Original Article

The Impact of Pre-hospital 12-Lead Electrocardiography, Rapid ST-Elevation Myocardial Infarction Detection, and Paramedic-Led Hospital Pre-notification on Door-to-Needle Times

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Abstract

Introduction: Door-to-needle time (DNT) for ST-elevation myocardial infarction (STEMI) in developing countries still falls behind the recommended standard. This study assessed the effects of paramedics performing pre-hospital 12-lead ECG, detecting STEMI, and hospital pre-notification on ambulance scene time, transport time, and door-to-needle time in a developing country. **Method**: This was an observational cross-sectional study with retrospective data comparison. The first stage of the survey assessed paramedics' competency in performing pre-hospital in-ambulance 12-lead ECG and detecting STEMI from twenty 12-lead ECG allocated. The second stage compared the ambulance response time and door-to-needle time between the two groups of pre-hospital ECGs and the first ECG performed upon arrival at the hospital (control group). The time recordings were obtained from the ambulance response data sheet. Data from the control group were obtained from a retrospective chart review. **Results**: Twelve paramedics and 149 patients were included in this study. All paramedics were able to perform pre-hospital 12-lead ECG satisfactorily. Only 2 out of the 12 paramedics had acceptable knowledge of detecting STEMI. The mean scene times for the pre-hospital ECG group (n=82) and the control group (n=66) were 13±7 min and 11±6 min, respectively. The mean transport times were 10±4 min and 9±3 min, respectively. There was an improvement in DTN time (4 minutes–19.8±7.4 minutes vs 23.8±4.8 minutes when STEMI patients were pre-notified). **Discussion**: The performance of the paramedic on pre-hospital 12-lead ECG was acceptable; however, identifying STEMI mimics was poor. Delays on scene and transport time when pre-hospital ECG was performed were as anticipated. **Conclusion**: Introducing pre-hospital ECG in ambulances and pre-hospital pre-notification in developing countries is feasible, and the mean time for ECG is acceptable.

Keywords: *12-lead electrocardiography, STEMI, pre-hospital, door-to-needle time*

INTRODUCTION

Pre-hospital detection of ST-Elevation Myocardial Infarction (STEMI) with in-ambulance electrocardiography (ECG) can decrease the door-to-needle time by an average of 11.5 (95% CI [6.06, 16.94]) minutes per patient. [1] Paramedics can be trained to obtain and interpret ECG; however, how accurately STEMI can be identified is unknown.[2] A previous report from two hospitals within the same region in the present study revealed that knowledge of STEMI detection among paramedics was poor.[3] ECG and early detection of STEMI are needed before the administration of pre-hospital thrombolytic therapy, hence reducing the time to thrombolytic therapy. This therapeutic modality is underutilized in most developing or low- to middle-income countries. [4,5]

Pre-hospital 12-lead ECG has not been initiated in the tertiary centre studied. Assessment of pre-hospital care (PHC) paramedics in performing in-ambulance 12-lead ECG, interpretation of STEMI, and whether it significantly delays total ambulance response time is required to improve door-to-needle time.[6]

This study aims to determine the ability of paramedics to perform pre-hospital 12-lead ECGs and detect STEMI and its influence on critical-time parameters

duration such as transport time, on-scene time, and door-to-needle time (DTN). It also determines whether the time taken to obtain a pre-hospital 12-lead ECG is acceptable. The recommended time for obtaining a 12-lead ECG is ≤8 minutes. This time is significantly associated with achieving PCI in ≤90 minutes.[7]

METHODOLOGY

Study Design and Setting

This was an observational cross-sectional study with retrospective comparison performed in the pre-hospital unit of Hospital Tuanku Muhriz (HCTM), National University of Malaysia Medical Centre, Cheras, Kuala Lumpur, from July 2018 to September 2019. Control data were collected retrospectively from ambulance run charts between January and December 2017.

1st stage: Assessment of pre-hospital care paramedics

Pre-hospital paramedic recruitment was performed in July 2018. Paramedics were briefed on the general symptoms of cardiac chest pain, clinical features, pathophysiology, and ECG diagnosis of STEMI. Pre-hospital 12-lead ECG and the ability to detect STEMI from 20 sets of ECGs were assessed.

