Improved door-to-balloon time for primary percutaneous coronary intervention for patients conveyed via emergency ambulance service

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ABSTRACT

Introduction: Early reperfusion of ST-segment elevation myocardial infarction (STEMI) results in better outcomes. Interventions that have resulted in shorter door-to-balloon (DTB) time include prehospital cardiovascular laboratory activation and prehospital electrocardiogram (ECG) transmission, which are only available for patients who arrive via emergency ambulances. We assessed the impact of mode of transport on DTB time in a single tertiary institution and evaluated the factors that affected various components of DTB time.

Methods: We conducted a retrospective cohort study using registry data of patients diagnosed with STEMI in the emergency department (ED) who underwent primary percutaneous coronary intervention. We compared patients who arrived by emergency ambulances with those who came via their own transport. The primary study end point was DTB, defined as the earliest time a patient arrived in the ED to balloon inflation. As deidentified data was used, ethics review was waived.

Results: A total of 321 patients were included for analysis after excluding 7 with missing data. The mean age was 61.4±11.4 years old with 49 (15.3%) females. Ninety-nine (30.8%) patients arrived by emergency ambulance. The median DTB time was shorter for patients arriving by ambulance versus own transport (52min, interquartile range [IQR] 45–61 vs 67min, IQR 59–74; *P*<0.001), with shorter door-to-ECG and door-to-activation time.

Conclusion: Arrival via emergency ambulance was associated with a decreased DTB for STEMI patients compared to arriving via own transport. There is a need for public education to increase the usage of emergency ambulances for suspected heart attacks to improve outcomes.

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INTRODUCTION

Early reperfusion of ST-segment elevation myocardial infarction (STEMI) has been shown to result in better outcomes,[1-3] and guidelines for treatment of STEMI recommend a rapid and coordinated response.[4] The American Heart Association guidelines released in 2014 recommend a door-to-balloon (DTB) time of less than 90 minutes,[5] and timings of less than 60 minutes have been associated with better outcomes.[6]

In Singapore, patients presenting to the emergency departments (ED) of our public hospitals with acute STEMI are usually offered emergency percutaneous coronary intervention (PCI) as first-line treatment. In line with international recommendations, the national target for DTB time is 90 minutes. This target is met by public hospitals more than 90% of the time.[7]

Worldwide, interventions that have resulted in shorter DTB time include direct emergency physician activation of cardiovascular laboratory (CVL), prehospital CVL activation and prehospital electrocardiogram (ECG) transmission.[8-10] As these interventions are only available to patients being conveyed by emergency ambulances, it is recommended that patients should call an emergency ambulance when experiencing symptoms such as severe

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chest pain, especially when associated with sweating, breathlessness, nausea or vomiting. Despite this, some international studies report that only 60% of STEMI patients use an ambulance.[11] In Singapore, a previous study found that only 50% percent of STEMI patients come to hospital by emergency ambulance.[12]

We aimed to study the impact of mode of arrival on DTB time in our institution, Singapore General Hospital. We hypothesise that usage of emergency ambulances will be associated with shorter DTB time compared to arriving via own transport. Subsequently, we aimed to analyse the impact of mode of transport on the various components of DTB time. Amongst patients conveyed by emergency ambulances, we further analysed the impact of hospital ED standby, ECG transmission and CVL activation on the various components of DTB time.

METHODS

Study design

We conducted a single-centre retrospective cohort study of all patients who underwent emergency PCI for STEMI from the ED from January 2018 to August 2019. We conducted a chart review combining emergency department records, cardiology department registry data, as well as an ongoing national myocardial infarction registry. Ethics review was waived by the SingHealth Centralised Institutional Review Board (2020/3011).

Setting

Singapore General Hospital is Singapore's largest tertiary hospital with 1,735 beds. The ED sees an annual volume of more than 125,000 patients, with emergency PCI supported by the National Heart Centre Singapore, a specialist heart centre.

