Original Article

Improving Door-to-balloon Times in Primary Percutaneous Coronary Intervention for Acute ST-elevation Myocardial Infarction: The Value of an Audit-driven Quality Initiative

Rabind A Charles,[1] *FRCS (A+E), FCEM (UK)*, Shiou Liang Wee,[2] *PhD*, Bernard WK Kwok,[3] *FAMS, MRCP*, Caren Tan,[2] *BA*, Swee Han Lim,[1] *FRCS (A+E), FAMS*, Venkataraman Anantharaman,[1] *FRCS, FAMS*, Wasantha Hemanthakumari,[1] *MBBS*, Terrance SJ Chua,[3] *FAMS, MRCP*

Abstract

Introduction: The study was designed to reduce door-to-balloon times in primary percutaneous coronary intervention for patients presenting to the Emergency Department with acute ST-elevation myocardial infarction, using an audit as a quality initiative. Materials and Methods: A multidisciplinary workgroup performed a pilot study over 3 months, then implemented various process and work-flow strategies to improve overall door-to-balloon times. Results and Conclusion: We developed a guideline-based, institution-specific written protocol for triaging and managing patients who present to the Emergency Department with symptoms suggestive of STEMI, resulting in shortened median door-to-balloon times from 130.5 to 109.5 minutes (P <0.001).

Ann Acad Med Singapore 2008;37:568-72

Key words: Angioplasty, Quality indicators, ST elevation myocardial infarction

Introduction

Primary percutaneous coronary intervention (PCI) for patients with acute ST-elevation myocardial infarction (STEMI) has been shown to be superior to thrombolytic therapy in terms of its ability to achieve higher patency rates, minimise infarct size, improve left ventricular function and improve long-term survival, as well as lower rates of reinfarction and stroke.[1,2] Infarct-related vessel patency is achieved more frequently and consistently with PCI, even when compared with outcomes where second and third generation thrombolytics are employed.[3,4] However, it is also known that any mortality benefits that PCI may have over thrombolysis are lost if "door-to-balloon" time (defined as the time interval between the patient's arrival in the Emergency Department to first angioplasty balloon inflation) exceeds 120 minutes.[3,5] In fact, the American College of Cardiology (ACC)/American Heart Association (AHA) guidelines[6,7] recommend PCI if door-to-balloon times are within 90 ± 30 minutes and a skilled PCI laboratory (defined as operator experience greater than a total of 75 primary PCI cases/year) is available with surgical back-up.

In our institution, patients presenting to the Emergency Department (ED) within 6 hours of the onset of an acute STEMI are routinely offered PCI as first-line treatment by cardiologists and supported by an on-site cardiothoracic service. An average of 200 to 250 patients presenting to the ED will undergo emergency PCI each year.

The aim of this study was to reduce door-to-balloon times in primary PCI for patients presenting to the ED of an urban hospital with acute STEMI, by the use of audit as a quality initiative.

Materials and Methods

A workgroup was set up to look into the door-to-balloon times at our institutions comprising emergency physicians, cardiologists, ED nurses, cardiovascular catheterisation laboratory (CVL) staff and a health programme group. This work was conducted in a 1500-bed tertiary-level acute-care hospital with an on-site cardiology and cardiothoracic service.

A pilot study was conducted from October 2002 to December 2002 to examine the workflow for handling patients presenting to our ED with acute STEMI. We studied all cases (n = 38) that presented within 6 hours of symptom onset who were offered acute PCI, and ED staff completed a record sheet documenting the time taken for

[1] Department of Emergency Medicine, Singapore General Hospital, Singapore
[2] Quality Management, Department Singapore Health Services Pte Ltd, Singapore
[3] Department of Cardiology, National Heart Centre, Singapore
Address for Correspondence: Dr Rabind A Charles, Department of Emergency Medicine, Singapore General Hospital, Outram Road, Singapore 169608.
Email: rabindcharles@yahoo.com.sg

various steps in the workflow.

Patients who were excluded from the analysis were:

(i) those with no evidence of acute STEMI on the first electrocardiograph (ECG) in the ED, and
(ii) those who had presented to other hospital EDs with acute STEMI and were transferred to our centre for PCI

The times that we examined were:

(a) Presentation at ED
(b) ED triage
(c) First ED ECG
(d) Time at which ECG was shown to ED physician
(e) Time the patient was seen by ED physician
(f) Time of diagnosis of STEMI by ED physician
(g) Times at which the cardiologist was contacted, call returned, and then arrived in the ED
(h) Time at which decision was made by the cardiologist to offer PCI
(i) Time at which patient consented to PCI
(j) Activation of cardiac catheterisation team
(k) Time at which ED was instructed to send patient to CVL
(l) Transport/transfer time from ED to CVL
(m) First balloon inflation

