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ORIGINAL ARTICLE

Electronic Referral System for Transferred Patients with Acute Myocardial Infarction

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Introduction: The electronic referral system (ERS) in Taiwan was designed to improve the efficiency and quality of patient transfer through a coordinated system of care intervention by imposing mutual responsibility on medical network systems. Information regarding the effects of ERS implementation on the door-to-balloon time (DBT) in transferred patients with ST-segment elevation myocardial infarction (STEMI) is scant. **Methods:** Data were retrospectively collected from the emergency registry database at Tri-Service General Hospital, Taipei, between January 2012 and February 2015. Patients were categorized into before and after groups depending on the time of ERS implementation. Baseline demographics and duration at the Emergency Department were recorded and analyzed. **Results:** We recruited 81 and 106 patients for the before and after groups, respectively. The mean age of patients was 57.7 years and 58.4 years ($P = 0.704$), respectively. Patients were predominantly men in both groups (92.6% vs. 86.8%, $P = 0.203$). The door-to-electrocardiography and door-to-catheterization laboratory time differed significantly between the two groups. The results of the general linear model analysis for STEMI patients from networked hospitals revealed that ERS implementation is an independent risk factor for shortened DBT. The average hospital stay, hospital death, and 3-month mortality or major adverse cardiac event differed nonsignificantly between the two groups (11.1% vs. 14.2%, $P = 0.823$). **Conclusion:** ERS implementation reduced the DBT for transferred STEMI patients. A coordinated system of care intervention can improve the efficiency of managing transferred patients with STEMI.

Key words: Acute myocardial infarction, door-to-balloon time, electronic referral system

INTRODUCTION

The timely transfer of patients with acute ST-segment elevation myocardial infarction (STEMI) to the nearest percutaneous coronary intervention (PCI)-capable health facility is critical for reducing the door-to-balloon time (DBT). PCI is currently the recommended procedure for the diagnostic and therapeutic management of acute myocardial infarction (AMI). American College of Cardiology and American Heart Association (ACC-AHA) guidelines recommend a DBT of 90 min or less for STEMI patients.[1] Delayed transfer of STEMI patients to the catheterization room is associated with poor outcomes and high mortality.[2]

In 2008, the ACC-AHA recommended two performance measures for transferred patients with STEMI: Time spent at the first hospital (referring hospital) should be <30 min, and total time to primary PCI should be <90 min. However, achieving <30 min duration may be infeasible for some referring hospitals.[3] The subsequent 2013 STEMI guidelines specify immediate transfer to a PCI-capable hospital for

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primary PCI with an ideal first medical contact-to-device time system of 120 min or less, which is the recommended triage strategy for STEMI patients who initially arrive or are transported to a non-PCI capable hospital.[1] Therefore, reducing the total time elapsed from the first medical contact to definite PCI in STEMI patients is equally dependent on the referring hospitals and the receiving centers. Moreover, establishing partnerships with an STEMI receiving center improves the time-to-reperfusion markedly.[4]

The Ministry of Health and Welfare in Taiwan launched a quality improvement project in 2013 by implementing the electronic referral system (ERS) for ensuring the transfer and improving care intervention of patients with critical illnesses at the Emergency Department (ED). In this project, 181 designated hospitals with first-aid facilities around Taiwan were organized into 27 emergency transfer network systems, and a web platform was established for transferring real-time patient information, facilitating online communication. Gaudet *et al*. were the first to propose the ERS and reported that the traditional referral system was less effective and expensive, and lacked accurate or complete patient information and quality monitoring.[5] At present, the referral system has advanced from a computer-based record to an extensive online network.[6] In the United States, most referral systems are used by general physicians for communicating with specialists at a receiving center or for setting appointments. By contrast, the ERS in Taiwan improves the efficiency and quality of patient transfer through a coordinated system of care information, such as information concerning bed vacancy and services at regional network hospitals, and imposing mutual responsibility on medical network systems.

To study the effect of the ERS on the outcome of STEMI patients, we analyzed the DBT of STEMI patients transferred from referring networked hospitals to receiving centers before and after ERS implementation.

METHODS

Study design

We retrospectively collected data from the emergency registry database at the Tri-Service General Hospital (TSGH) in Taipei. Taipei has a population of more than 2.7 million and is spread across 270 km^2 (approximately half of San Francisco) in Northern Taiwan. Taipei has 17 first-aid responsibility hospitals, of which 7 are Tertiary Medical Centers. These hospitals are distributed into two networks, and each network comprises one base hospital and several networked hospitals. Each base hospital is closely associated with its networked hospitals. A base hospital can take over care for STEMI patients from its own networked hospitals, although this is not mandatory. TSGH, a base hospital, is a Tertiary Medical Center with more than 85,000 annual emergency visits every year.

