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Original Article

Diagnostic performance of emergency medical technician for ST-segment elevation myocardial infarction

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Abstract This study was conducted to determine whether level-1 emergency medical technicians (EMTs) can adequately recognize ST-segment elevation myocardial infarction (STEMI) in the emergency department (ED) and whether their ability to do so differs from that of emergency medicine physicians (EMP). From December 2022 to November 2023, patients aged 20 years or older visiting the ED with chief complaints suggesting acute coronary syndrome (ACS) were enrolled. As soon as the patient arrived at the ED, a level-1 EMT conducted a 12-lead electrocardiogram (ECG) to assess STEMI; an EMP subsequently assessed whether to activate the percutaneous coronary intervention team. Demographic characteristics, test results, and final diagnoses were collected from the medical records. Among the 723 patients with case report forms, 720 were included in the analysis. These were categorized as follows: 117 (16.3%) with STEMI, 159 (22.1%) with non-ST-segment elevation ACS, and 444 (61.7%) with other conditions. STEMI was correctly recognized in 100 patients (91.7%) by level-1 EMTs and in 104 patients (95.4%) by EMPs (kappa=0.646). EMTs with less than 1 year of ED work experience correctly recognized 60 out of 67 STEMI patients (89.6%), which was comparable with the EMPs who recognized 65 out of 67 STEMI patients (97.0%, kappa=0.614). EMTs with more than 1 year of ED work correctly recognized 40 out of 42 STEMI patients (95.2%), and therefore performed better than EMPs, who recognized 39 out of 42 STEMI patients (92.9%, kappa=0.727). The level-1 EMTs adequately recognized STEMI using a 12-lead ECG and were in substantial agreement with the evaluations of the EMPs.

Key words: ST elevation myocardial infarction, Percutaneous coronary intervention, Emergency medical technicians

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INTRODUCTION

Rapid reperfusion treatments such as percutaneous coronary intervention (PCI) or fibrinolysis play a pivotal role in the treatment of patients with ST-segment elevation myocardial infarction (STEMI). The link between a delay in time to reperfusion and higher mortality in patients with STEMI is well established, and prolonged ischemic time is associated with impaired myocardial perfusion, larger infarct area, and higher 1-year mortality.[1] De Luca et al.[2] reported that each 3-minute delay in PCI in patients with acute myocardial infarction could increase the relative risk of mortality within 1 year by approximately 7.5%.

Prehospital notification and hospital preparation by emergency medical service (EMS) providers can shorten the symptoms to reperfusion time and improve the treatment outcomes of STEMI.[3] Prehospital diagnosis of STEMI can guide the transport of patients to PCI-capable hospitals, bypassing the nearest medical institution.[4] Therefore, American Heart Association guidelines recommend that EMS providers acquire a 12-lead electrocardiogram (ECG) at the prehospital stage to recognize STEMI in advance.[5]

However, in Korea, there have been few studies investigating whether level-1 emergency medical technician (EMT), who play an important role as first medical contact personnel in the EMS system, can properly interpret 12-lead ECGs.

This study aimed to determine whether level-1 EMTs who graduated from the department of emergency medical technology and obtained national certification, subsequently working in the emergency department (ED) of a tertiary academic teaching hospital, could accurately recognize STEMI. Additionally, this study investigated how the ability of level-1 EMTs to recognize STEMI differs from that of emergency medicine physicians (EMP) in the ED.

METHODS

This prospective observational study was conducted between December 2022 and November 2023 in the ED of an academic teaching hospital with an annual average of 35,000 patient visits. The study subjects included all adult patients aged >20 years who visited the ED with the chief complaint of acute coronary syndrome (ACS). All patients who complained of chest pain, chest discomfort, epigastric pain, dizziness, syncope, dyspnea, or sudden cardiac death were included in this study.