2nd stage: performing pre-hospital 12-lead ECG

A 12-lead ECG was then performed on scene during the response of the PHC team to patients with chest pain. This phase was carried out from September 2018 to September 2019. Patients with chest pain were identified after calls were received from the Medical Emergency Coordinating Centre (MECC). MECC then activated the PHC HCTM-PPUKM team, and the case responded as per the protocol. ECG was performed on patients who fulfilled the eligibility criteria. The emergency department (ED) was pre-notified if STEMI was diagnosed. Pre-hospital paramedics will call the EDCC (Emergency Department Communication Centre), and an announcement will be made to prepare for the reception of a potential STEMI patient. The arriving patient was then directed straight to the red zone in the ED where the ECG was repeated, bypassing triage and vital sign monitoring. STEMI diagnosis and management (thrombolysis vs PCI) will be discussed with the cardiology team on call. Comparisons between pre-hospital diagnoses and treating physicians were performed to determine the sensitivity and specificity of STEMI detection by paramedics. Data from ambulance records between January and December 2017 for chest pain patients were retrieved for the control group (no pre-hospital ECG). Due to the same study site and small PHC unit, the same cohort of paramedics (n=12) in stage 1 was employed for stage 2.

Participants

Paramedics participated in stages 1 and 2 of the study and actively worked in the pre-hospital care unit during the study period. All patients with complaints of chest pain were eligible for the study. Patients who were less than 18 years old, hemodynamically unstable, had cardiorespiratory arrest, experienced trauma, were pregnant, were 30 days postpartum, or were unable to perform 12-lead ECG at the pre-hospital scene for any reason were excluded. All participants who fulfilled the eligibility criteria during the study period were employed. Retrospective data for the control group followed the same eligibility criteria.

Variables

The outcome for the 1st stage, pre-hospital 12-lead ECG, was satisfactorily performed when paramedics were able to perform all the required steps on the checklist. The satisfactory outcome for STEMI detection from the ECG is that paramedics would be able to detect STEMI from all twenty ECG allocated and an 80% correct rate of ECG diagnosis (9 ECG with STEMI).

During the 2nd stage, a favourable outcome would be if the door-to-needle time could be reduced if pre-hospital ECG was performed. The total pre-hospital time consists of response time (the time from ambulance call receipt to arrival of the ambulance at the scene), on-scene time (the time from arrival of the ambulance at the scene to departure), and transport time (the departure time of the ambulance from the scene to arrival at the hospital).[8] Potential confounders for the ability to perform pre-hospital ECG and detection of STEMI among paramedics include years of experience and other education/courses taken by the paramedics.

Data Sources/Measurement

Performance of pre-hospital 12-lead ECG

A psychomotor assessment was conducted on paramedics by performing a 12-lead ECG on a standardised patient following a verified checklist by two emergency specialists. The ECG was performed in an ambulance to replicate the scenario of pre-hospital care. Marks were awarded based on one (done correctly) or no marks (for not done steps or done incorrectly). Marks were given based on 8 steps. These

steps included the correct position of the chest leads (V1-V6), the correct position of the limb leads, the proper position of the electrodes, proper instruction to patients during ECG recording, recording patient's information, ECG monitoring, ensuring an acceptable quality of ECG tracing, heart rate identification and identifying baseline artifacts. The checklist is a standard protocol used for ECG tracing and was presented and verified by two content experts. The researcher collects the marks and records them on a data collection sheet.

Performance of detecting STEMI from sets of ECGs given

Each paramedic was given 20 ECG recordings for interpretation and diagnosis. Each paramedic was required to determine the ECG with STEMI. There were 9 ECGs of STEMI and 11 ECGs of other diagnoses. The non-STEMI ECG consists of 2 cases of right bundle branch block (RBBB), 2 cases of ventricular pacing, 2 cases of left ventricular hypertrophy (LVH), 2 cases of left bundle branch block (LBBB), 2 cases of supraventricular tachycardia (SVT), and 1 case of sinus rhythm. All the ECG recordings were obtained from http://www.litfl.com.[9] The selection of this ECG was based on an equal distribution of STEMI and STEMI mimics and was verified by content experts. The researcher records the results from the ECG detected by the paramedics.