From the findings of this pilot survey, the workgroup then proposed and executed various strategies to improve the overall door-to-balloon times. The key interventions included:

(i) creating a fast-track for patients with chest pain to get ECGs done immediately by a nurse, and ensuring that these ECGs are immediately reviewed by an ED physician
(ii) educating ED doctors/cardiologists/ED and CVL nursing and support staff on the importance of "time-is-muscle" to ensure that patients with STEMI who consent for emergency PCI have workflow processes expedited
(iii) setting target timelines for each step of the workflow process, so as to minimise delay and achieve AHA target times of 90 ± 30 minutes
(iv) regular review by the workgroup of progress made, and constant reinforcement at ground level among the various medical and nursing personnel involved
(v) clocking the time required for each step on a specially designed worksheet which was to be used for each patient, attached to a clip-board with a stopwatch

Data were then collected from January 2003 to March 2004, excluding the months of April to June 2003 during the height of the severe acute respiratory syndrome (SARS) crisis. A total of 234 cases of primary PCI for STEMI were performed during this time.

Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS) version 11.0 for Windows (SPSS, Chicago, IL). As the distributions of the time components do not satisfy the normality assumption, the non-parametric test Mann-Whitney U test was used for pair-wise comparison to test if there were any differences between the readings from the 2 groups, and whether the observed differences were statistically significant. Statistical significance was implied at P values <0.05.

Results

The median door-to-balloon time improved from 130.5 minutes to 109.5 minutes (P <0.001) over a study period of 12 months. Figure 1 shows the overall door-to-balloon times for the entire study period, before and after the audit process and Table 1 shows the breakdown of timings between stages. Significant reductions in timing were seen in 3 areas (Table 2): time to inform the cardiology registrar via paging, time taken for cardiology registrar to arrive in the ED, and time from patient's arrival in the CVL to angiographic reperfusion. Improvement was seen both for cases during office hours (118.0 minutes pre-audit to 99.0

Table 1. Grouped Stages: Timings

	Pre-audit (Oct-Dec 02) n = 38	**Post-audit (Jan 03-Mar 04) n = 234**	***P* value (Mann-Whitney U test)**
	Median time	**Median time**	
From registration to diagnosis of STEMI by ED doctor	13	12	0.448
From CVM registrar being informed and arrival in ED	20	11	<0.001
From offer of reperfusion to patient acceptance	23	19	0.362
Cath lab activation	6	15	0.104
From CVL inform ED to transfer patient to patient arrival in CVL	15	10	0.274
From arrival in CVL to first balloon inflated	41	29	0.005

CVL: cardiovascular catheterisation laboratory; CVM: cardiovascular medicine; ECG: electrocardiograph; ED: Emergency Department

Table 2. Individual Stages: Timings

Stage description	Pre-audit (Oct 02-Dec 02)	Post-audit (Jan 03-Mar 04)	*P* value
	Median time (minutes)	Median time (minutes)	(Mann-Whitney U test)
Time of registration	-	-	-
Time of triage	4.0	2.0	0.064
Time of first ECG	2.0	3.0	0.197
Time ECG shown to ED doctor	1.0	1.0	0.909
Time patient seen by ED doctor	0.0	0.0	0.585
Diagnosis of STEMI by ED doctor	1.0	1.0	0.175
Time CVM registrar paged	5.0	3.0	0.009
Time CVM registrar responds	2.0	2.0	0.540
Time CVM registrar arrives in ED	8.0	5.0	0.001
Decision by CVM to offer reperfusion	5.0	6.5	0.246
Decision/consent by patient to accept	5.0	5.0	0.087
Time of cath lab activation (CVM lab staff paged)	5.0	5.0	0.369
Cath lab informs ED to transfer patient	5.5	15.0	0.104
Time patient leaves ED	8.0	4.0	0.103
Time of arrival at cath lab	5.0	5.0	0.948
Time to angiographic reperfusion	40.0	29.0	0.005

CVM: cardiovascular medicine; ECG: electrocardiograph; ED: Emergency Department

minutes post-audit, $P = 0.021$) as well for out-of-hours procedures (135.0 minutes pre-audit to 113.0 minutes post-audit, $P = 0.001$) (Fig. 2).

There were 4 cases with prolonged door-to-balloon times (all exceeding 220 minutes) where the patients took more than 30 minutes to make a decision on PCI. In another instance, 2 patients arrived simultaneously and PCI was delayed for 1 patient as another patient was undergoing emergency PCI for acute myocardial infarction (AMI). These outliers would have resulted in skewing of the data, but have not been excluded from statistical analysis as they reflect the reality and challenges of providing a primary PCI service.