All patients presenting to the ED with a complaint that could represent an acute coronary syndrome are prioritised for an ECG. This is done in the ambulatory triage area for ambulatory patients and in the critical care area for non-ambulatory patients. All ECGs are immediately reviewed by a senior doctor, who would assess for the presence of STEMI.

Singapore's emergency medical services system is run by the Singapore Civil Defence Force (SCDF). The service is activated by a centralised 995 dispatching system, with the service handling 191,468 ambulance calls in 2019.[13] SCDF's 60 ambulances are manned by specially trained paramedics, who are able to put an ED on standby for patients in whom they suspect a STEMI, and are also able to fax ECGs on route to the ED. On receipt of an ECG diagnostic of a STEMI, the emergency physician has the option to activate the CVL lab prior to the patient's arrival.[9,12]

Data source and study population

All patients who presented to the ED with STEMI and subsequently underwent emergency PCI were included for analysis. Patients with missing data on mode of arrival or DTB time were excluded from analysis.

We obtained the list of patients from the Primary PCI database that is maintained by the National Heart Centre Singapore. This database comprises patients who underwent primary PCI from the emergency department. It contains demographic data and a breakdown of the components of DTB time, including the time of arrival, time of ECG, time of CVL activation, time of arrival to the CVL lab, as well as time of perfusion. The database has exclusion criteria that exclude patients who suffered a cardiac arrest, had cardiogenic shock requiring resuscitation or showed a non-diagnostic ECG. As such, only patients with clear STEMI on ECG and did not require prolonged resuscitation in the ED were included in this cohort. Full exclusion criteria are available in Table S1 of Supplementary Materials (in the online version of this article.)

Data on mode of arrival were obtained from the ED records. The triage note written by nurses contains information on the mode of arrival. We also matched outcomes from the Singapore Myocardial Infarction Registry,[14] which is a national registry that contains outcome data pertaining to our patients. We also accessed the SCDF ECG transmission records to identify patients for whom prehospital ECGs were transmitted. Data were extracted by 2 study team members, with disagreements resolved by consensus.

Study variables

Our primary outcome was DTB time in minutes, defined as the earliest time the patient was registered in the ED to the time the balloon was inflated. We also examined inpatient mortality as well as the components of DTB time as secondary outcomes, such as door-to-ECG time, and door-to-CVL time. Components of DTB time were recorded by the ED staff and CVL staff, and extracted from the Primary PCI database.

The independent variable was mode of arrival, which was obtained from the ED patient records. Other independent variables included prehospital transmission of ECG as well as whether the ED was put on standby. These were obtained from the ED records and SCDF ECG transmission records.

Data analysis

We described patient characteristics using percentages for categorical data. Mean and standard deviation, or median and interquartile range (IQR) were used for normally and non-normally distributed continuous variables, respectively. Statistical comparisons for differences in baseline characteristics among patients arriving by emergency ambulance and own transport were performed using chi-square tests for categorical variables. T-test and Wilcoxon rank-sum test were used for normally and non-normally distributed data, respectively. DTB time and its components were described using median and IQR based on mode of transport.

Subsequently, we conducted multivariable linear regression with DTB time in minutes as the primary outcome. For the predictors, we included factors that have been reported to be associated with DTB time, including age, sex, presentation during working hours, and ambulance usage.[15,16] Secondary outcomes include door-to-ECG time, door-to-activation time, activation-to-lab time and lab-to-balloon time.

The primary and secondary endpoints (in minutes) were log transformed for use in regression models to maintain normality. Statistical output is therefore reported as percent change in time and 95% confidence interval. All tests were 2-sided, with statistical significance predefined as a P value <0.05.

All statistical analyses were performed using R software version 4.0.2.

RESULTS

Patient characteristics

There were 328 patients in the cohort from January 2018 to August 2019. After excluding 7 patients due to missing data, 321 patients were included for analysis.

