Background—Timely reperfusion in ST-segment elevation myocardial infarction (STEMI) patients improves clinical outcomes. Implementing strategies to target institutional-specific delays are crucial for improved patient care.

Methods and Results—Using a novel strategy to analyze specific components of door-to-balloon time (DBT) at our institution, we previously identified several specific interval delays in our prior STEMI protocol. We then implemented 4 strategies to reduce DBT: (1) emergency department physician activation of the STEMI protocol; (2) “single call” broadcast paging of the STEMI team by the page operator; (3) immediate feedback to the emergency and cardiology departments with joint monthly quality improvement meetings; and (4) transfer of the off-hours STEMI patient directly to the laboratory on activation by an in-hospital team. After implementation of the new protocol, we examined each component time interval from the first 59 consecutive STEMI patients treated with the new protocol between March 2007 and June 2008 and compared time intervals with the previous 184 STEMI patients. Compared with the previous 184 STEMI patients, the median DBT of the subsequent 59 STEMI patients significantly improved from 125 to 86 minutes ($P<0.0001$). This improvement was largely driven by a decrease in the interval from the initial 12-lead ECG to activation of the on-call catheterization team (from 40 to 11 minutes, $P<0.0001$).

Conclusions—After examining specific component delays in our institution’s DBT, we were able to successfully use quality improvement strategies to focus on specific sources of delay in our institution. This dramatically improved our median DBT toward the goal of achieving a guideline-recommended <90 minutes for all patients. (Circ Cardiovasc Qual Outcomes. 2009;2:116-122.)

Key Words: ST-segment elevation myocardial infarction ■ door-to-balloon time ■ quality improvement

Goals and Vision of the Program

The importance of timely reperfusion in patients who present with ST-elevation myocardial infarction (STEMI) is well established. If performed by experienced operators, primary percutaneous coronary intervention (PCI) is the preferred method of reperfusion, with a 2% absolute reduction in mortality risk compared with thrombolytic therapy. However, the benefits of primary PCI over fibrinolytic therapy are clearly time dependent, and faster reperfusion of the infarct-related artery, as measured by a shorter door-to-balloon time (DBT), is associated with decreased rates of mortality, improved left ventricular dysfunction, and smaller infarct sizes. Reflecting increased appreciation of the adverse consequences of delay in primary PCI, the most recent American Heart Association/American College of Cardiology Guidelines for STEMI recommend a goal door-to-balloon time of <90 minutes (a class IA recommendation). Although there has been a heightened awareness regarding the significance of timely reperfusion, only 30% to 60% of patients treated at US acute care hospitals receive care within this recommended time frame. Our goal was to achieve DBT of <90 minutes by (1) identifying institution-specific areas of delay contributing to our prolonged door-to-balloon times, and (2) implementing evidence-based strategies to target these delays.

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Local Challenges in Implementation

The primary challenge in implementing our vision of timely reperfusion for STEMI patients is related to the
obstacles that exist in a large, urban, teaching-hospital setting. This setting has been previously shown to be a predictor of delayed DBT. With the multitude of emergency medicine and cardiology personnel typically involved in the care of the STEMI patient, care delivery is often unnecessarily complex. These local challenges were evident in our 2000 to 2006 median DBT of 125 minutes, well above the guideline recommended time.

At our institution, 2 specific time intervals were identified that contributed to the majority of delay in our prolonged DBT. One source of major delay occurred between ECG acquisition and catheterization team activation (Figure 1). The second significant time delay occurred between activation of the catheterization laboratory and procedure start. The latter delay was particularly significant during off-hours cases: a median of 45 minutes (interquartile range [IQR], 40 to 55) versus 20 minutes (IQR, 15 to 48) for patients who presented during the weekend compared with weekday presentation ($P < 0.05$), and median of 50 minutes (IQR, 45 to 56) versus 16 minutes (IQR, 15 to 40) for patients presenting between 6 PM and 6 AM compared with presentation between 6 AM and 6 PM ($P < 0.05$). Although the D2B Alliance for Quality recommends response of the catheterization laboratory team within 20 to 30 minutes after activation, this strategy would be difficult to achieve, as our hospital is located in a large metropolitan area, and the majority of cardiac catheterization laboratory staff live a significant distance from the hospital.

