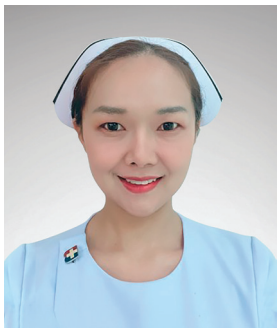
Original Article

Effectiveness of 3-1-5 Model in ST-Elevation Myocardial Infarction (STEMI) Patients in Bangkok Heart Hospital

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Abstract

OBJECTIVES: To assess treatment timeliness using the 3-1-5 model in patients with ST-elevation myocardial infarction (STEMI) undergoing primary percutaneous coronary intervention (PCI) and to identify factors associated with delayed reperfusion and adverse clinical outcomes.

MATERIALS AND METHODS: This retrospective observational study included adults (≥18 years) with STEMI undergoing primary PCI between June 2020 and December 2023. Patients who declined reperfusion, required interhospital transfer, or died before PCI were excluded. After Institutional Review Board approval, data were collected using a standardized case record form. Timeliness was assessed using the 3-1-5 model (≤ 90 minutes from first medical contact (FMC) to PCI). Outcomes included in-hospital and 30-day mortality and hospital readmission.

RESULTS: Among 52 patients (mean age 59.83 ± 10.97 years; 88.46% male), FMC-to-device time ≤ 90 minutes was achieved in 69.23%. In-hospital mortality was 3.85%, with no mortality at 30 days or 6 months. Complications included cardiogenic shock (7.69%), arrhythmia, and intra-aortic balloon pump use (3.85%). Hospital readmission within 6 months occurred in 7.50%. The median door-in–door-out time was 35 minutes, exceeding the recommended 30 minutes. Delays were mainly attributed to system- and patient-related factors, including atypical or absent chest pain, delayed diagnosis, poor communication, and hemodynamic instability.

CONCLUSION: Although the key performance indicator (KPI) for achieving coronary reperfusion time within 90 minutes was not met, this study identified key contributors to treatment delays, particularly during the door-in door-out (DIDO) time. These delays were related to both system delay and patient delay. The door in door out interval is a critical early phase that directly affects timely diagnosis and subsequent reperfusion. System delay improvements in triage, diagnostic workflows and continuous training of healthcare personnel may help optimize this process and facilitate timely care across subsequent stages. In addition, enhancing public awareness of STEMI symptoms and the importance of early hospital presentation may reduce patient delay.

Keywords: ST-elevation myocardial infarction, STEMI, percutaneous coronary intervention, PCI, FMC-to-device time

Cardiovascular disease is a leading global cause of death, accounting for 32% of all deaths. Among these, 85% are due to acute myocardial infarction (heart attack).[1] In Thailand, over the past five years, deaths from ischemic heart disease have increased by 1.3 times, with 48 individuals dying from this condition each day.[2] Between 2006 and 2018 - 2019, the incidence of STEMI rose from 14% to 28%.[3] The mortality rate due to ischemic heart disease increased from 22.5 per 100,000 populations to 31.8 in 2017. The in-hospital mortality rate was 2.14%[4], while the national mortality rate in Thailand was approximately 10%. At one-year follow-up, STEMI patients had a mortality rate of 14.5%[5], with a trend toward continued increase.

STEMI is a condition where a coronary artery is completely occluded (100%), leading to acute necrosis of the myocardial tissue. Prompt and accurate diagnosis is critical, as time is a key factor in treatment success. Treatment options include fibrinolytic therapy and/ or PCI for reducing incidence of preventive complication. Early assessment and electrocardiogram (ECG) within 10 minutes of emergency room (ER) arrival are essential for patients presenting with suspected acute coronary syndrome (ACS).[4] Leite L, et al.[6] demonstrated the effectiveness of combining the Manchester Triage System with the HEART score in ER for quick and accurate assessment of chest pain, improving prediction of major adverse cardiac events (MACE) and further treatment plan. Prompt and accurate patient assessment, rapid ECG and timely treatment can significantly reduce myocardial damage.

