Improvement in Door-to-Balloon (D2B) Time in Acute ST-Elevation Myocardial Infarction Through the D2B Alliance – Experience of 15 Primary Percutaneous Coronary Intervention Centers in Taiwan –

Su-Kiat Chua, MD; Jun-Jack Cheng, MD, PhD; Kou-Gi Shyu, MD, PhD; Jen-Yuan Kuo, MD; Yu-Lin Ko, MD; Chun-Chieh Wang, MD; Kuan-Cheng Chang, MD; Po-Ming Ku, MD; Shih-Huang Lee, MD, PhD

Background: Currently, the door-to-balloon (D2B) times observed in clinical practice in Taiwan are different from those recommended by evidence-based guidelines. D2B Alliance, a countrywide initiative for quality supported by the Taiwan Joint Commission on Hospital Accreditation, sought to achieve the goal of administering treatment to 75% of patients with ST-elevation myocardial infarction (STEMI) within 90 min of hospital presentation.

Methods and Results: The current study was designed to be prospective, national, and multicenter. We conducted a longitudinal study of the D2B times recorded in 15 primary percutaneous coronary intervention centers and examined the changes caused by implementing the D2B Alliance strategies. A total of 1,726 patients were enrolled in the D2B Alliance and implementation of the D2B Alliance strategies resulted in a significant decrease in the average D2B times (128.8±42.9 min vs. 83.2±16.2 min; P<0.001) from those at baseline. By the end of the year-long study, the percentage of patients treated under 90 min had increased from 46.2% to 80.1% in the hospitals enrolled in the D2B Alliance.

Conclusions: Over the 1 year, hospitals enrolled in the D2B Alliance achieved the goal of reducing the D2B times of 75% of STEMI patients to less than 90 min. (Circ J 2013; 77: 383–389)

Key Words: Acute myocardial infarction; Door-to-balloon time; National registries; Quality improvement

Patients with acute ST-segment elevation myocardial infarction (STEMI) require quick and efficient reperfusion treatment. The time from arrival at the hospital to percutaneous coronary intervention (PCI) for the infarct-related artery, the so-called “door-to-balloon (D2B) time”, is associated with the clinical outcome of patients.1–7 Clinical practice guidelines recommend that STEMI patients receive primary PCI (PPCI) as soon as possible, and definitely within 90 min.8–10 For the full realization of the benefits of PPCI in STEMI, an improved system needs to be established to decrease the total D2B time. In recent times, various innovations and key strategies have been shown to be associated with short D2B times.11–14 Despite the implementation of such strategies, studies published hitherto,15–17 except for a few,18 indicate that only approximately 50% of STEMI patients receive PPCI within the recommended 90-min D2B time. Many patients do not receive prompt PPCI, and some of the institutions participating in the studies have shown that underuse of strategies is associated with longer D2B times. Several recent studies have examined the effectiveness of the formation of a D2B Alliance in reducing the D2B times to less than 90 min in STEMI.19–21 Those studies have found marked changes in both the practice...
and performance of PPCI for STEMI patients in the involved hospitals.

A comparison of the data from the Taiwan Acute Coronary Syndrome (ACS) Full Spectrum Registry and findings of a retrospective study on the quality of care of ACS patients in Taiwan indicates a disparity between the D2B times recommended by evidence-based guidelines and those observed in clinical practice. The Taiwan Joint Commission on Hospital Accreditation has recently initiated a D2B Alliance to improve hospital performance with respect to D2B times. The goal of the D2B Alliance is to attain D2B times of less than 90 min for at least 75% of non-transfer STEMI patients by using the strategies described in previous studies. In this study, the differences in the D2B times brought about by the adoption of the recommended strategies were examined in PPCI centers involved in the D2B Alliance.