Sampled patients

All STEMI patients who were referred to the ED of TSGH and received primary PCI between January 2012 and February 2015 were included. Patients were categorized into two groups depending on the time of ERS implementation. Patients who were transferred before the ERS was implementation, between January 2012 and May 2013, formed the before group; and those transferred after the ERS implementation, between June 2013 and February 2015, formed the after group. Patients who eventually received a coronary artery bypass graft (n = 5), critically ill patients (receiving cardiopulmonary resuscitation or airway management, n = 4), those who received an inaccurate STEMI diagnosis (n = 2), those who had a recent myocardial infarction (n = 2), those who did not receive timely intervention because of the lack of a facility or equipment availability (n = 2), and those with a history of heart surgery (n = 1) were excluded. Furthermore, missing data and loss to follow-up occurred in three patients.

Baseline variables

We obtained baseline variables, namely age, sex, comorbidities, personal and familial history, and DBT. DBT was defined as the overall time interval between a patient arriving at the ED and the time of balloon inflation in the catheterization laboratory. DBT was further categorized into 5 time frames, as follows: T1 was the time when the first electrocardiography (ECG) was available; T2 was the time when cardiologist was informed; T3 was the time when the catheterization laboratory was available; T4 was the time of patient arrival at the catheterization laboratory; and T5 was the time of balloon inflation.

Outcomes

The effect of ERS on DBT for transferred STEMI patients was the primary outcome. Secondary outcomes comprised hospital stay, in-hospital death, and 3-month mortality or a major adverse cardiac event (MACE), including cardiac arrest.

Statistical analysis

The baseline characteristics of the patients in the two groups were compared and examined through the Chi-square test for categorical variables, and the t-test for continuous variables. General linear model analysis was performed to examine the effect of ERS on the DBT. All analyses were performed using IBM SPSS Statistics for Windows (Version 19.0, IBM Corp., Armonk, NY, USA). The value $P < 0.05$ was considered statistically significant.

RESULTS

Between January 2012 and February 2015, we included 81 and 106 patients in the before and after groups, respectively [Table 1]. The mean age of the patients was 57.7 years and 58.4 years ($P = 0.704$), respectively. Patients were predominantly men (92.6% vs. 86.8%, $P = 0.203$) in both groups. All patients were activated by ED physicians and received dual antiplatelet agents. Among them, 27.2% patients visited ED during the day, 52.9% had hypertension, 33.1% had dyslipidemia, 23.5% had diabetes mellitus, 64.7% had a history of cigarette smoking, and 38.0% consumed alcohol. The demographics in both groups were similar, without significant differences. Timelines for STEMI patients at ED revealed that the door-to-ECG and door-to-catheterization laboratory differed significantly between the two groups.

The results of the general linear model analysis for STEMI patients from networked hospitals revealed that ERS implementation is an independent risk factor for a shortened DBT [Table 2]. DBT was significantly lower in the after group compared with the before group (73 ± 20 vs. 65 ± 27 min, $P = 0.007$) [Table 3]. A shortened DBT was particularly significant for patients transferred from the networked hospitals [Figure 1].

In our study, 89.3% of the patients achieved <90 min DBT. The major target vessel in both groups was the left anterior descending coronary artery (53.1% vs. 69%). The average hospital stay (4 ± 2 vs. 4 ± 1 day, $P = 0.149$), and in-hospital death (3.7% vs. 3.8%, $P = 1.00$) were similar between the two groups. MACE or 3-month mortality differed nonsignificantly between the two groups (11.1% vs. 14.2%, $P = 0.823$).