According to the American Heart Association (AHA), in patients with STEMI presenting within 12 hours after symptom onset, primary PCI should be performed within a goal of FMC to device activation within 90 minutes.[7,8] For patients who arrive at the hospital capable of performing PCI, achieving revascularization within this 90-minute timeframe requires effective coordination among all relevant healthcare personnel and systems. Minimizing delays in the emergency department is crucial. According to the standard, the Door-to-ECG Time should be within 10 minutes, meaning that patients suspected of having STEMI should receive an ECG immediately, with rapid interpretation to promptly notify the team and proceed with coronary intervention as soon as possible. The guideline specifies only the time requirement for primary PCI — within 90 minutes — but does not detail the step-by-step process. Therefore, the research team developed specific procedural steps to ensure all processes are covered and completed within the recommended timeframe, allowing all related departments to manage their workflow appropriately to meet this target.

In addition, Bangkok Heart Hospital implemented a Clinical Care Program Certification of Acute Myocardial Infarction (CCPC of AMI), which established KPI of achieving coronary revascularization within 90 minutes in 94.80% of cases[9]. Based on data collected between 2016 - 2019, the proportion of patients achieving coronary reperfusion within 90 minutes was 80.77%, which did not meet the predefined performance benchmark. Consequently, the investigators, as part of the multidisciplinary care team, developed the 3-1-5 model, which was implemented in June 2020 to guide and optimize time-based management across each stage of care for all patients diagnosed with STEMI. Clinical outcomes were subsequently followed for 6 months after primary PCI.

The efficiency of processes for caring of patients with STEMI are as follows:

1. **Safe Life**–Achieving Optimal Survival Outcomes: Ensuring timely recognition and treatment of STEMI to reduce mortality. This includes minimizing delays in diagnosis, rapid reperfusion, effective monitoring, and adherence to evidence based guidelines.
2. **Safe Myocardial**–Preserving Heart Muscle (Abort MI): Protecting as much viable myocardium as possible by reducing total ischemic time. Strategies include early symptom identification, rapid triage, activation of the catheterization team, and consistent implementation of reperfusion protocols.
3. **Safe Quality of Life**–Restoring Functional Well Being: Supporting patients to return to a quality of life close to their pre event baseline. This involves comprehensive secondary prevention, cardiac rehabilitation, medication optimization, and addressing psychosocial factors.

To evaluate the effectiveness of the 3-1-5 Model in terms of:

1. In-hospital mortality, 30-day and 6-month mortality, and complication rates among STEMI patients undergoing primary PCI.
2. The proportion of STEMI patients undergoing primary PCI within 90 minutes and identify reasons for delays.
3. Time intervals for each component of the 3-1-5 model, including ER or the first point where the patient is diagnosed, patient transfer (transportation), and catheterization lab procedures.

Research Benefits

1. **For Participants:** The co-principal investigator identified factors contributing to delays in coronary intervention among patients with acute myocardial infarction and examined processes aimed at reducing such delays. Patients diagnosed with acute myocardial infarction are expected to receive timely coronary intervention in accordance with established clinical standards, potentially reducing the incidence of major adverse cardiovascular events (MACE) and mortality.
2. **For the Profession:** A new, comprehensive, and standardized protocol was developed to serve as a guideline for clinical practice within the hospital and its network.
3. **For Society:** To reduce the budget spent on post-treatment patient care and hospital readmissions.

Materials and Methods

This study employed a retrospective cohort study, utilizing data from medical records of STEMI patients who successfully underwent primary PCI between June 2020 and December 2023. Outcomes were followed up for six months. All relevant hospital staff received annual training on the 3-1-5 Model to standardize assessment and treatment procedures. The study was approved by the Institutional Review Board (IRB) Bangkok Hospital Headquarters.

Sample Size

Based on prior literature, hospital mortality in STEMI patients undergoing PCI is estimated at 2.1% internationally[4] and 10% in Thailand.*5* Using an infinite population proportion estimate with a proportion = 10%; margin of error of 8%; and $\alpha = 0.05$, the calculated sample size was 55 cases.

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Inclusion Criteria

1. Adult patients (≥18 years) with a diagnosis of STEMI.
2. Patients who underwent primary PCI.

Exclusion Criteria

1. Patients with STEMI who declined or refused reperfusion therapy.
2. Patients transferred from another hospital.
3. Patients transferred to another hospital for further management.
4. Patients who died before undergoing primary PCI.

Data collection process

Data collection was initiated after approval from the Institutional Review Board (IRB) and was conducted using a case record form (CRF) specifically designed by the investigators.