Table 1 lists the patients' characteristics. Median age was 61.2 years and 82.9% were men. In terms of ethnicity, 62.6% were Chinese, 13.1% were Malay and 13.4% were Indian. Compared to Singapore Census of Population 2020 data (Chinese 74.3%, Malays 13.5%, Indians 9.0%), a larger proportion of our study cohort were Indians.

In total, 99 (30.8%) patients arrived by emergency ambulance and 222 (69.2%) arrived via own transport. Fig. 1 shows the study flow chart. Among the characteristics listed in Table 1, age, diabetes mellitus and smoking status was different between those arriving via emergency ambulance versus own transport.

Association between DTB timings, inpatient mortality and mode of transport

Fig. 2 shows that the median DTB time was shorter for patients arriving by emergency ambulance (52min, IQR 45–61) than by own transport (67 min, IQR 59–74, P<0.001). Further analysis showed that arrival via emergency ambulance was also associated with shorter median door-to-ECG time (11 min, IQR 5–15 vs 1 min, IQR 0–3; P<0.001) and door-to-activation (18 min, IQR 12–25 vs 2 min, IQR 0.10–7.50; P<0.001) (Table 2). There was no difference in inpatient mortality among patients arriving by emergency ambulance vs own transport (6.1% vs 2.7%, P=0.252)

DTB timings and prehospital measures

Table 3 shows median DTB time of patients based on whether they had prehospital ED standby, ECG transmission and CVL activation. Patients arriving via emergency ambulance without prehospital standby had a median DTB time of more than 60 minutes. With each additional measure (standby, prehospital ECG transmission and prehospital CVL activation), there was a trend towards shorter DTB times.

Other factors affecting various components of DTB time

Table 4 shows the results of multivariate adjustment for potential confounders (age, sex, office hours arrival). Usage of emergency ambulance remained significantly associated with shorter DTB time (18.5% shorter, 95% CI -22.3% to -14.5%, P<0.001), largely attributable to decreased door-to-ECG (87.7% shorter, 95% CI -91.7% to -81.8%, P<0.001) and door-to-CVL activation times (90.6% shorter, 95% CI -93.6% to -86.2%, P<0.001). Presentation during office hours was also significantly associated with shorter DTB time (8.5% shorter, 95% CI -12.5% to -4.3%, P<0.001), largely attributable to decreased time from arrival
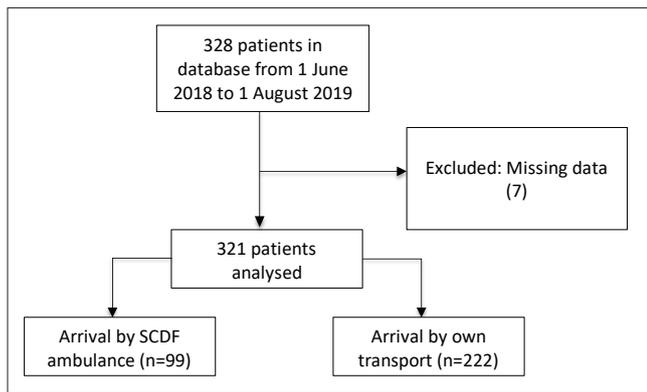
Fig. 1. Study flow chart.
SCDF: Singapore Civil Defence Force

at CVL lab to balloon inflation (21.1% shorter, 95% CI -28.3% to -13.2%, $P<0.001$)

DISCUSSION

Emergency ambulance usage and DTB time

In this study, we found that arrival via emergency ambulance was associated with DTB times roughly 15 minutes shorter than arriving via other modes of transport.