As of December 2022, there were 13 level-1 EMTs working in the ED of the hospital, and level-1 EMTs who attended prior education and signed consent forms participated in the study. In the event of a vacancy, another staff member participated in the study after obtaining separate prior education with the same content. A total of 22 level-1 EMTs participated in this study over the entire study period. The contents of the preliminary education session included study objectives, changes in the flow of the existing critical pathway in the ED, the basic concepts of 12-lead ECGs, the diagnostic criteria of STEMI, and case reviews. The prior education provided by the EMPs who conducted this study took approximately 2 hours.

All level-1 EMTs who participated in the study performed 12-lead ECGs on patients in the ED. When the patient's chief complaint suggested ACS, level-1 EMTs first evaluated the patient's ECGs and then recorded their interpretation of the ECGs in a case report form. Afterward, the EMPs evaluated the patients' ECGs secondarily and recorded their interpretation of the ECGs in the case report form. The EMPs made a final decision on whether to activate the STEMI critical pathway (CP) in consultation with cardiologists via phone (Fig. 1).

Level-1 EMTs and EMPs evaluated the real-time ECGs of patients, classified them into three categories (STEMI, non-ST segment acute coronary syndrme [NSTE-ACS], and nonspecific), and recorded them in the case report form. In addition, information such as the patients' basic demographics, medical history, vital signs, laboratory results, reperfusion treatment (PCI or fibrinolysis), final diagnosis, and treatment results were collected through an electronic medical record review.

The collected data were entered into Microsoft Excel (version 2016; Microsoft, Redmond, WA, USA), and statistical analyses were performed using SPSS (version 24.0; IBM Corporation, Armonk, NY, USA). According to the 2023 European Society of Cardiology guidelines for the management of ACS, in the case of STEMI, a working diagnosis is made based on clinical features and ECG only, and the final diagnosis is made based on coronary angiogram.[6] Therefore, we first evaluated the differences

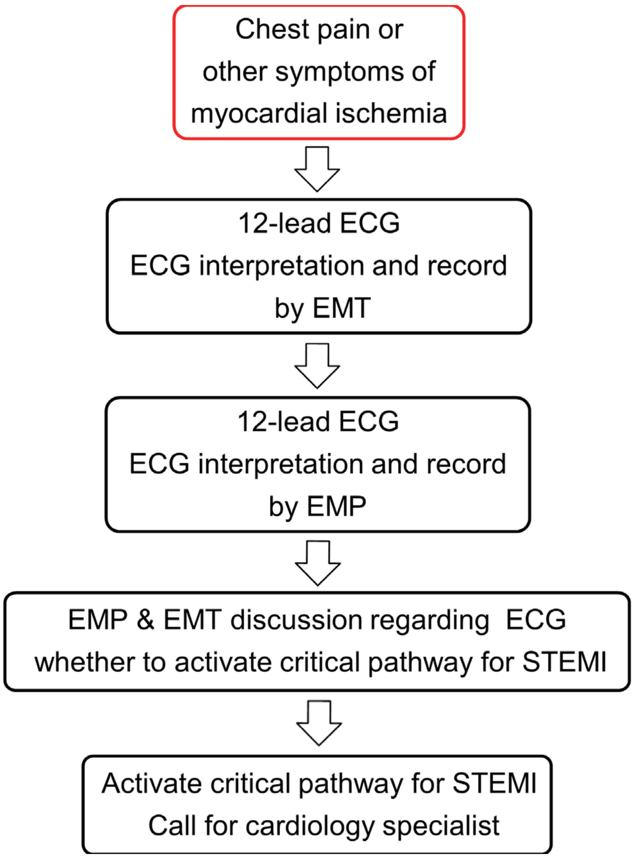

Figure 1. Critical pathway for ST-segment elevation myocardial infarction. ECG: electrocardiogram, EMT: emergency medical technician, EMP: emergency medicine physician, STEMI: ST-segment elevation myocardial infarction.

between EMTs and EMPs for STEMI ECG readings in the working diagnosis stage. In addition, based on the final diagnosis, diagnostic performance, such as sensitivity and specificity, was compared between the two groups. Sensitivity, specificity, accuracy, positive predictive value, and negative predictive value were obtained only from cases in which the final diagnosis was STEMI, excluding cases in which STEMI CP activation was performed, but not STEMI. The differences between EMTs and EMPs in STEMI ECG readings in the working diagnosis stage were compared using McNemar's test, and the inter-rater agreement of STEMI interpretation was evaluated using Cohen's kappa coefficient. Statistical significance was set than 0.05, it was considered statistically significant.