Performance of real-time 12-lead ECG

During this study section, where paramedics perform real on-scene pre-hospital 12-lead ECG, on-scene time, transport time, and time arrival at the ED were recorded from the ambulance response registry for each activation. All the stated times were recorded during the scene. Data were collected from these records after the scene by the researcher. Written consent for patients was not needed, as 12-lead ECG is part of the necessary investigation for every patient with chest pain. Only verbal consent was taken. Data were extracted from HCTM, ambulance run reports, emergency thrombolysis records, and in-hospital records. Ambulance run time was compared with retrospective data, for which no pre-hospital ECG was performed.

Bias

Steps were taken to reduce bias. Convenience sampling was employed for paramedic and patient recruitment. The same sample size was used retrospectively to calculate the ambulance time without pre-hospital ECG recordings. Only one researcher was involved in data collection. The same cohort of paramedics was taken from stage 1 and stage 2, as briefing was made to the same group on ECG/STEMI detection and clinical symptoms. It was not feasible to exclude paramedics who failed in STEMI detection in the first phase because the group of PHC paramedics in the unit was small (n=12) and the service run was real-time. This can lead to considerable bias in data interpretation in the second stage.

Study size

The study size was calculated based on an average ambulance response from HCTM and PPUKM for all medical cases every month. The calculation was done using the open epi website. A total of 68 cases were suggested: 20% were added to avoid missing data or a dropout rate. The adequate sample size was 81.

Quantitative variables

Quantitative variables were collected and handled by only one researcher to avoid mishandling. The data were recorded in a data collection sheet and entered into the statistical program for data analysis.

Statistical methods

SPSS version 22.0 (IBM SPSS Statistics 2014) was used for statistical analysis. Data from paramedic demography and ambulance run time were analysed into mean and standard deviations. On-scene time was obtained by calculating the difference in the time of ambulance departure from the scene with the arrival time at the scene. The transport time was calculated by subtracting the arrival time at the hospital from the departure time from the scene. The control population was obtained from retrospective data. Associations between categorical variables and demographic characteristics were determined using crosstab analysis/t-tests, and non-parametric data were analysed using the Mann–Whitney U test. A P value of less than 0.05 for a two-sided test was considered statistically significant. Missing data were excluded from the analysis. Sensitivities and specificities of detection of STEMI were analysed in the second phase of the study, where true STEMI was defined as treatment with thrombolysis following consultation with a cardiologist.

RESULTS

Participants

Twelve PHC paramedics and 149 patients with chest pain were eligible, included, and analysed in the study. 84 patients from the study group (patients with pre-

hospital ECG) and 65 patients from the control group (patients without pre-hospital ECG) were included. All paramedics in the pre-hospital unit participated in the study. Some female patients refused to participate to perform a pre-hospital ECG due to a lack of available female pre-hospital staff. Table 1 shows the demographic profile of the PHC paramedics, and Table 2 shows the demographic profile of the patients. The flow chart of the results is depicted in Figure 1.