1. Time interval measurements according to the 3-1-5 Model:
   - 3 = 30 minutes for patient history taking, diagnosis, and preparation for PCI from hospital arrival. (Door-In Door-Out (DIDO) within 30 minutes)
   - 1 = 10 minutes for patient transfer to the catheterization laboratory. (Transfer to Cath Lab within 10 minutes)
   - 5 = 50 minutes for reperfusion procedure in the catheterization lab. (Reperfusion time within 50 minutes)

Total time from arriving FMC to undergoing primary PCI was within 90 minutes. Clinical outcomes included in-hospital mortality, 30-day mortality, and hospital readmission rates.

2. Clinical and demographic data, including patient demographic characteristics, causes of delay in achieving the target reperfusion time, in-hospital complications, in-hospital mortality, and hospital readmission, along with the reasons for readmission.

No personally identifiable information was collected. All data were anonymized and recorded using coded identifiers only.

Data Analysis

Descriptive statistics were used to summarize patient characteristics and risk factors. Continuous variables (e.g., age, time intervals) were reported using mean ± standard deviation or median as appropriate. Categorical data were presented as frequency and percentage. Data management and statistical analyses were performed using IBM SPSS Statistics for Windows, version 30.0 (IBM Corp., Armonk, NY, USA), licensed to Bangkok Dusit Medical Services.

Results

A total of 52 patients were included, with a mean age of 59.83±10.97 years (range: 37-93). Males accounted for 88.46%. The majority of patients had a history of hyperlipidemia (67.31%), hypertension (59.62%), and diabetes mellitus (25.00%), respectively. Additionally, 13.46% had a family history of coronary artery disease, had previously been diagnosed with CAD, or had undergone prior PCI. A total of 63.46% had never smoked, and 88.46% did not consume alcohol (Table 1).

Clinical events occurring during and after the procedure included cardiogenic shock in 7.69% of patients, arrhythmias and the used of an intra-aortic balloon pump (IABP) in 3.85% for each other outcome, and temporary pacemaker insertion in 1.92%. Additionally, myocardial infarction, heart failure, gastrointestinal bleeding and requiring intubation, and cardiac arrest were each reported in 1.92% of cases. In-hospital mortality due to cardiac causes was 3.85% (Table 2).

Table 1: The number and percentage of demographic characteristics, medical history, and other risk factors (n = 52).

Demographic characteristics	n (%)
Age	
Mean±Standard Deviation	59.83 ± 10.97
Minimum-Maximum	37 - 93
Gender	
Male	46(88.46)
Female	6(11.54)
Medical history and risk factors*	
Hyperlipidemia	35 (67.31)
Hypertension	31 (59.62)
Diabetes Mellitus	13 (25.00)
Family history of coronary artery disease	7 (13.46)
Prior coronary artery disease	7 (13.46)
Prior PCI	7 (13.46)
Stroke	4 (7.69)
Chronic pulmonary disease	2 (3.85)
Prior myocardial infarction	2 (3.85)
Non-drinkers	46 (88.46)
Non-smokers	33 (63.46)

* A single patient may have experienced more than one clinical event.

Table 2: Clinical Events During and After PCI*

Variables	n (%)
Cardiogenic shock	4 (7.69)
Intra-aortic balloon pump (IABP)	2 (3.85)
Arrhythmias	2 (3.85)
Myocardial infarction	1 (1.92)
Heart failure	1 (1.92)
GI bleeding	1 (1.92)
Requiring endotracheal intubation	1 (1.92)
Cardioversion/ defibrillation	1 (1.92)
Temporary pacemaker	1 (1.92)
Coronary artery bypass grafting	1 (1.92)
In-hospital mortality (cardiac causes)	2 (3.85)

*A single patient may have experienced more than one clinical event.

At the 6 months follow up, 80% of patients were successfully monitored. Of these, 7.50% were readmitted to the hospital. The reasons for readmission included myocardial infarction, chest pain, and palpitations, each accounting for 33.33% of cases. No mortality was reported within 30 days and 6 months follow up (Table 3).

Table 3: The outcomes of treatment follow up over 6 months (n = 40).