This study was approved by the Institutional Review Board (IRB) of Jeju National University Hospital (IRB number, 2022-09-019).

RESULTS

A total of 720 patients were included in the analysis of 723 patients with case record forms, excluding those with insufficient data. The average age of the patients was 58.6 years, and there were 451 men (62.6%). Among the chief complaints, chest pain was the most common (n=682, 94.7%), followed by shortness of breath (2.6%), fainting (0.8%), epigastric pain (0.4%), dizziness (0.3%), loss of consciousness (0.3%), and palpitations (0.3%) (Table 1). Based on the initial ECG and clinical features, 117 patients (16.3%) were classified into the STEMI group, 159 patients (22.1%) were classified into the NSTE-ACS group, and the remaining 444 patients (61.7%) were classified into the nonspecific group (Fig. 2). STEMI equivalents on ECG, which activate the CP according to clinical features, were also included in the STEMI group.

Five EMPs participated in this study. All five EMPs were professors of emergency medicine, with specialist careers of 12, 9, 4, 4, and 3 years, respectively. A total of 22 level-1 EMTs participated in this study. The median age of the EMTs was 26 years, with an interquartile range of 3. The proportion of female EMTs was 59%, and the average working career at an emergency medical center at the time of study participation was 8.7 months. Of the 720 patients enrolled in the analysis, ECG for 432 patients (60%) were performed by a level-1 EMT with less than 6 months of work experience in the emergency medical center.

Among the 117 patients with activated STEMI CP, cases where the initial ECG was normal but the ECG changed later, cases where the STEMI ECG was present only on the ECG obtained from an outside hospital, and cases in which evaluation could not be performed owing to worsening symptoms while staying in the ED were excluded from the analysis. For the 109 STEMI CP cases, the differences between EMTs and EMPs and their inter-rater agreement for STEMI ECG readings in the working diagnosis stage

Table 1. Basic demographics of patients according to initial ECG and clinical features

Variable	Total (n=720)	STEMI (n=117)	NSTE-ACS (n=159)	Nonspecific (n=444)
Age (years)	61.0 (50.4, 74.0)	63.2 (53.0, 74.0)	65.0 (55.5, 75.0)	59.0 (47.1, 72.0)
Sex				
Male	451 (62.6)	90 (76.9)	112 (70.4)	249 (43.9)
Female	269 (37.4)	27 (23.1)	47 (29.6)	195 (43.9)
Chief complaints				
Chest pain	682 (94.7)	115 (98.3)	156 (98.1)	411 (92.6)
Dyspnea	19 (2.6)	1 (0.9)	2 (1.3)	16 (3.6)
Syncope	6 (0.8)	1 (0.9)		5 (1.1)
Epigastric pain	3 (0.4)		1 (0.6)	2 (0.5)
Dizziness	2 (0.3)			2 (0.5)
Mental change	2 (0.3)			2 (0.5)
Palpitation	2 (0.3)			2 (0.5)
Others	4 (0.6)			4 (0.9)
Final diagnosis				
STEMI	105 (14.6)	105 (89.7)		
NSTE-ACS	118 (16.4)	10 (8.5)	141 (88.7)	27 (6.1)
Nonspecific	437 (60.8)	2 (1.7)	18 (11.3)	417 (93.6)
Emergent CAG				
Yes	249 (34.6)	116 (99.1)	121 (76.1)	12 (2.7)
No	471 (65.4)	1 (0.9)	38 (23.9)	432 (97.3)
PCI				
Yes	195 (27.1)	104 (88.9)	88 (62.9)	3 (1.5)
No	264 (36.7)	13 (11.1)	52 (37.3)	199 (98.5)
ED results				
Discharge	379 (52.6)	2 (1.7)	27 (17.0)	350 (83.1)
Transfer	7 (1.0)		5 (3.1)	2 (0.5)
Admission	310 (43.1)	114 (97.4)	127 (79.9)	69 (16.4)
Death	1 (0.1)	1 (0.9)		
Hospital results				
Discharge	297 (41.3)	108 (94.7)	123 (96.9)	66 (95.7)
Transfer	5 (0.7)	2 (1.8)	1 (0.8)	2 (2.9)
Death	7 (1.0)	3 (2.6)	3 (2.4)	1 (1.4)
Others	1 (0.1)	1 (0.9)		