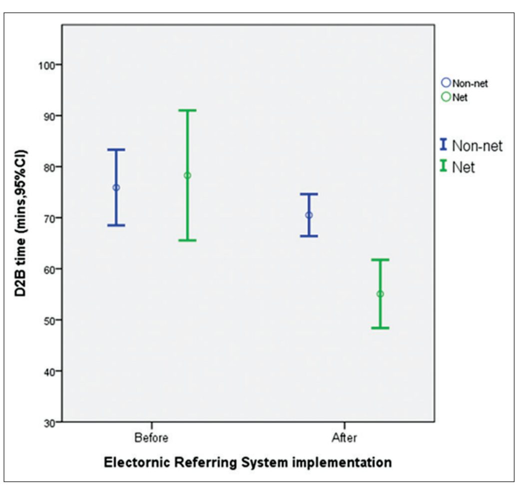

Figure 1: Door-to-balloon time before and after electronic referral system implantation

DISCUSSION

ERS implementation significantly reduced the ED stay duration for STEMI patients who were transferred from collaborative networked hospitals. The shortened time frame was mainly attributable to the shortening of the door-to-catheterization laboratory time.

Various hospital-wide strategies and initiatives have been implemented globally for reducing the total time-to-treatment of patients with acute coronary syndrome, specifically STEMI. Approximately, 60% of hospitals in the United States use at least one strategy for shortening the DBT.[7] Eight of the most

Table 1: Demographics and ER timelines of STEMI patients by the implementation of electronic transferring system

	Before (n=81) n (%)	After (n=106) n (%)	P
Demographic characteristics			
Male	75 (92.6)	92 (86.8)	0.239
Age (year), mean±SD	57.7 (12.1)	58.4 (12.8)	0.704
Interfacility transfer	27 (33.3)	43 (40.6)	0.361
ASA/plavix	81 (100)	106 (100)	-
ER activation	81 (100)	106 (100)	-
Day shift	21 (25.9)	30 (28.3)	0.743
Clinical history			
Hypertension	42 (51.9)	57 (53.8)	0.883
Diabetes mellitus	25 (30.9)	19 (17.9)	0.055
Cerebral vascular event	6 (7.4)	5 (4.7)	0.536
Malignancy	5 (6.2)	4 (3.8)	0.504
Coronary artery disease	4 (4.9)	12 (11.3)	0.186
Chronic kidney disease	5 (6.2)	2 (1.9)	0.242
Dyslipidemia	32 (39.5)	30 (28.3)	0.119
Arrhythmia (AF or VPCs)	4 (4.9)	4 (3.8)	0.729
Smoking	53 (65.4)	68 (64.2)	0.878
Alcohol drinking	32 (39.5)	39 (36.8)	0.762
Family CAD history	14 (17.3)	11 (10.4)	0.196
Timeline			
Time (min), median±IQR			
Door to ECG, T1	3 (4)	2 (4)	0.025
Door to activation, T2	5 (5)	5 (6)	0.707
Door to catheterization laboratory available, T3	35 (14)	33.5 (29)	0.472
Door to catheterization laboratory, T4	43 (22)	36 (25)	0.005
Door to balloon time	73 (20)	65 (27)	0.003

P<0.05. STEMI = ST-segment elevation myocardial infarction; SD = Standard deviation; ASA = Aspirin; ER = Emergency room; AF = Atrial fibrillation; VPC = Ventricular premature complexes; CAD = Coronary artery disease; IQR = Interquartile range; ECG = Electrocardiography

Table 2: Results of general linear model analysis for network hospital STEMI patients with door to balloon time as dependent variable

	B coefficient	Standard error	95% CI		P
			Lower	Upper	
Patients from network hospitals					
Door to ECG, T1	1.799	0.931	−0.086	3.684	0.061
Electronic referring system implementation	−21.033	6.532	−34.257	−7.089	0.03

R^2=0.260; P<0.05. STEMI = ST-segment elevation myocardial infarction; CI = Confidence interval; ECG = Electrocardiography

Table 3: Outcomes of STEMI patients by implementation of electronic transferring system

	Before (n=81) n (%)	After (n=106) n (%)	P
Target vessel			
LAD	43 (53.1)	69 (65.1)	0.210
LCx	5 (6.2)	4 (3.8)	
RCA	33 (40.7)	32 (30.2)	
Hospital stay (day), median±IQR	4 (2)	4 (1)	0.149
Hospital death or critical discharge	3 (3.7)	4 (3.8)	1.000
3-month mortality or CV events	9 (11.1)	15 (14.2)	0.659