Methods

Study Design

The current investigation was designed as a prospective, national, multicenter study comprising 15 PPCI centers enrolled in the D2B Alliance. Each participating site recruited approximately 50–100 consecutive eligible patients. The sites were selected by the Scientific Committee of Taiwan Joint Commission on Hospital Accreditation to ensure good representation of the STEMI population. Data from all enrolled hospitals were used to examine the differences in performance before

<table>
<thead>
<tr>
<th>Table. Characteristics of Primary Percutaneous Coronary Intervention Centers Enrolled in the D2B Alliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>D2B Alliance</td>
</tr>
<tr>
<td>Geography</td>
</tr>
<tr>
<td>Location</td>
</tr>
<tr>
<td>Rural</td>
</tr>
<tr>
<td>Urban</td>
</tr>
<tr>
<td>Region</td>
</tr>
<tr>
<td>Northern Taiwan</td>
</tr>
<tr>
<td>Central Taiwan</td>
</tr>
<tr>
<td>Southern Taiwan</td>
</tr>
<tr>
<td>Eastern Taiwan</td>
</tr>
<tr>
<td>Bed size</td>
</tr>
<tr>
<td>&lt;500</td>
</tr>
<tr>
<td>≥500</td>
</tr>
<tr>
<td>Ownership</td>
</tr>
<tr>
<td>Government</td>
</tr>
<tr>
<td>For profit</td>
</tr>
<tr>
<td>Part of a multi-hospital system</td>
</tr>
<tr>
<td>No</td>
</tr>
<tr>
<td>Yes</td>
</tr>
</tbody>
</table>

Values are n (%). D2B, door-to-balloon.

Figure 1. (A) Time from arrival at the emergency department (ED) to acquiring the 12-lead electrocardiogram. (B) Time until ST-elevation myocardial infarction was diagnosed by ED physicians. (C) Time elapsed between the paging and arrival of an interventional cardiologist before and after forming the Door-to-Balloon (D2B) Alliance. (D) Time elapsed between the paging and arrival of catheterization laboratory staff. *P<0.05 when examined alongside intervals before forming the D2B Alliance.
Door-to-Balloon Alliance in STEMI

and after joining the D2B Alliance. A baseline survey of the participating centers before enrollment was conducted from July 2008 to June 2009, and the follow-up survey was conducted from July 2009 to June 2010. The principle goal of the D2B Alliance was that the involved hospitals administer PPCI to 75% of their non-transfer STEMI patients within 90 min of arrival at the hospital. The chief executive officer provided contact information for the person in the organization deemed most appropriate for responding to this survey. The institutional review boards at the local institutions approved the study protocol.

Data Collection and Measures

The data for all STEMI patients admitted to emergency departments (ED) between July 2008 and June 2010 for PPCI were pooled to analyze the differences in performance before and after implementing the D2B Alliance strategies. STEMI was diagnosed by the presence of chest pain lasting >30 min, ST-segment elevation >1.0 mm in at least 2 contiguous leads on electrocardiogram (ECG), and >3-fold increase in serum creatine kinase (CK) above the normal value.24,25 The exclusion criteria were: (1) fibrinolytic therapy before cardiac catheterization; (2) D2B times >6h or unknown, because these cases likely did not represent PPCI cases; (3) transfer from another acute-care facility, and (4) occurrence of STEMI after arrival at the ED. The D2B time was specifically defined as the number of minutes from hospital arrival to first balloon inflation, thrombus aspiration or device deployment to establish reperfusion.19

This research was completed using surveys of hospitals that administered PPCI and submitted publicly available data to the Taiwan Joint Commission on Hospital Accreditation. In order to improve the D2B times in the 15 participating PPCI centers, a variety of learning processes derived from a breakthrough series model and evidence-based methods were implemented. The following techniques were found to have considerable and significant relationships to shorter D2B times: (1) mobilization of the catheterization laboratory by ED physicians; (2) requirement of only one call by ED physicians to page an interventional cardiologist and catheterization laboratory staff; (3) availability of catheterization laboratory staff in less than 30 min from being paged; (4) quick (<1 week) data feedback regarding D2B times to both the ED and catheterization laboratory staff; (5) quick patient transportation from the ED to the catheterization room; (6) storage of STEMI drug packs in the ED; (7) packaging of single-catheter device in the catheterization laboratory; and (8) availability of an interventional cardiologist and catheterization team within the hospital at all times.12,14,21,26–28

The principle result was the difference in the percentage of STEMI patients receiving PPCI treatment with D2B times <90 min during the observed period. The difference in time was also evaluated in terms of the following parameters: (1)
time to complete 12-lead ECG; (2) time to confirm the STEMI diagnosis by ED physicians; (3) arrival of an interventional cardiologist at the ED after paging; (4) paging and arrival of staff to the catheterization laboratory; (5) length of patient’s stay in the ED; (6) time to move patient from the ED to the catheterization laboratory; (7) time between arrival at the catheterization laboratory and balloon inflation of the infarct-related artery; (8) average of D2B times; and (9) percentage of STEMI patients with D2B time <90 min.