Variables are presented as median (1st, 3rd interquartile range) or number (%).
ECG: electrocardiogram, STEMI: ST-segment elevation myocardial infarction, NSTE-ACS: non-ST-segment elevation acute coronary syndrome, CAG: coronary angiography, PCI: percutaneous coronary intervention, ED: emergency department.

were evaluated (Fig. 3). They were 100 people (91.7%) and 104 people (95.4%), respectively (P=0.508), and the kappa value was 0.646 (95% confidence interval [CI], 0.432-0.860), showing a substantial degree of agreement between the EMTs and EMPs.

To determine whether EMT carriers in the ED affect the diagnostic performance of STEMI, an additional analysis was conducted by dividing EMTs into two groups based on 1 year as carriers in the ED. For EMTs who had worked less than 1 year in the ED, the differences between EMTs and

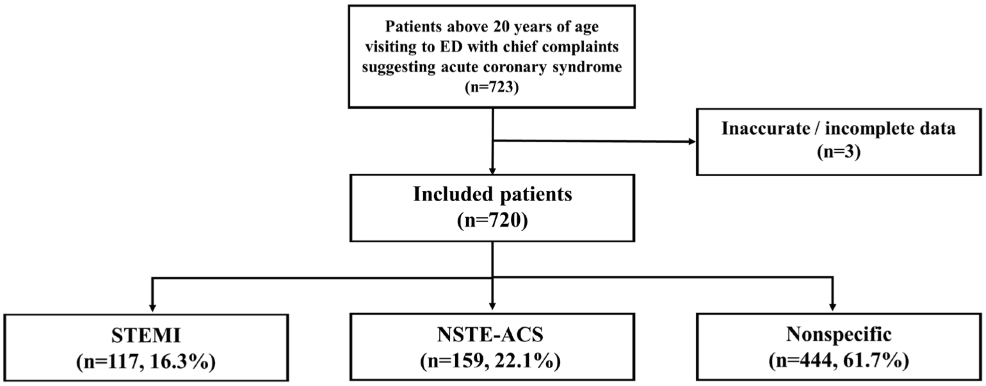

Figure 2. Flow diagram of inclusion. ED: emergency department, STEMI: ST-segment elevation myocardial infarction, NSTE-ACS: non-ST-segment elevation acute coronary syndrome.