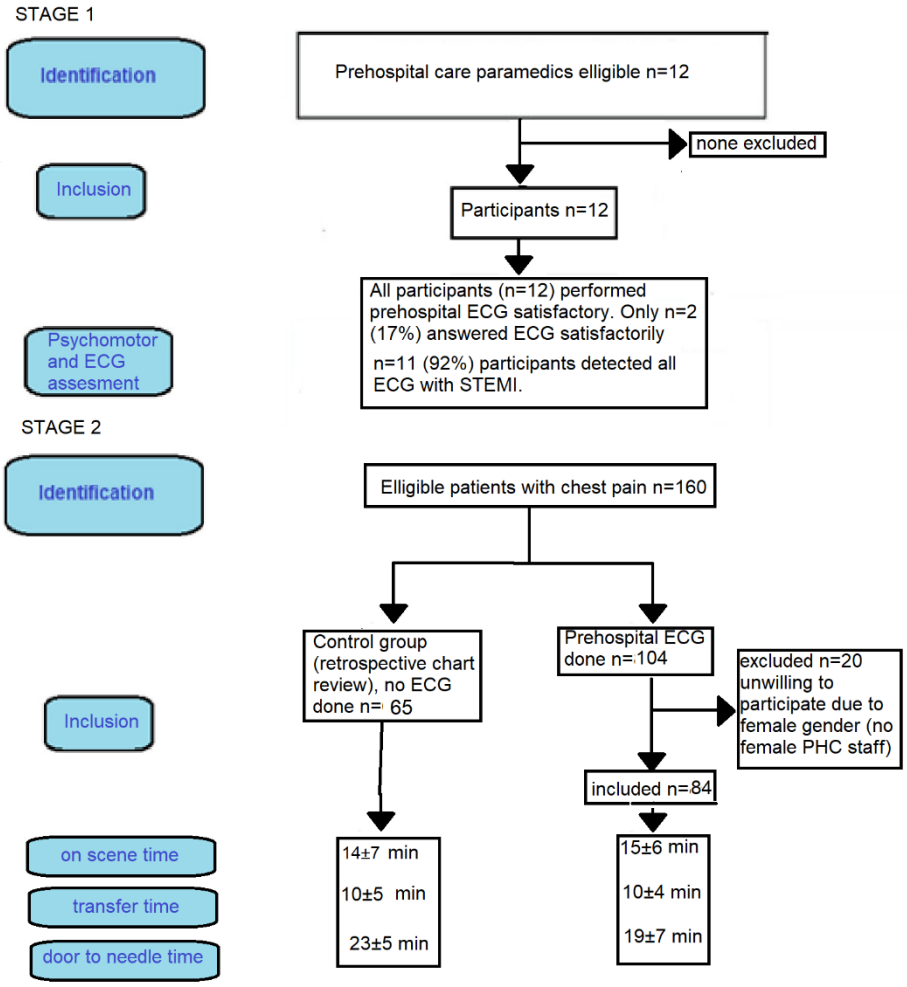

Figure 1: Results flow chart

Descriptive data

As shown in Table 1, the majority of PHC paramedics had post-basic training with more than five years of experience as paramedic and working in the PHC unit. All had completed Basic and Advanced Cardiac Life Support courses. All of the paramedics were male. Psychomotor assessment in performing 12 lead ECGs among PHC paramedics includes the proper correct position of leads, correct attachment of electrodes, quality tracing, communication with the patient, identifying artifacts, complete printing, and removal of leads. All of the paramedics were able to perform 12 lead ECGs correctly. Eleven out of the 12 paramedics were able to diagnose STEMI in all 9 STEMI ECGs. However, the majority (10 out of 12) perceived a non-STEMI ECGS, which was LBBB, paced rhythm, and LVH, as a STEMI (Table 1).

Main Results

Among the PHC 12-lead ECG done, 11 (13.1%) out of the 84 patients with complaints of chest pain were confirmed to have a diagnosis of STEMI, and 71 (84.5%) did not have STEMI. Six (54.5%) out of the 11 patients were correctly diagnosed with STEMI by the PHC team. Five (45.5%) out of 11 cases were missed from the STEMI diagnosis, where they did not interpret the ECG as STEMI on a STEMI ECG (Table 3). Hence, the true positive is 6 (specificity of 54.5%), and the true negative is 58 (sensitivity of 81.7%).

Table 1: Demographic data for PHC staff and patients

PHC staff demographic (n=12)	Description	Number (n)	Percentage (%)
Age (years)	Minimum, maximum Mean SD	25,43 34.17 (±4.49)	-
Highest Level Education	Diploma Post Basic Degree Master	3 8 0 1	25 66.7 0 8.3
Experience as Paramedic	1 to 5 years More than 5 years	1 11	8.3 91.7
Experience in ED	1 to 5 years More than 5 years	3 9	25 75
Experience in PHC Unit	Less than 1 year 1 to 5 years More than 5 years	1 2 9	8.3 16.7 75
Passing psychomotor assessment in performing 12 lead ECG		12	100
Satisfactory STEMI interpretation of 12 lead ECG (>80% of correct diagnosis for 12 ECG		2	20
Able to detect all true STEMI from 12 lead ECG (true positive)		11	92
Identified STEMI in a non-STEMI ECG (false positive)		10	83

Table 2: Demographics of patients with chest pain.