Variables	n (%)
Follow up	40 (80.00)
Hospital readmission	3 (7.50)
Myocardial ischemia	1 (33.33)
Chest pain	1 (33.33)
Palpitations	1 (33.33)
No mortality	0

The median FMC-to-Device time was 81 minutes (69.23%). The most common cause of FMC-to-Device time delay was due to delay in the Door-In Door-Out (DIDO) phase (59.62%). The cause of DIDO delays was categorized into two main causes which were: 1) Patient delay – including atypical or absent chest pain symptoms upon hospital arrival, unstable condition, communication barriers particularly among international patients affecting consent for treatment, and financial concerns; 2) System delay – such as delayed diagnosis due to limitations in clinical assessment by medical personnel, prolonged waiting time to see a physician and medical history taking, need for additional diagnostic investigations, and limited team readiness during off-hours. The primary cause of delayed transfer to the catheterization laboratory was bradycardia during patient transport (3.85%). Delays during the reperfusion phase occurred in 19.23% of cases and were primarily attributed to cardiac arrest and/or the need for intubation, difficult vascular access, and difficulty crossing the culprit lesion (Table 4).

Table 4: The time intervals for each component of the 3-1-5 model and the causes of delay (n = 52).

Variables	Yes (n (%))	No (n (%))
FMC-to-Device time within 90 minutes	36 (69.23)	16 (30.77)
Mean ± SD	90.81 ± 37.79	
Median (Min-Max)	81.00 (47-231)	
Door in door out time within 30 minutes	21 (42.38)	31 (59.62)
Mean ± SD	43.48 ± 32.77	
Median (Min-Max)	35.00 (2-160)	
Transfer to Cathlab within 10 minutes	50 (96.15)	2 (3.85)
Mean ± SD	4.71 ± 2.55	
Median (Min-Max)	4.00 (1-13)	
Reperfusion time within 50 minutes	42 (80.77)	10 (19.23)
Mean ± SD	42.71 ± 14.51	
Median (Min-Max)	40.00 (21-119)	
Cause of Door in door out time delay		31 (59.62)
Patient delays		
Atypical/no chest pain		4 (12.90)
Financial concerns in international patient		1 (3.23)
Language barriers in international		1 (3.23)
patient consent		1 (3.23)
Unstable condition		1 (3.23)
System delays		
Delayed diagnosis		10 (32.26)
Off-hours team availability		3 (9.68)
Prolonged waiting time and medical history taking		3 (9.68)
Limitation in clinical assessment by medical personnel		2 (6.45)
Additional diagnostic investigations		1 (3.23)
Cause of transfer to CathLab time delay		2 (3.85)
Bradycardia occurring during patient transport		1 (50.00)
Unspecified		1 (50.00)
Cause of reperfusion time delay*		10 (19.23)
Cardiac arrest and/or the need for intubation prior to the procedure		1 (10.00)
Difficult vascular access		1 (10.00)
Difficult crossing culprit lesion		1 (10.00)
Others		7 (70.00)

*A single patient might experience more than one clinical event.

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Discussion

According to the study, the effectiveness of 3-1-5 Model in STEMI patients in Bangkok Heart Hospital showed promising results. The mean age at presentation was 59.83 ± 10.966 years, with a male preponderance (88.46%). And 69.23% of patients had a D2B time within 90 minutes. The in-hospital mortality rate due to cardiac causes was 3.85%, which is lower compared to rates reported in other studies. No mortality was recorded within 30 days and 6 months after discharge. The 6-month readmission rate was 7.50%, primarily due to myocardial infarction, chest pain, and palpitations. The most common clinical events occurring during and after the procedure were cardiogenic shock (7.69%), arrhythmias and the used of mechanical circulatory support with an intra-aortic balloon pump (IABP), both accounting for 3.85%.

An analysis of the causes of delay based on the 3-1-5 model revealed that delays during the Door-In Door-Out (DIDO) phase stemmed from both patient delay and system delay factors. Some patients presented with atypical symptoms or absence of chest pain at the time of hospital arrival, which led them to be admitted to other departments than cardiology or the emergency department, resulting in delayed diagnosis. Additional contributing factors included limited team readiness during off-hours and the clinical assessment limitations of medical personnel, as staff from other departments unfamiliar with cardiac emergencies were sometimes assigned to these cases. Communication was also significant in treatment decision-making, particularly regarding informed consent and financial considerations, especially among international patients who required insurance coordination. Due to these factors, the DIDO time often did not meet the expected target. The most of delays were attributed to system delay, which were critical in the initial assessment and diagnosis phase. This highlighted the need for further development to enhance timely and accurate triage. In the phase of transfer to Cath lab, one patient presented bradycardia and required medication support during transfer. Nonetheless, this phase was generally completed efficiently. With prompt and accurate assessment during the DIDO phase and stable patient conditions, this transfer process could consistently meet target timelines. In the reperfusion time phase, delays were attributed to cardiac arrest and/or the need for intubation prior to the procedure, difficulties vascular access, and difficulties crossing culprit lesion. While performance in this phase was satisfactory, continued training and experience-building were necessary to enhance proficiency in managing such complications.