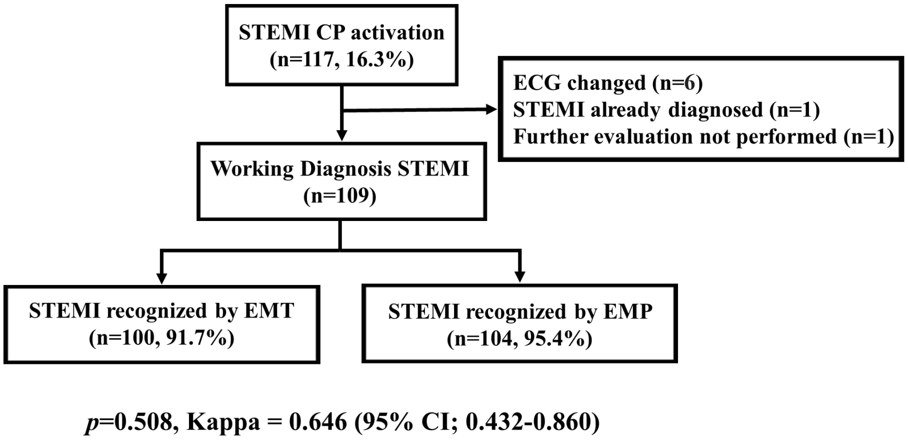

Figure 3. The differences and inter-rater agreement between EMTs and EMPs for STEMI ECG readings in the working diagnosis stage. STEMI: ST-segment elevation myocardial infarction, CP: critical pathway, ECG: electrocardiogram, EMT: emergency medical technician, EMP: emergency medicine physician, CI: confidence interval.

EMPs in STEMI ECG readings at the working diagnosis stage were 60 patients (89.6%) and 65 patients (97.0%), respectively (P=0.125). A kappa value of 0.614 (95% CI, 0.359-0.869) showed a substantial degree of agreement. In contrast, for EMTs who had worked more than 1 year in the ED, the differences between EMTs and EMPs for STEMI ECG readings in the working diagnosis stage were 40 patients (95.5%) and 39 patients (92.9%), respectively (P=0.500). The kappa value was 0.727 (95% CI, 0.370-1.000), which showed a higher degree of agreement between EMTs who had worked for more than 1 year in the ED, compared to those with less than a year's experience, and EMPs (Fig. 4).

The sensitivity, specificity, accuracy, positive predictive value, and negative predictive value of ECG interpretation using level-1 EMTs were 85.7%, 97.1%, 95.4%, 83.3%, and 97.6%, respectively. The sensitivity, specificity, accuracy, positive predictive value, and negative predictive value of ECG interpretation using EMPs were 87.6%, 98.1%, 96.5%, 88.5%, and 97.9%, respectively (Fig. 5).

Among the cases in which CP for STEMI was activated by EMPs, nine cases were missed by level-1 EMTs. Among them, three cases showed relatively definite ST-segment elevation, and two cases had very slight ST-segment elevation on ECG. The remaining four cases were 1) ECG

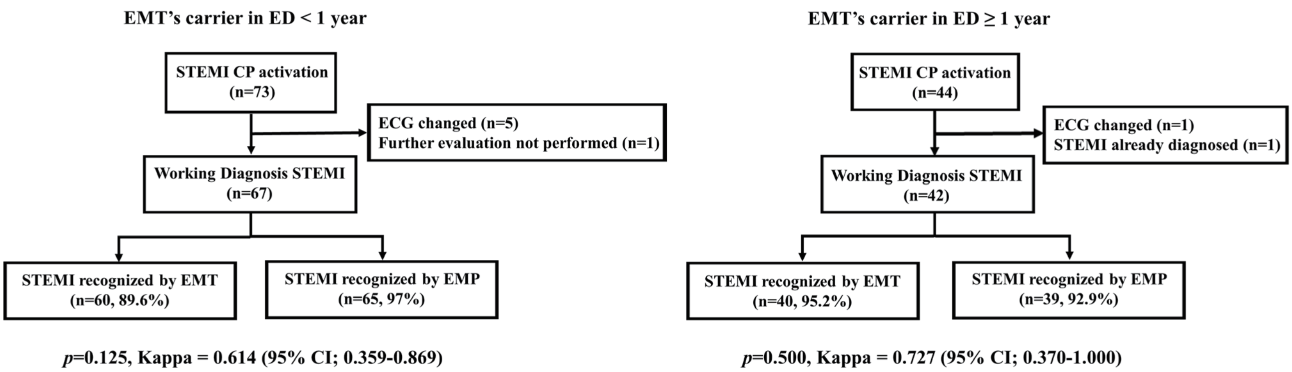

Figure 4. The differences and inter-rater agreement between EMTs and EMPs for STEMI ECG readings in the working diagnosis stage according to EMT's carrier in emergency department. EMT: emergency medical technician, ED: emergency department, STEMI: ST-segment elevation myocardial infarction, CP: critical pathway, ECG: electrocardiogram, EMP: emergency medicine physician, CI: confidence interval.