A final challenge identified is not unique to our institution, but is critical to recognize to achieve success of an interdisciplinary initiative regarding patient care outcomes. This is the recognition that for changes to be successful, continual interdepartmental collaboration between the emergency and cardiology departments is required, as both play essential roles in the care of the STEMI patient.

**Design of the Initiative**

Given our specific institutional challenges in achieving timely reperfusion as outlined above, new initiatives were designed to target these interval delays. The prior STEMI protocol (Figure 2) was analyzed in detail for areas of potential improvement. The prior protocol was a sequential, 14-step algorithm that required the involvement of multiple physicians before activating the catheterization laboratory. The notification of the interventional cardiologist on-call to confirm the diagnosis of STEMI followed by catheterization laboratory activation contributed to the majority of delay occurring between ECG acquisition and catheterization team activation. Thus, we decided to use the strategy of direct emergency physician activation of the catheterization laboratory without interventional cardiologist notification, which has been shown to improve DBTs. Our prior protocol also required multiple sequential telephone calls, including calls from the emergency department to the interventional cardiologist, and then from the interventional cardiologist to the emergency department and catheterization laboratory staff. It was evident that a single phone call to the operator would allow for a more streamlined system in catheterization laboratory activation, as reported by others. The central operator could then notify all essential personnel involved in the procedure by 1 group page.
A significant contribution of delay also occurred between pager activation and procedure start, primarily driven by our off-hours cases. The main source of this delay was the considerable distance between the catheterization team’s homes and the hospital, making it difficult for the staff to arrive within the recommended 20- to 30-minute time frame. Although a portion of this delay was unavoidable, we realized there was room for optimization of our prior STEMI algorithm. Under the old protocol, the catheterization laboratory staff would initially arrive at the emergency department to pick up the patient and transport him or her to the catheterization laboratory, where they would then turn on the equipment and prepare for the procedure. We realized that if it were possible to have the patient already in the laboratory by the time the staff arrived to the hospital, this would minimize delays caused by long travel time during off-hours cases. Khot et al.13 have also shown that immediate transfer of the patient to the laboratory after activation has been associated with improved DBTs.

**Implementation of the Initiative**

In March 2007, we implemented 4 proven strategies to reduce DBT in our STEMI protocol, including (1) emergency department physician activation of the catheterization laboratory,13–19 (2) “single call” broadcast paging of the STEMI team by the page operator,14–16 (3) immediate feedback to the emergency and cardiology departments after joint monthly quality improvement meetings to review every STEMI case,14–16 and (4) transfer of the off-hours STEMI patients directly to the laboratory on activation.13

Direct activation of the catheterization laboratory by the emergency department required extensive teaching of emergency medicine nurses and physicians. This education was provided by the emergency department medical director and the nurse managers. The education included instruction in the appropriate and rapid ECG identification of STEMI, procedural steps to activate the on-call catheterization team, and immediate paging of the cardiology fellow on-call to discuss cases when the diagnosis of STEMI was ambiguous or the decision to proceed with catheterization laboratory activation was not clear. Additionally, direct feedback to the emergency department physician regarding case outcome was initiated by the interventional cardiologists to assist in ongoing education.

Education of the cardiac catheterization laboratory staff, cardiology fellows, and interventional cardiologists was provided by the medical director of the catheterization laboratory and the catheterization laboratory nurse manager. This focused on the appropriate identification and rapid response to the broadcast group page by the page operator, and details on how to facilitate transfer of the patient to the catheterization laboratory. The fellows were also given a pocket-sized card with the telephone numbers of the page operator and interventional attendings, and instructions on how to activate the catheterization laboratory.