There was no significant difference in measures of morbidity and mortality (Table 3), including 30-day mortality, between patients in the pre-audit and post-audit period, but the sample size was small for detecting such a difference.

Table 3. Morbidity and Mortality Data

Complication	Pre-audit	Post-audit	*P* value
Blood loss requiring transfusion	1/38	1/234	0.260
Local groin haematoma	1/38	3/234	0.454
Reinfarction	0/38	3/234	0.483
Heart failure	3/38	14/234	0.652
Inpatient death	2/38	10/234	0.677
30-day mortality	0/35 data not available for 3 cases	1/220 data not available for 14 cases	0.689

Discussion

Primary PCI is a highly effective but time-dependent treatment for STEMI, the mortality benefit of PTCA hinges on prompt time to treatment and especially the door-to-balloon time. Numerous strategies can be used to reduce door-to-balloon times and thus improve clinical outcomes with primary PCI. Our aim was to evaluate the effect of continuous quality improvement methods, monitoring of time delays to reduce door-to-balloon delay in primary PCI.

This study clearly demonstrates the role of audit as a quality improvement tool, as evidenced by the marked reductions in door-to-balloon times for acute STEMI. The median door-to-balloon time improved from 130.5 minutes to 109.5 minutes (P <0.001) as a result of changes implemented during the audit process – this is within the AHA recommendation of 90 ± 30 minutes. There were 2 key factors underlying this successful audit process:

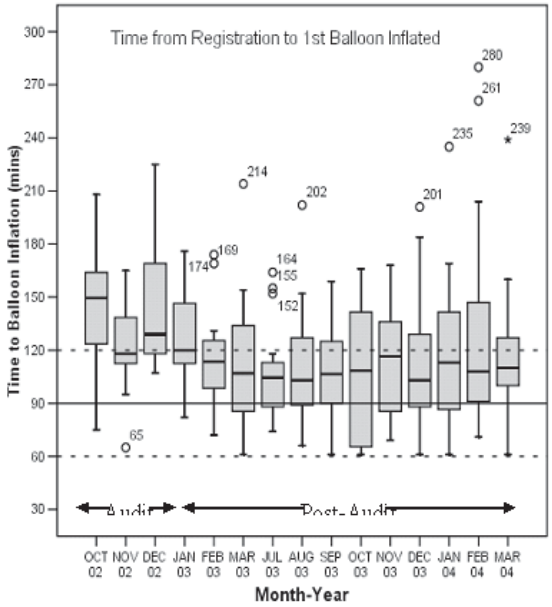

Fig. 1. Time from registration to first balloon inflation.

(1) the various steps in the pathway from patient's arrival in the ED to balloon inflation were charted out, weaknesses/delays were identified and measures taken addressing these weak links
(2) the process of regular audit and review highlighted the importance of the "time-is-muscle" concept to all staff concerned. This resulted in "buy-in" of the internal customers (i.e. the medical and nursing staff involved) leading to greater compliance and resulting improved efficiency.

We were able to formalise and implement a management algorithm for expediting care for patients with STEMI incorporating target timings. Improvements occurred when treatment protocols were adapted or amended in response to the audit process. With the algorithm, medical and nursing staff had clear and concise directions to follow, leading to enhanced efficiency. It has also been shown that simple passive monitoring of time intervals in the treatment of AMI leads to a reduction in door-to-balloon delays.[8]

Although our study did not look at the differences in mortality and morbidity between the 2 groups (pre-audit and post-audit), there are many examples in the medical literature to support the association between early primary angioplasty and reduced mortality/morbidity.[9-11]

To effectively reduce overall mortality and morbidity from acute STEMI, it is also important to reduce the "onset-to-opening" times i.e. the time interval between onset of chest pain and reperfusion of the culprit vessel. Delays in this process may be attributed to several factors:

(i) patient: delay between onset of symptoms and patients seeking medical attention

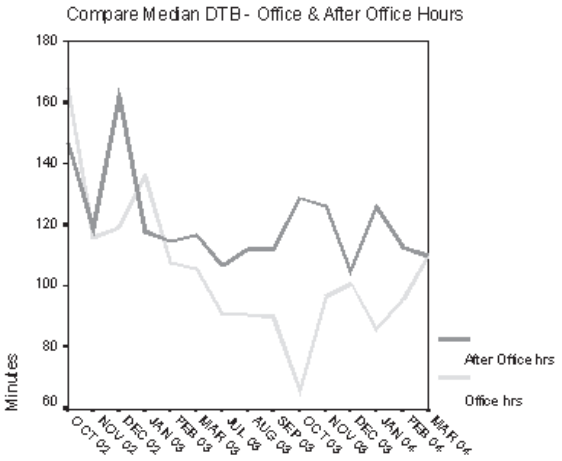

Fig. 2. Median results: during and after-hours.