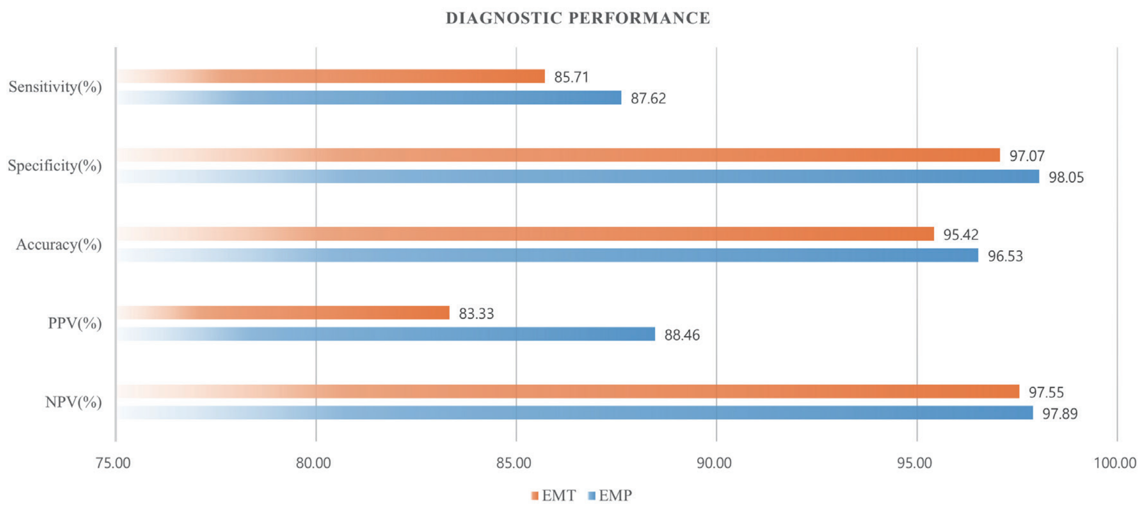

Figure 5. Overall diagnostic performance of ECG interpretation in EMT and EMP groups. PPV: positive predictive value, NPV: negative predictive value, EMT: emergency medical technician, EMP: emergency medicine physician.

showing very slight ST-segment elevation in the aVR lead and ST-segment depressions in other overall leads, suggesting the involvement of multiple coronary arteries, 2) ECG showing a tall T-wave on the precordial leads, suggesting hyperacute myocardial infarction, 3) ECG showing a tall R-wave and ST-segment depression on the precordial V1-V3 leads, suggesting posterior myocardial infarction, and 4) The ECG showed a deep Q-wave, T-wave inversion, and relatively normalized ST-segment elevation, suggesting myocardial infarction with a relative time lapse (Fig. 6). Five of the seven cases recognized as false-positive STEMI by level-1 EMTs did not show any ischemic ST-T changes on their ECGs. The remaining two patients had baseline wandering noise on ECG in dyspneic patients with chronic obstructive pulmonary disease and left ventricular hypertrophy with strain on ECG in patients with congestive heart failure.

DISCUSSION

In this study, level-1 EMTs appropriately recognized STEMI patients by evaluating the 12-lead ECGs of patients with suspected ACS who visited the ED and showed substantial agreement with the interpretation of the EMP. In