Prior studies have found that prehospital ECG transmission and CVL activation reduces DTB time. A nationwide, before- after-study in Singapore, showed a reduction of DTB time of 24 minutes after

Table 1. Characteristics of patients

| Characteristics	Own transport (n=222) No. (%)	Emergency ambulance (n=99) No. (%)	*P* value
Man	182 (82.0)	90 (90.9)	0.059
Age, mean (SD), years	62.47 (11.01)	58.98 (11.85)	0.011
Race			0.085
Chinese	147 (66.2)	54 (54.5)	
Malay	26 (11.7)	16 (16.2)	
Indian	31 (14.0)	12 (12.1)	
Others	18 (8.3)	17 (17.1)	
Office-hours presentation	81 (36.5)	45 (45.5)	0.163
Day of the week			0.152
Monday	31 (14.0)	10 (10.1)	
Tuesday	35 (15.8)	16 (16.2)	
Wednesday	30 (13.5)	13 (13.1)	
Thursday	26 (11.7)	16 (16.2)	
Friday	29 (13.1)	21 (21.2)	
Saturday	37 (16.7)	7 (7.1)	
Sunday	34 (15.3)	16 (16.2)	
Diabetes mellitus	78 (35.3)	20 (21.1)	0.017
Hypertension	123 (55.7)	46 (48.4)	0.289
Dyslipidaemia	128 (57.9)	47 (49.5)	0.207
Current smoker	72 (32.6)	43 (45.3)	0.043
Prior myocardial infarction	23 (10.4)	8 (8.4)	0.735
Cerebrovascular disease	10 (4.5)	3 (3.2)	0.761
Peripheral arterial disease	5 (2.3)	1 (1.1)	0.672
Current dialysis	4 (1.8)	1 (1.1)	1

SD: standard deviation
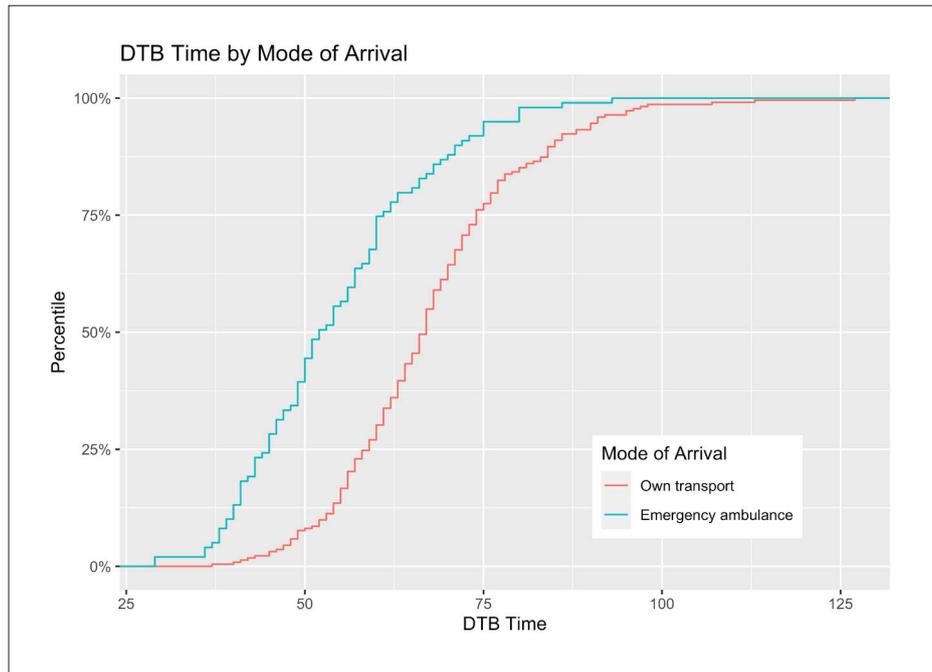
Fig. 2. DTB time by mode of arrival.
DTB: door-to-balloon