To achieve activation of the laboratory through a single call to the page operator, strategy meetings between the emergency department, cardiology representatives, and the paging center were held to develop the text page verbage identifying patient name, diagnosis, and location, which would be sent to the on-call catheterization team. A strategy was developed to confirm interventional cardiology faculty response to the notification, which required that the interventional attending call the page operator on receipt of the page. If the page operator did not receive this call within 5 minutes, the group page was sent out again. The cardiology fellows were instructed if they received a second identical group page to call the interventional attending from the numbers on their pocket card to ensure attending notification. The page operator was also given a monthly call schedule of all individuals that would need to be activated by the page each day. The paging center also allowed the use of the stat page line for this initiative, which results in a direct response by an operator within 3 seconds.

To facilitate a multidisciplinary approach between both the emergency and cardiology departments, we implemented a strategy of providing immediate feedback to both departments after joint monthly quality improvement meetings to discuss every STEMI activation case. These meetings are attended by representatives from the emergency department, interventional cardiology, the paging system, hospital administration, nursing, and performance improvement. The Performance Improvement and Clinical Safety team aided these efforts by compiling all of the time data on each STEMI patient to present at these multidisciplinary meetings, and providing continuous weekly reporting of DBT intervals on all patients. All members of the emergency department, cardiology department, and the paging system are encouraged to communicate difficulties with the process in between these monthly meetings to rapidly target any system difficulties.

For our off-hours cases, we designed an in-hospital catheterization laboratory activation (CAT) team in November 2007 to assist with patient transfer to the catheterization laboratory directly from the emergency department following activation. The CAT team is comprised of the medical intensive care unit charge nurse and the on-call cardiac care unit resident, who are also notified by the STEMI group page. They assist with patient transfer from the emergency department to the catheterization laboratory, placement of the patient on the procedure table and connection to monitoring equipment, and activation of the catheterization laboratory equipment, when the on-call catheterization laboratory team is en route. Education of the medical intensive care nurse was given by the catheterization laboratory nurse manager, and the cardiac care unit residents are reminded of their duties at the start of every rotation cycle by their cardiac care unit attending. The goal of this process was to allow the on-call catheterization team to start the procedure immediately on arrival to the catheterization laboratory.

The authors had full access to and take full responsibility for the integrity of the data. All authors have read and agree to the manuscript as written.
Success of the Initiative

To assess the overall effects of implementing the steps detailed above, we examined the first 59 consecutive STEMI patients presenting between March 2007 and June 2008, after implementation of our new protocols. We divided DBT into 4 distinct time intervals as we did in our prior study, including (1) door to initial ECG, (2) ECG to on-call catheterization team activation, (3) on-call catheterization team activation to start of the procedure, and (4) start of the procedure to first balloon inflation. STEMI was defined from ECG criteria as ST-segment elevation >0.1 mV in ≥2 contiguous precordial leads or a new left bundle branch block.

Data were analyzed using the SAS statistical software package (version 9.13, SAS Institute, Cary, NC). Because of the skewed nature of the underlying response times, nonparametric comparisons were used to compare time intervals between the prior STEMI patients and the new STEMI patients, and results are reported as medians and interquartile ranges. For intergroup comparisons, the Wilcoxon rank-sum test was used, and 2-tailed probability values \( P < 0.05 \) were considered statistically significant. Because of the potential problems arising from multiple comparisons, we used the Bonferroni correction to evaluate statistical significance; \( P < 0.01 \) was our corrected threshold.

Our median DBT significantly improved from a median of 125 minutes (IQR, 100 to 166) to 86 minutes (IQR, 68 to 102) (Wilcoxon rank-sum test statistic, 4277; \( P < 0.0001 \)), largely driven by a decrease in the time interval between initial ECG acquisition and on-call catheterization team activation, from 40 minutes (IQR, 20 to 59) to 11 minutes (IQR, 7 to 18) (Wilcoxon rank-sum test statistic, 4018.5; \( P < 0.0001 \)) (Figure 3). The time interval between door and ECG acquisition also improved from 14 minutes (IQR, 8 to 28) to 10 minutes (IQR, 3 to 18) (Wilcoxon rank-sum test statistic, 5596.5; \( P = 0.0006 \)). There was a slight increase from 40 minutes (IQR, 15 to 50) to 43 minutes (IQR, 32 to 52) in the time between catheterization team activation and start of the procedure (Wilcoxon rank-sum test statistic, 8305.0; \( P = 0.02 \)). Time between the start of the procedure to the first balloon inflation improved from 29 minutes (IQR, 22 to 36) to 20 minutes (IQR, 17 to 27) (Wilcoxon rank-sum test statistic, 4952; \( P < 0.0001 \)).