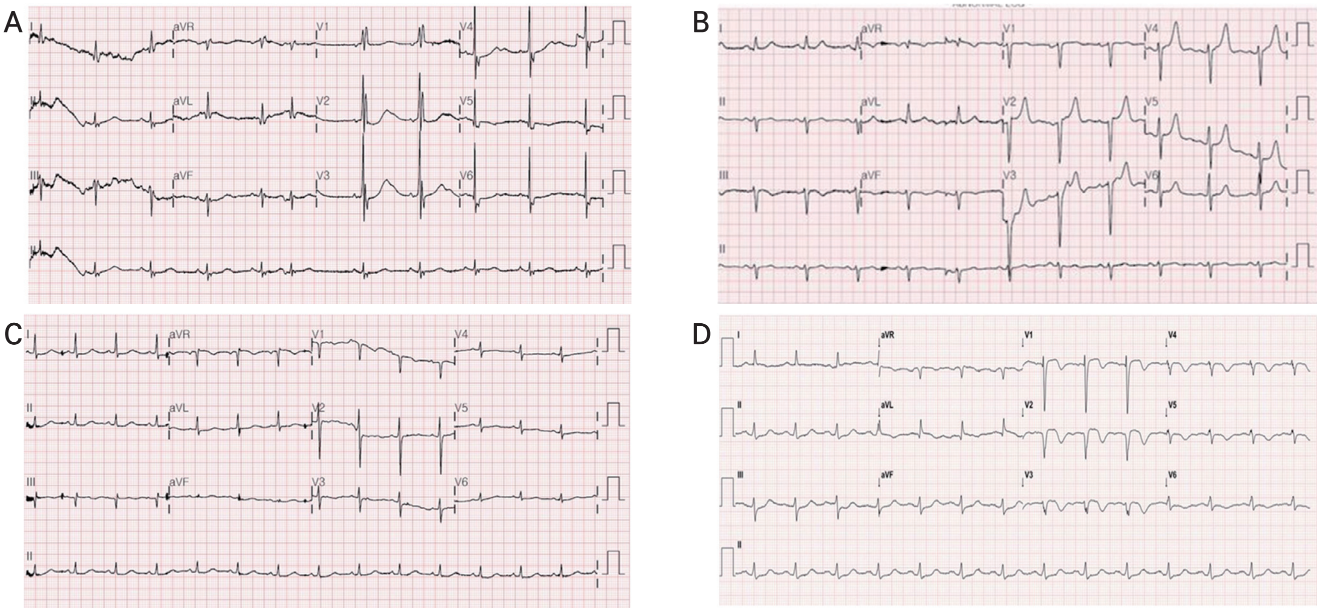

Figure 6. Four ECGs of STEMI cases missed by EMTs (false negative). (A) indicates posterior wall infarction (left circumflex lesion). (B) indicates hyperacute tall T-wave (left anterior descending lesion). (C) indicates minimal aVR ST-segment elevation with multi-lead ST-segment depression (multi-vessel disease). (D) indicates precordial pathologic Q-wave, T-wave inversion, and normalized ST-segment elevation (left anterior descending lesion). ECG: electrocardiogram, STEMI: ST-segment elevation myocardial infarction, EMT: emergency medical technician.

addition, level-1 EMTs with more than 1 year of experience working in the ED showed almost the same degree of accuracy as EMPs.

In developed countries, where a prehospital 12-lead ECG program was introduced earlier and its effects on emergent cardiovascular care have been studied, earlier acquisition and interpretation of ECGs by EMS providers enable faster evaluation of patients with chest pain and shorten their total ischemic time. In addition, by checking the 12-lead ECG before arriving at the destination hospital, a transport protocol to bypass the nearest non-PCI facility and transfer the patient to a reperfusion-capable hospital reduces unnecessary interhospital transfer.[3] From the perspective of EMS providers, a prehospital 12-lead ECG program can improve the accuracy of the prehospital evaluation of patients with chest pain. It can help in the early detection of transient ischemic changes or fatal arrhythmias, such as wide QRS tachycardia that improves or disappears upon arrival at the hospital and provides a comparison between the prehospital ECG and the ECG taken in the ED of patients with ACS. It also contributes to improving the treatment process and outcomes of patients with myocardial infarction in a regional community by notifying the medical staff in the ED and preparing the cardiac catheterization team before the patient arrives. However, for the prehospital 12-lead ECG program to function effectively, it is essential to cultivate highly trained EMS providers and quality management of the prehospital 12-lead ECG program through continuous and repetitive education, evaluation, and feedback.[7,8]