Patients demographic Total (n = 149)	Study group: with pre-hospital ECG, n=84	Control group: without pre-hospital ECG, n=65	P value 95% CI p value<0.05
Age (years)			
Minimum, maximum	24, 94	22, 94	0.549
Mean± SD	55 ±16	54 ±15	
Gender			
Female	12 (14%)	17 (26%)	-
Male	71 (84%)	48 (73%)	
Ethnicity			
Malay	44 (52%)	34 (52%)	
Chinese	23 (27%)	18 (27%)	
Indian	14 (16%)	10 (15%)	
Others	3 (3%)	3 (4%)	
Medical Condition			
Diabetes	31(37%)	19 (29%)	-
Hypertension	37 (44%)	22 (34%)	
IHD	27 (32%)	20 (30%)	
Dyslipidaemia	17 (20%)	10 (15%)	

Table 3: Ambulance time, diagnosis, and recipient of thrombolytic therapy for patients with chest pain

Patient's ambulance time and diagnosis (n = 149)	Study group: with pre-hospital ECG, n=84	Control group: without pre-hospital ECG, n=65	P value (95%CI) p value<0.05
Mean On Scene Time ± sd./	15±6	14±7	0.101
Max, Min (minutes).	38,5	38,4	
Mean Transport Time ± sd/	10±4	10±5	0.134
Max, Min (minutes).	28,1	35,3	
Mean Door-to-needle Time ± sd/	19±7	23±5	0.775
Max, Min (minutes)	30,10	31,15	
Number received thrombolysis	6	10	-
Confirmed diagnosis of STEMI =n	11	10	-

*Mann-Whitney test at 95% confidence interval

Table 4: Crosstabulation number of cases in which the PHC detects STEMI with confirmation STEMI by the in-hospital team within the study group (n=84)

		In Hospital Diagnosis*		
		STEMI	Not STEMI	Total
PHC Interpreted	STEMI	6	13	21
	Not STEMI	5	58	63
	Total (in-hospital diagnosis)	11	71	84

*Reference standard

DISCUSSION

Key results

From the psychomotor assessment during the first phase of this study, all paramedics could perform 12 lead ECGs in an ambulance in a pre-hospital setting. This includes the correct position of leads, correct attachment of electrodes, communication with the patient, identification of artefacts, complete printing, and removal of leads. This allows paramedics to fulfil the recommendation that a 12-lead ECG should be performed at the point of first medical contact for patients with signs or symptoms consistent with acute STEMI.[10,11]

Eleven out of the 12 paramedics were able to diagnose STEMI in all 9 STEMI ECGs. However, the majority (10 out of 12) perceived a non-STEMI ECGS, which was LBBB, paced rhythm, and LVH, as a STEMI. In

developed countries, paramedics have been reported to be able to recognise STEMI, with a sensitivity and specificity of 80% to 95% and 86% to 96%, respectively.[2] UK paramedics were able to satisfactorily detect STEMI 20 years ago.[12] Unfortunately, we lag over 20 years behind a developed country.

Only 2 (16.7%) of the 12 paramedics scored more than 80% correct detection of STEMI. All the paramedics labelled a Left Bundle Branch Block ECG pattern as a STEMI. However, 11 paramedics (91.7%) correctly recognized a STEMI ECG (Table 1). This finding is comparable to that of a study by Nik Azlan et al. (2019) in the same setting, where the passing percentage was 80%, in which only 20.8% of participants passed.[3] The poor passing rate requires intervention, such as further training, incorporating intensive ECG training in diplomas or bachelor's degrees, and scheduled renewal of the Advanced Cardiac Life Support (ACLS) license. An alternative would be implementing online medical services, where the ECG is transmitted directly to the ED physician or senior medical officer in charge.

During the second phase, true positive patients (STEMI patients recognized by the PHC team and confirmed with STEMI in the ED) comprised 6 out of 20 STEMI patients. The other 14 patients were non-STEMI when the ECG was repeated in the ED. Missed STEMI by the PHC staff were only 5 out of the total 62 patients (8%). PHC paramedics had a specificity of 30% and sensitivity of 91.9% compared with the in-hospital diagnosis of STEMI made by the treating physician. The high sensitivity in ruling out STEMI is comparable to that reported in a study by Whitbread et al. (2002) on paramedics in the UK. (97% sensitivity and 91% specificity in diagnosing STEMI).[12] The confounding factor that resulted in discrepancies in ECG was the development of STEMI during transport.