There was a significant improvement in time between catheterization team activation and procedure start for off-hours cases, from 52 minutes (IQR, 49 to 64) to 45 minutes (IQR, 39 to 48) after implementation of the CAT team strategy (\( P = 0.0003 \)). The median DBT for off-hours cases also improved, from 101 minutes (IQR, 89 to 125) to 86 minutes (IQR, 68 to 99) (\( P = 0.008 \)). The fraction of off-hours patients at goal DBT also improved after CAT initiation, from 27.8% to 73.3% (\( P = 0.01 \)). Overall, the entire group of patients at goal DBT of <90 minutes increased from 17.4% to 61.0% after the implementation of our new strategies (\( P < 0.0001 \)).

Summary of the Experience, Future Directions, and Challenges

Timely reperfusion of patients presenting with STEMI is critical to optimize patient outcomes and DBT is now a national quality measure. Bradley et al\(^{14} \) has described several time-saving strategies to reduce DBT and demonstrated that DBT decreases as the number of strategies utilized increases. There has also been an initiative aimed at the national level, the D2B Alliance for Quality,\(^ {12,20} \) which gives hospitals across the country the assistance needed to improve their care of STEMI patients. To identify specific targets for interventions at our own institution, we previously reported our DBT and identified several time intervals between specific components that required improvement. At our hospital, 2 specific time intervals were responsible for the majority of our delayed time to reperfusion: ECG to catheterization team activation for all cases, and catheterization team activation to procedure start, primarily for off-hours cases.

The origin of delay during the time between the first ECG and catheterization team activation was evident in our old STEMI protocol, which revealed that the majority of delay occurred between steps 6 and 9, which involved notification of the interventional cardiologist on-call to activate the catheterization laboratory. To address this problem, we implemented the following 2 strategies: (1) emergency department activation of the catheterization laboratory without interventional cardiologist notification,
and (2) “single call” broadcast paging of the STEMI team through a single call to the central page operator. These 2 interventions alone were responsible for the majority of time saved in our new DBT, with a median decrease of 29 minutes from first ECG to on-call catheterization team activation. These new strategies also reduced the number of steps within the STEMI protocol from 14 to 9 (Figure 4).

A significant predictor of delay during the time interval between on-call catheterization team activation and start of the procedure occurred during patient presentation during off-hours, which has previously been reported as a contributor to delayed reperfusion.21–22 Other studies have also described the difficulty in obtaining goal DBTs for patients who present during off-hours despite systematic protocol implementation, which is primarily attributed to delayed time between laboratory activation and procedure start.23 Although an in-house interventional cardiologist has been identified as a successful strategy in improving delays,15 this strategy was not a realistic option at our large, urban, teaching hospital. Thus, we subsequently created the CAT team to assist with the STEMI patients who presented during off hours. CAT implementation significantly decreased the median time between on-call catheterization team activation and procedure start for our off-hours patients (52 minutes versus 45 minutes; Wilcoxon rank-sum test statistic, 154.5; *P* = 0.0003), and it improved the overall median DBT (101 versus 86 minutes; Wilcoxon rank-sum test statistic, 181.5; *P* = 0.008), including the fraction of patients achieving goal DBTs (27.8% versus 73.3%; *χ²* = 6.8; *P* = 0.01). This strategy seems to be a feasible alternative to achieving improved times in large, urban centers where there is not an in-house cardiologist present during off-hours. Although no specific interventions directly addressed the interval between procedure start and balloon inflation, our significantly improved times likely represent a heightened awareness that exists for the interventional cardiologist in improving the care of our STEMI patients, and the feedback provided to them monthly regarding their personal DBTs.