Korea has a history and system of EMSs that differ from those of other developed countries. Through the revision of the equipment standard of 119 ambulances in 2015, advanced defibrillators capable of 12-lead ECG finally began to be deployed in ambulances, the proportion of ambulances equipped with the existing 3-lead ECG machine decreased, and the proportion of ambulances that can take and print 12-lead ECGs increased.[9] However, the rate of 119 EMS transport in patients with acute myocardial infarction was as low as 30.6% in 2016, and the rate of prehospital 12-lead ECG acquisition of 119 EMS providers was also very low (1.3% in 2014, 2.3% in 2015, and 4.5% in 2016). In addition, the rate of inter-hospital transfer of patients with acute myocardial infarction in Korea was 11.5% in 2016.[10]

Few studies have investigated whether level-1 EMTs can properly recognize STEMI using a 12-lead ECG in Korea. In 2010, Jang et al.[11] reported that the STEMI diagnostic ability of level-1 EMTs improved significantly via an in-hospital ECG educational program, but the accuracy of STEMI diagnosis was still low (sensitivity, 48.6%; specificity, 44.3%; accuracy, 45.5%). However, in this study, the diagnostic accuracy of STEMI was significantly higher than those in the previous study, and comparable to foreign studies targeting paramedics.[12] We believe that this is because the level-1 EMTs who participated in this study would have been exposed to significantly more ECGs (>20 per week) after the education they received from EMPs. Huitema et al.[13] reported that exposure to more than 20 ECGs per week could improve the diagnostic accuracy of ECGs regardless of their experiences. The findings suggested that continuous exposure to 12-lead ECG and work experience in the ED are beneficial for improving the STEMI ECG reading ability of level-1 EMTs. Therefore, it can be used as an important tool for training highly skilled EMS providers in prehospital 12-lead ECG programs in Korea.

In developed countries that implement prehospital 12-lead ECG, there have been several observational studies on whether EMS providers can communicate with hospital medical staff by adequately conducting and interpreting 12-lead ECGs. There are three major prehospital ECG interpretation models known. First model is interpretation by experienced paramedics alone, second model is automatic machine reading using a computer algorithm, and third one is reading by doctors via wireless ECG image transmission via Wi-Fi or Bluetooth.[14] However, depending on the available emergency medical resources, geographic conditions, and regional EMS leadership, the optimal model to adopt may vary from region to region. Therefore, further research is required to successfully apply a prehospital 12-lead ECG program that is adequate for the Korean population.

This study has several limitations. First, this was a single-institution study with a relatively small number of participants, and the level-1 EMTs who participated in this study did not have experience with field EMS. Their experience in the ED was as short as 8.7 months on average. Therefore, it is difficult to generalize the conclusions of this study to all level-1 EMTs in Korea. Second, it has not been confirmed whether the culprit lesion can be accurately interpreted on a 12-lead ECG, and the possibility of choosing the correct answer by chance cannot be excluded by simply determining whether the answer is STEMI, NSTE-ACS or nonspecific. Third, this study did not measure the level-1 EMT reading performance of ECGs before participation, and we could not directly compare the effect of improving ECG reading based on clinical experience in the ED. Fourth, considering that automatic ECG equipment readings are printed on paper and that level-1 EMTs and EMPs participating in the study worked in the same ED simultaneously, this study was unlikely to be a completely independent evaluation of the patient's ECG. It is possible that the diagnostic accuracy of the level-1 EMT ECG interpretation was overestimated. Fifth, because this study was conducted on level-1 EMTs working in an emergency medical center, it is not expected to directly reflect the ability of prehospital EMS providers to interpret ECG for STEMI.

In conclusion, if EMTs are given appropriate education and training on 12-lead ECGs, there will be no significant difference in the diagnostic performance of level-1 EMTs for STEMI using a 12-lead ECG compared with EMPs.

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