Statistical Analysis
Quantitative data are expressed as mean±SD. Non-parametric data were analyzed with a t-test. P<0.05 was considered statistically significant. The percentage of patients with D2B times <90 min was plotted against months since enrollment in the D2B Alliance in order to describe the differences in D2B times before and after implementing the recommended strategies.

Results
Study Samples
Hospitals enrolled in the D2B Alliance with respect to size, geographic location, and nature of ownership are summarized in Table. In all, 1,726 non-transferred, consecutive STEMI patients underwent PPCI at the 15 PPCI centers were enrolled in the D2B Alliance. Of these patients, 781 were enrolled before (July 1, 2008 to June 30, 2009) and 945 after (July 1, 2009 to June 30, 2010) the formation of the D2B Alliance.

Time Trends Among Techniques After Forming the D2B Alliance
After the launch of the D2B Alliance campaign, considerable improvement was noted in the following parameters: time from arrival at the ED to completion of the 12-lead ECG recording (Figure 1A), time for ED physicians to diagnose STEMI (Figure 1B), and the interval between paging and arrival of the catheterization laboratory staff (Figure 1D). However, the interval between the paging and arrival of the interventional cardiologist at the ED (Figure 1C) did not show any significant difference.

Similarly, a significant decrease was noted in the length of patients’ stay in the ED and in the time to move patients from the ED to the catheterization laboratory (Figures 2A,B) after the implementation of the D2B Alliance strategies. However, no such change was noted in the duration from arrival at the catheterization laboratory door-to-balloon inflation of the infarct-related artery (Figure 2C).

The differences in the parameters before and after implementation of the D2B Alliance strategies, with the average of each interval, are summarized in Figure 3. The implementation of the D2B Alliance strategies resulted in a significant decrease in the following parameters compared with baseline: time to completion of the 12-lead ECG recording (17.0±16.6 min vs. 6.5±3.9 min, P=0.03), time to confirm STEMI diagnosis (24.0±18.2 min vs. 8.6±4.9 min, P=0.01), paging and arrival of catheterization laboratory staff (27.1±10.6 min vs. 16.5±7.2 min, P=0.01), length of patient’s stay in the ED (78.1±36.5 min vs. 51.4±12.8 min, P=0.02), and the time to
Figure 4. (A) Tracking of the average door-to-balloon (D2B) times recorded over the year after forming the D2B Alliance. (B) Contrast of the average D2B times before and after forming the D2B Alliance. *P<0.05 when examined alongside the interval before forming the D2B Alliance; †P<0.001 when examined alongside the interval before forming the D2B Alliance.

Figure 5. (A) Tracking of the percentage of ST-elevation myocardial infarction patients with door-to-balloon (D2B) times under 90min before and 1 year after forming the D2B Alliance; (B) Contrast of D2B times of less than 90min before, 1–6 months after, and 7–12 months after forming the D2B Alliance.
transport patients from the ED to the catheterization laboratory (25.3±27.6 min vs. 7.8±2.9 min, P=0.03). However, the time between the paging and arrival of an interventional cardiologist at the ED (9.9±8.4 min vs. 9.5±6.3 min, P=0.90) and the time between arrival at the catheterization laboratory and balloon inflation of the infarct-related artery (27.5±8.0 min vs. 24.7±5.8 min, P=0.31) displayed no significant change after implementation of the D2B Alliance strategies.

**Time Trends in D2B Times Among All Hospitals**

The charting of D2B times over 1 year showed significant improvement after implementing the D2B Alliance strategies. The average D2B times showed considerable improvement within 3 months of implementing the D2B Alliance strategies (Figure 4A). The improvement steadily continued until the end of the observation period. Compared with the baseline values, the average D2B times at the end of the study period were considerably shorter (128.8±42.9 min vs. 83.2±16.2 min, P<0.001; Figure 4B).

Only 32.3% of STEMI patients had D2B times <90 min before implementing the D2B Alliance. This percentage improved every month after implementing the D2B Alliance strategies (Figure 5A); within 6 months, the value was 73.5%. This improvement steadily continued, and by the end of the study, 80.1% of STEMI patients had D2B times <90 min. After implementation of the D2B Alliance strategies, the average percentage showed considerable improvement during the first 6 months (from 32.3±25.3% to 68.3±21.0%, P<0.001), and even more improvement in the subsequent months (80.2±15.3%, P<0.001). Overall, the extent of improvement of this percentage among the 15 participating PPCI centers was 37±17%.