IQR = Interquartile range; RCA = Right coronary artery; LAD = Left anterior descending; LCx = Left circumflex; CV = Cardiovascular; STEMI = ST-segment elevation myocardial infarction

common strategies that are positively associated with DBT have been identified,[8,9] namely emergency physician-induced cardiac catheterization laboratory activation, single call to a central paging system, prehospital activation, expecting cardiac catheterization laboratory personnel to arrive within 20 min of activation, the on-site presence of the attending cardiologist, real-time data feedback, senior management commitment, and a team-based approach. However, these strategies focus on the management of STEMI patients who directly present at a catheterization-capable center. For STEMI patients transferred from regional hospitals, other key strategies for reducing PCI delays have been proposed, and successful results have been obtained. The strategies were establishing a mature hospital referral network, a time-oriented transfer protocol, an advanced responsive transport system in the form of ground ambulance or helicopter, empowering the transfer hospital physician to activate the PCI-capable hospital catheterization laboratory, and the presence of an online feedback tracking system of transport time and patient outcomes to the transfer hospital.[10,11] Overall, these strategies have emphasized a collaborative referral system with a preplanned protocol as well as an online tracking system that are effective in shortening the DBT for transferred STEMI patients.

The online ERS of Taiwan links hospitals with several network systems aiming to facilitate the transfer of critically ill patients at ED, particularly those with AMI, acute ischemic stroke, and major trauma. Before ERS implementation, patient transfer between hospitals was not monitored, and the transfer was based solely on ED physicians in local hospitals contacting potential referral centers over the phone. Information may have been lost, or incomplete during the transfer of patients to a referral hospital, and delay in DBT was occasionally expected. The ERS was designed as an online source of patient transport information that includes patient identity, current vital signs, and laboratory data, such as imaging and ECG data at a local hospital. Thus, ED physicians at a referral center can receive a patient's information at once. Furthermore, the ERS facilitates real-time communication among physicians. Therefore, when a patient is diagnosed with STEMI, the physician at the referring hospital can inform the physician at the referral center and transfer complete data immediately. In addition, the catheterization laboratory team can be activated once the STEMI is confirmed by the ED physicians at the referral hospital. Thus, the catheterization facility is alerted immediately, and the medical staff is prepared to treat the patient on arrival.

We believe that the DBT for transferred STEMI patients improved after ERS implementation because of the establishment of a well-collaborated network system that ensures patient transfer to the referral hospital, and facilitates the early activation of the catheterization laboratory through close communication among the referring physicians, receiving physicians, and cardiologists. As a mandatory health care policy for transferred patients in Taiwan, ERS may likely exert the role as a monitoring system tracking for the transfer processes among the networked hospitals. The specific reduction in the door-to-catheterization time was indicative of a shortened ED stay, meaning that the patient flow through the ED was efficient. Although this can be explained by the early availability and activation of the catheterization laboratory, a nonsignificant difference in the door-to-catheterization laboratory time was observed between the two groups. However, early cardiologist assessments and takeover during a patient stay at ED enhance and improve the control of a patient's disposition.

The study has several limitations. Information on the time spent at the first medical contact and transport between hospitals is lacking, because the ERS does not require this information; therefore, we could not access the total time from arrival at the referring hospital to balloon inflation at the receiving center. However, the significant shortened DBT at the receiving hospital suggests that the transferred STEMI patients benefited from the ERS because they received efficient PCI management throughout the transfer process. Future researchers may collaborate with regional hospitals to ensure a superior quality of care in patients with coronary artery disease. Despite the reduction in DBT from the networked hospitals, the length of stay, hospital death, and 3-month mortality did not improve significantly. This may have occurred because of the relatively short baseline DBT of 73 min in our 2012 study, which is lower than that reported in other studies after interventions for DBT improvement were established.[12,13] However, a recent study on in-hospital mortality reported that the death rates have remained constant, despite a significant improvement in DBT for patients receiving primary PCI for STEMI, suggesting that additional strategies are required to reduce in-hospital mortality in this population.[14] This study was a retrospective study from a single medical center with a relatively small sample and lacked details such as Killip classifications of AMI, shock status, transport distances, and medications such as beta-blockers, angiotensin converting enzyme inhibitors, and statins. Although we have excluded those who required intubation and further medical supports that might apparently delay PCI processes, these limitations restrict the study strengths and its generalization to all city-wide hospitals. Nevertheless, the significant improvement in DBT highlights that the first medical contact to balloon time of <90 min can be achieved for a regional STEMI transfer network in Taipei. Future efforts for improving systems of care should focus on monitoring total DBT by collaborating with regional hospitals for patients with myocardial infarctions.

In conclusion, ERS implementation can shorten the DBT for transferred patients with STEMI. This reduction in ED stay emphasizes the importance and benefit of network collaboration in a system of care for STEMI patients.

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Conflicts of interest

There are no conflicts of interest.

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