(ii) transport: time taken for patient to arrive at a centre with acute PCI facilities
(iii) hospital: time between registration at ED and balloon-inflation

Our audit only examined the aspect of in-hospital delay – there is a clear and definite need for further audits to scrutinise and hopefully rectify the various causes of delay in transport of the patient to hospital.[12,13] In addition, in our institution, we are currently auditing Emergency Physician direct activation of the cardiac catheterisation team for patients with acute STEMI to further reduce the door to balloon inflation times.

Conclusion

Through this audit, our multidisciplinary team (emergency medicine physicians, cardiologists, nurses, CVL staff and quality management team) has developed a guideline-based, institution-specific written protocol for triaging and managing patients who present to the ED with symptoms suggestive of STEMI. This has resulted in shortened door-to-balloon times with better clinical outcomes without compromising safety or efficacy.

REFERENCES

1. Weaver WD, Simes RJ, Betriu A, Grines CL, Zijlstra F, Garcia E, et al. Comparison of primary coronary angioplasty and intravenous thrombolytic therapy for acute myocardial infarction: a quantitative review. JAMA 1997;278:2093-8.
2. Keeley EC, Boura JA, Grines CL. Primary angioplasty versus intravenous thrombolytic therapy for acute myocardial infarction: a quantitative review of 23 randomised trials. Lancet 2003;361:13-20.
3. A clinical trial comparing primary coronary angioplasty with tissue plasminogen activator for acute myocardial infarction. The Global Use of Strategies to Open Occluded Coronary Arteries in Acute Coronary Syndromes (GUSTO IIb) Angioplasty Substudy Investigators. N Engl J Med 1997;336:1621-8.
4. Zijlstra F, de Boer MJ, Hoorntje JC, Reiffers S, Reiber JH, Suryapranata H. A comparison of immediate coronary angioplasty with intravenous

streptokinase in acute myocardial infarction. N Engl J Med 1993;328: 680-4.
5. Cannon CP, Gibson CM, Lambrew CT, Shoultz DA, Levy D, French WJ, et al. Relationship of symptom-onset-to-balloon time and door-to-balloon time with mortality in patients undergoing angioplasty for acute myocardial infarction. JAMA 2000;283:2941-7.
6. Ryan TJ, Antman EM, Brooks NH, Califf RM, Hillis LD, Hiratzka LF, et al. 1999 update: ACC/AHA guidelines for the management of patients with acute myocardial infarction. A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee on Management of Acute Myocardial Infarction). J Am Coll Cardiol 1999;34:890-911.
7. Antman EM, Anbe DT, Armstrong PW, Bates ER, Green LA, Hand M et al. ACC/AHA guidelines for the management of patients with ST-elevation myocardial infarction – executive summary. A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to revise the 1999 guidelines for the management of patients with acute myocardial infarction). J Am Coll Cardiol 2004;44:671-719.
8. Shry EA, Eckart RE, Winslow JB, Rollefson WA, Simpson DE. Effect of monitoring of physician performance on door-to-balloon time for primary angioplasty in acute myocardial infarction. Am J Cardiol 2003;91:867-9.
9. Cannon CP. Time to treatment: a crucial factor in thrombolysis and primary angioplasty. J Thromb Thrombolysis 1996;3:249-55.
10. Liem AL, Van't Hor AW, Hoomtje JC, de Boer MJ, Suryapranata H, Zijlstra F. Influence of treatment delay on infarct size and clinical outcome in patients with acute myocardial infarction treated with primary angioplasty. J Am Coll Cardiol 1998;32:629-33.
11. Brodie BR, Stuckey TD, Wall TC, Kissling G, Hansen CJ, Muncy DB et al. Importance of time to reperfusion for 30 day and late survival and recovery of left ventricular function after primary angioplasty for acute myocardial infarction. J Am Coll Cardiol 1998;32:1312-9.
12. Khot UN, Johnson ML, Ramsey C, Khot MB, Todd R, Shaikh SR, et al. Emergency department physician activation of the catheterization laboratory and immediate transfer to an immediately available catheterization laboratory reduce door-to-balloon time in ST-elevation myocardial infarction. Circulation 2007;116:67-76.
13. Kraft PL, Newman S, Hanson D, Anderson W, Bastani A. Emergency physician discretion to activate the cardiac catheterization team decreases door-to-balloon time for acute ST-elevation myocardial infarction. Ann Emerg Med 2007;50:520-6.