Table 2. Door-to-balloon (DTB) parameters and mortality by mode of arrival

DTB parameters	Own transport (n=222)	Emergency ambulance (n=99)	*P* value
DTB time, median (IQR), min	67.00 (59.00–74.00)	52.00 (45.00–60.50)	<0.001
DTB time <60 min, no. (%)	67 (30.2)	74 (74.7)	<0.001
DTB time <90 min, no. (%)	210 (94.6)	98 (99.0)	0.124
Deceased during stay, no. (%)	6 (2.7)	6 (6.1)	0.252
Door-to-ECG time, median (IQR), min	11.00 (5.00–15.00)	1.00 (0–3.00)	<0.001
Door-to-CVL activation time, median (IQR), min	18.00 (12.00–25.00)	2.00 (0.10–7.50)	<0.001
CVL activation to CVL arrival, median (IQR), min	29.00 (25.00–33.00)	30.00 (25.00–36.00)	0.178
CVL arrival to balloon, median (IQR), min	19.00 (14.00–24.00)	17.00 (13.00–22.75)	0.126

CVL: cardiovascular laboratory; ECG: electrocardiogram; IQR: interquartile range

Table 3. Door-to-balloon (DTB) time for various prehospital factors

Prehospital factor	DTB time, median (IQR), min
Arriving via own transport (n=222)	67.00 (59.00–74.00)
Arriving via SCDF but ED not put on standby (n=7)	62.00 (58.00–71.50)
Arrived via SCDF, ED put on standby but no ECG transmitted (n=37)	54.00 (44.00–67.00)
Arrived via SCDF, ED put on standby, ECG transmitted but no prehospital activation (n=15)	51.00 (45.50–60.00)
Arrived via SCDF, ED put on standby, ECG transmitted with prehospital activation (n=40)	51.00 (43.00–57.25)

ECG: electrocardiogram; ED: emergency department; IQR: interquartile range; SCDF: Singapore Civil Defence Force

Table 4. Variables associated with change in components of door-to-balloon time after adjustment for confounders

	Ambulance usage (95% CI)	*P* value
Door-to-balloon time	18.5% shorter (-22.3 to -14.5%)	**<0.001**
Door-to-ECG time	87.7% shorter (-91.7 to -81.8%)	**<0.001**
Door-to-activation time	90.6% shorter (-93.6 to -86.2%)	**<0.001**
Activation-to-lab time	10.5% longer (-2.5 to 25.5%)	0.12
Lab-to-balloon time	6.2% shorter (-15.2 to 3.8%)	0.22
	Office-hours presentation (95% CI)	***P* value**
Door-to-balloon time	8.5% shorter (-12.5 to -4.3%)	**<0.001**
Door-to-ECG time	1.5% longer (-29.6 to 46.2%)	0.93
Door-to-activation time	1.4% shorter (-31.1 to 41.1%)	0.94
Activation-to-lab time	9.7% shorter (-19.8 to 1.64%)	0.09
Lab-to-balloon time	21.1% shorter (-28.3 to -13.2%)	**<0.001**

CI: confidence interval; ECG: electrocardiogram
P values in bold are significant

implementation of out-of-hospital ECG recording and transmission.[9] Another study by Rao et al. showed that mean DTB time for patients was reduced from 90.5 to 60.2 minutes when ECG was transmitted prehospital.[8] In both studies, prehospital CVL activation was done if STEMI was diagnosed on the transmitted ECG prior to hospital arrival.

As such capabilities are only available to patients arriving by emergency ambulance, this might account for some of the reduction in DTB time that our study has identified. The main timings impacted by mode of transport relate to processes within the ED such as obtaining an ECG, with no impact on timings after CVL activation. This suggests that there are workflows within the ED pertaining to the patients arriving via emergency ambulance that allow for speedier CVL activation, and deeper analysis of the processes might identify potential areas of improvement for patients arriving via own transport. Notably, a prior study by Lee et al. has suggested that door-to-ECG time is a key in reducing DTB time.[17] In their study, they achieved a median door-to-ECG time of 5 minutes for walk-in patients.

