[PUBMED](#) | [CROSSREF](#)
26. Sejersten M, Sillesen M, Hansen PR, et al. Effect on treatment delay of prehospital teletransmission of 12-lead electrocardiogram to a cardiologist for immediate triage and direct referral of patients with ST-segment elevation acute myocardial infarction to primary percutaneous coronary intervention. *Am J Cardiol* 2008;101:941-6.
[PUBMED](#) | [CROSSREF](#)
27. Ong ME, Wong AS, Seet CM, et al. Nationwide improvement of door-to-balloon times in patients with acute ST-segment elevation myocardial infarction requiring primary percutaneous coronary intervention with out-of-hospital 12-lead ECG recording and transmission. *Ann Emerg Med* 2013;61:339-47.
[PUBMED](#) | [CROSSREF](#)