Previous studies have reported a door-to-device (D2D) time exceeding 90 minutes have an approximately 50% higher risk of in-hospital mortality compared with those whose D2D time is less than or equal to 30 minutes. Furthermore, system delay exceeding 90 minutes has been associated with a 40–70% increase in the risk of in-hospital mortality.

Additionally, patient delays were linked to a higher incidence of Major Adverse Cardiovascular Events (MACE) post-procedure[10-12] and reperfusion delays were often observed in the emergency department, where patients with atypical or absent chest pain symptoms were not promptly identified, along with Triage process, delay in obtaining ECG, especially in unstable patients requiring stabilization or additional imaging, difficulties in vascular access, and difficulties crossing culprit lesion also contributed to increased mortality rates. Language barriers and cultural differences significantly impacted the informed consent process, decision-making, and financial arrangements, especially among international patients.[10,12-14] Furthermore, limited team availability during off-hours significantly increased the odds of activation to Cath lab arrival time being more than 30 minutes (aOR: 2.11; 95% CI: 1.44-3.11, $p < 0.001$) when compared with regular hours.[15,16] Other key causes of delay included insufficient availability of catheterization labs and misdiagnosis. Hence, it is essential to ensure an adequate number of Cath labs and to provide consistent training and supervision for medical trainees to ensure readiness at all times.[17]

Limitations

In the context of Bangkok Heart Hospital, a private healthcare institution, the annual number of patients presenting with STEMI is relatively limited. This may partly be attributed to concerns regarding treatment expenses, as well as the fact that some individuals have not previously sought medical care at Bangkok Heart Hospital. Moreover, the wide availability of healthcare facilities across Bangkok allows patients to select hospitals based on convenience. In emergency situations, patients may opt to receive treatment at the nearest hospital to ensure their safety.

Conclusion

Although the KPI for achieving coronary reperfusion time within 90 minutes was not met, this study identified specific factors contributing to treatment delays across different stages of care. In particular, delays were most evident during the DIDO time, which were attributable to both system delay and patient delay factors.

The DIDO interval represents a critical initial phase of care, as it directly influences the accuracy and timeliness of diagnosis and the ability to achieve reperfusion within the recommended 90-minute timeframe. system delay delays highlight the need for process optimization, including improvements in patient triage, diagnostic workflows, and ongoing training and supervision of healthcare personnel. Effective management of this early phase is likely to facilitate timely progression through subsequent stages of care and improve overall treatment efficiency.

With regard to patient delay factors, public education and awareness should be strengthened to emphasize the importance of early recognition of symptoms and prompt presentation to medical facilities when STEMI symptoms occur.

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Recommendations

Policy: Although clear policies had been established to promote awareness and improve recognition of the importance of acute myocardial infarction (AMI), challenges remained due to limited staffing and high employee turnover, which could hinder effective communication of these policies across all departments. Therefore, proactive strategies should be implemented to enhance understanding and emphasize the significance of AMI. These might include displaying posters highlighting key symptoms and appropriate actions in each department, as well as holding weekly meetings to monitor and evaluate patient care, and to collaboratively address any issues that arise.

Academic: The implementation of the model had provided valuable insights into the root causes of delays, leading to improvements in workflow processes that enhanced both efficiency and patient safety. Clear roles and responsibilities had been assigned to all relevant departments, and KPIs had been established for each unit. However, some gaps remained in departments that were not directly involved in core cardiac care. These areas required further development in terms of knowledge and procedural understanding to ensure consistent and effective patient management.

Operational: For the triage process, responsibility had been assigned to nurses (level 4) or to the in-charge. The documentation system had been revised to allow data to be used for improving patient care processes. The researcher also planned to further develop the workflow to achieve a time of reperfusion within 60 minutes from EKG diagnosis to coronary reperfusion, in accordance with the 2017 ESC Guidelines for the Management of Acute Myocardial Infarction in Patients Presenting with ST-Segment Elevation.

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