We plotted the percentage of patients who received treatment in less than 90 min against the 12 months of enrollment in the D2B Alliance. By the end for the study period, this percentage had increased from 46.2% to 80.1% in the hospitals enrolled in the D2B Alliance (Figure 6). The percentage of patients receiving treatment in less than 90 min over the year after forming the D2B Alliance increased by 3.2% per month.

**Discussion**

In this study, a significant improvement was noted in the D2B times recorded in the hospitals enrolled in the D2B Alliance. Improvements in the D2B times were first noticed as early as 3 months after the formation of the D2B Alliance and implementation of its strategies and the goal of reducing the D2B times of 75% of STEMI patients to less than 90 min was achieved in the first 6 months. Our findings show that the trend of improvement continued until the end of the study period.

Improvements were noted in both the time to acquire and interpret a 12-lead ECG after arrival at the hospital and time to readiness of the catheterization laboratory after mobilization. These improvements contributed to the shortening of the length of the patient’s stay in the ED. This useful reference point was also used in this study for comparing the differences in the D2B times before and after forming the D2B Alliance. The percentage of patients receiving treatment in less than 90 min over the 1 year after forming the D2B Alliance increased by approximately 4% per month. Our findings are consistent with those of previous studies indicating that the D2B Alliance was successful in achieving a widespread coalition of practitioners, hospitals, and organizations agreeing to improve D2B times. 19-21

The present study demonstrated significantly greater improvement in the D2B times recorded in the hospitals enrolled in the D2B Alliance. These findings support the theory that the combined efforts of using the D2B Alliance strategies played a substantial role in improving the D2B times recorded in the involved hospitals. Although our findings indicate considerable improvement in the D2B times after forming the D2B Alliance, they do not necessarily establish a causal relation. It is difficult to determine whether some of the techniques were surrogates for unmeasured care procedures that might have contributed significantly to the reduction in D2B times. Furthermore, although some methods may have been significant in individual institutions, they may not be valid across the complete sample of centers, and our results should not inhibit innovations that may be effective in specific settings.

**Clinical Implications**

STEMI presents a true medical emergency in which the relationship between treatment and mortality is measured in minutes. Every minute of delay in the treatment of STEMI patients affects their long-term mortality. Therefore, the total ischemic time should be shortened by any and all possible efforts.

**Study Limitations**

First, the prehospital ECGs of the patients were not obtained at the institute involved in this study. Recent studies have shown that prehospital ECG diagnosis of STEMI with mobilization of the cardiac catheterization laboratory can markedly reduce D2B time. 19,30 The D2B times noted in this study might be reduced even further by obtaining prehospital ECGs. Second, it is difficult to attribute the changes of D2B times to a single strategy, because multiple strategies were performed simultaneously. However, the rapid improvement in the timeliness of care for STEMI patients is an impressive national accomplishment. Third, the investigated data were reported by hospitals involved in this study for comparing the differences in the D2B times recorded in the hospitals enrolled in the D2B Alliance. These findings support the theory that the combined efforts of using the D2B Alliance strategies played a substantial role in improving the D2B times recorded in the involved hospitals. Although our findings indicate considerable improvement in the D2B times after forming the D2B Alliance, they do not necessarily establish a causal relation. It is difficult to determine whether some of the techniques were surrogates for unmeasured care procedures that might have contributed significantly to the reduction in D2B times. Furthermore, although some methods may have been significant in individual institutions, they may not be valid across the complete sample of centers, and our results should not inhibit innovations that may be effective in specific settings.

**Conclusions**

The establishment of the D2B Alliance resulted in a significant improvement in the time to administer PPCI to STEMI
patients. Attributing the differences to a single strategy is difficult because multiple methods were simultaneously employed. However, the maintenance of D2B time at less than 90 min will probably require interdisciplinary cooperation, organizational leadership, and effective innovations to overcome the barriers to organizational change.

**Acknowledgments**

We thank Ching-Yin Yeh of the Graduate Institute of Public Health, Taipei Medical University, for her support with the statistical analysis of the D2B Alliance data. We also express our sincerest thanks and appreciation to the physicians and nurses who participated in the D2B Alliance.

**References**