A multidisciplinary approach involving both the emergency and cardiology departments has been crucial in our success of improving DBT at our institution. Implementing the strategy of providing immediate feedback to both departments after joint monthly quality improvement meetings to discuss every STEMI activation case has allowed direct feedback to all care members involved in the process.

We systematically identified the systemic component delays in our institution to detect the time intervals that would benefit the most from time-saving interventions. Although other tertiary care referral institutions have reported their reduced DBTs,24–25 our study is unique in that it is the largest to report on the feasibility of doing so in a large, urban, teaching hospital, a setting that has previously been shown to be a predictor of delay itself.10 Finally, our study highlights the speed with which improvement can be achieved. We have been able to report our systematic identification of delays and then report our significant improvements in DBT just 1 year after implementing several strategies targeted to our institution-specific delays.

Although we have significantly improved our DBT with 17.4% to 61.0% of patients achieving a DBT time <90 minutes (*P*<0.0001), our goal is to achieve a DBT time <90 minutes for all STEMI patients. An area of improvement includes the time interval between door and ECG acquisition, which is currently at a median of 10 minutes. Exploring the possibility of prehospital ECG transmission may assist in improving times for patients who arrive by ambulance. Another area of improvement still lies between the time of activation of the laboratory and procedure start. Our median time of 43 minutes is above the recommended goal of 20 to 30 minutes. Presentation during off-hours drives this increase in time. We are currently focusing on trying to implement prehospital activation of the catheter-
ization laboratory by EMS personnel, which has been shown to improve DBTs.26–27

Our study has several limitations. We did not include patients who were transferred from outside institutions for primary PCI into our analysis. However, there are only a few cases of transfer from outside hospitals to Parkland per year. We also did not systematically track patients in whom the diagnosis of STEMI was missed and the patient was subsequently activated by the admitting team. Given that the majority of these patients were referred to the catheterization laboratory, the number of such cases was small during the study period. However, we did include patients in whom the diagnosis was delayed by emergency room recognition or ECG acquisition. We also did not include 2 patients in whom the diagnosis and activation of the catheterization laboratory was not made by the emergency department because the patient was on an inpatients service at the time of development of acute STEMI. Additionally, 2 of our 59 patients did not undergo PCI after diagnostic catheterization and were referred for coronary artery bypass graft surgery.

In conclusion, achieving a DBT of <90 minutes in STEMI is critical for improved patient care, and it is feasible at large, urban, teaching hospitals. Systematically identifying institution-specific areas of delay can help focus efforts on implementing appropriate strategies to decrease the delay.

Disclosures

None.

References


EDITOR’S NOTE

With this issue of Circulation: Cardiovascular Quality and Outcomes Research, we are excited to launch a new type of article, Innovations in Care. We invite clinicians, hospitals, outpatient facilities, and health systems to examine novel changes in the structure and processes of care that they provide and to analyze the impact of these changes on clinically meaningful outcomes. The goal of this series is to disseminate novel innovations in healthcare delivery that have preliminary data to show improvements in clinically important process of care or outcomes. Please refer to the Instructions to Authors for details about the organization and presentation of these articles (http://circoutcomes.ahajournals.org/misc/ifora.dtl).

In this issue of the journal, an inner-city hospital evaluated its success in achieving rapid door-to-balloon times and noted several challenges to their standard approach (Circ Cardiovasc Qual Outcomes. 2009;2:116–122). In addition to drawing upon several of the tools from the National Door-2-Balloon initiative (www.D2Balliance.org), they developed novel strategies—including the creation of a transport team to take STEMI patients to the cardiac catheterization laboratory while the intervention team was preparing for the procedure—to successfully improve their performance. These types of interventions are novel and important to disseminate, and we hope that other members of our readership will evaluate and share their experiences for improving care in this new series.
Systems-Based Improvement in Door-to-Balloon Times at a Large Urban Teaching Hospital: A Follow-Up Study From Parkland Health and Hospital System

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