The mean on-scene time of the ECG PHC group was 15 ±6 minutes, in contrast to the control group which was 14±7 minutes. The difference in the mean is due to the time taken to perform the pre-hospital 12-lead ECG, which is within the time recommended by the AHA (≤ 8 minutes).[7] This is comparable to a study done by Patel et al. (2012) among paramedics in San Diego, where there was a minimal increase in median scene time (18 seconds) (19 min 10 seconds vs 19 min 28 seconds) ($p<0.01$ (95% CI)).[13]

There was no difference in the mean transport time between the study and comparison groups. This is comparable with a study by Patel et al., where the delay in transport time was minimal (8 seconds). [13] This is explained as the transport time, which is defined as the time of departure of the ambulance from the scene to arrival at the hospital. Hence, a 12-lead pre-hospital ECG was performed at the scene on a static ambulance before departure, and as expected, this should not affect the transport time.

The analysis of on-scene time, transport time, and DTN time between the study group and the comparison group is shown in Table 2. There was no significant difference in the mean on-scene time, transport time, or DTN time between the groups. This is due to an insufficient number of patients (n=6) who received thrombolytic therapy in this study. The mean on-scene time for the study group was 1 minute slower than that for the control group. The mean transport time was equal for both groups.

The door-to-needle time for the interventional group was 4 minutes shorter than that for the control group. (19.8±7.4 vs 23.8±4.8 minutes). Pre-notification allows early preparation of equipment and medication for ED staff to perform thrombolytic therapy. Pre-notified patients were directed straight to the red zone without undergoing triage assessment. This finding is comparable with that of a study by Kobayashi et al. (2016), which reported an improvement of 19 minutes (68 minutes vs 49 minutes) in door-to-balloon time with EMS notification.[14] Missed STEMI by the PHC staff was 5 out of 62 patients (8%). These patients received thrombolytic therapy but were not notified earlier by PHC staff.

LIMITATIONS

Gender differences between patients and PHC staff limit the number of patients, as for female patients a chaperone is needed to perform ECG. All paramedics in this study were male. The ambulance crew should include an equal number of both genders to facilitate the smooth process of pre-hospital ECG acquisition. This study only included patients with complaints of typical chest pain, whereas those with atypical presentations, such as fatigue and non-chest pain, were not included. Lim et al. (2019) reported that 18% of the STEMI population presented with atypical symptoms.[15] Further studies should include atypical findings, especially among females and diabetic patients with neuropathy. Many factors lead to inadequate sample sizes, especially among patients who receive thrombolytic therapy.

No accurate measurement of time to the second was taken. The time in seconds was not recorded on the ambulance run sheet. The time measurement was not synchronized between the PHC staff and ED staff. Data regarding the ambulance response time were collected by the researcher retrospectively from the pre-hospital records. It was not possible for a researcher to

be available all the time on the ambulance to personally record all the data on the scene for logistic reasons and medicolegal reasons, as there is a limit on the number of personnel allowed on the ambulance. Data were extracted from pre-hospital medical records.

The control group was retrospective, as it was a comparison between the previous system and the current new system. However, this can lead to many confounding issues that have not been addressed, such as different staff, shift work, and time frames.

RECOMMENDATION

A multicentre study with a larger sample size involving pre-hospital ECG, pre-notification, and transmission of ECG signals online via a STEMI network including cardiologists and emergency physicians is suggested. A better male-to-female ratio among the pre-hospital care team is needed before pre-hospital ECG implementation.

CONCLUSION

Paramedics of a representative of a developing country were able to perform pre-hospital ECG and initiate hospital pre-notification of STEMI. Eleven out of the 12 paramedics were able to detect STEMI in all STEMI ECGs. However, the majority of them perceived non-STEMI/STEMI mimics ECG as STEMI, resulting in high false positive rates. The time estimated to perform an ECG was acceptable. Pre-hospital ECG and pre-notification did not significantly influence transport, on-scene, or door-to-needle time. Nevertheless, there was a slight improvement in the mean DTN time following pre-hospital ECG and pre-notification.

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