Low rates of emergency ambulance usage

Our study population had a low proportion of STEMI patients who arrived via emergency ambulance. Compared to an emergency ambulance usage rate of 50–60% reported by national and international studies,[11,12] our study population had an ambulance usage rate of 30.8%. This could be due to the National Heart Centre Singapore being co-located with our hospital. Existing patients on follow-up with the specialist centre as well as patients who wish to be treated there might opt to be transported via their own transport, as there is public awareness that emergency ambulances do not allow users to choose their destination, and always convey patients to the nearest hospital. This is an area that would benefit from public education campaigns on the appropriate usage of ambulances.

Other factors affecting DTB time

When we analysed other factors that impacted various components of DTB time, we noted that presentation after hours was associated with a longer DTB time, which was largely related to longer timings after activation of CVL. This is in agreement with a large prospective observational study in England, which showed that after-hours admission was associated with a longer DTB time.[16] Our findings are unique as we were able to break down the components of DTB time to see which aspect was impacted. Based on our findings, we recommend that departments looking to improve after-hours DTB times focus on the processes after CVL lab activation such as movement of patients to the CVL as well as the call-back process for on-call CVL personnel.

Further research

Three areas would benefit from further research. Firstly, exploring the reasons behind a patient's choice of transport to the hospital would guide the crafting and delivery of public education campaigns. For example, a lack of awareness might have contributed to a patient's decision to call an ambulance, and further research would help us understand the extent of this problem. Secondly, deeper analysis of the PCI process in the hospital might identify the reasons for the slower door-to-ECG time we identified among patients who came via their own transport. Lastly, further studies on the impact of reduced DTB time on long-term outcomes of the patients should be conducted.

Limitations

This was not a randomised trial, and thus certain factors such as presenting complaint or patient comorbidity could have served as confounders. However, as inclusion in the database required clear-cut ECG changes of STEMI and the presence of symptoms, we believe that this should have a fairly small effect.

Secondly, in our institution, the patient's arrival time (first time stamp) is created upon scanning their identification at the screening area. For patients arriving by ambulance, this is done concurrently by the paramedics while the patient receives care (e.g. ECG, assessment). For these cases, if the ECG time was before the registration time, we recorded an ECG time of 0 minute (ECG on arrival). This might represent a source of bias if the patient had delayed ECG but had an even more delayed registration. We think this is unlikely to present a large bias, as the registration process in our institution is electronic, and unlikely to cause a long delay.

Thirdly, the SCDF ECG database might not be complete, as for some cases, the prehospital ECG might be transmitted prior to identification of the patient. Subsequently, when the patient has been identified and registered in the hospital, this prehospital ECG is not linked retrospectively. As such, some of the cases that were deemed not having a prehospital ECG might have actually had one. We tried to mitigate this by a medical record review as physicians document prehospital ECG interpretation and CVL activation.

Fourthly, we did not have information on the patients' clinical presentations, STEMI types, or long-term follow-up. While the entire cohort had to present with ECG changes and symptoms before being included, patients with very typical symptoms might opt for ambulance use, while others with milder/atypical symptoms might opt for their own transport. More subtle ECG changes might also affect the decision by the provider to activate the CVL. These might be sources of bias. Also, while we did not detect a difference in inpatient mortality, outcome differences might be present on long-term follow-up.

Lastly, while we were able to identify certain aspects of DTB time that was affected by mode of transport and time of arrival, the process of CVL activation is unique to every institution and thus the findings might not be generalisable. However, such a framework for studying the process can still serve as a guidance to other institutions looking to improve their DTB times.

CONCLUSION

For patients with STEMI undergoing PCI, arriving via emergency ambulance is associated with shorter DTB time. Mechanisms such as prehospital ECG transmission and CVL activation could contribute to this, but processes within the ED also account for part of the reduction in DTB time. Considering that only a third of patients with STEMI arrive via emergency ambulance, public education is sorely needed to increase awareness of STEMI symptoms and to utilise emergency transportation when experiencing those symptoms. Further studies that look into the various processes in detail would be useful to guide measures and workflows to improve DTB time, especially for walk-in patients and patients who present after hours.

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