Tohoku J. Exp. Med., 2018, **244**, 305-315

Reduction in Door-to-Balloon Time with Training for Effective and Efficient Action in Medical Service-Better Process (TEAMS-BP) at a Community Hospital in Japan

Hiroki Isono,[1,2] Tetsuhiro Maeno[3] and Shigeyuki Watanabe[4]

[1]Graduate School of Comprehensive Human Sciences, University of Tsukuba, Tsukuba, Ibaraki, Japan
[2]Department of Medicine, Tsukuba University Hospital Mito Clinical Education and Training Center, Mito Kyodo General Hospital, Mito, Ibaraki, Japan
[3]Department of Primary Care and Medical Education, University of Tsukuba, Tsukuba, Ibaraki, Japan
[4]Department of Cardiology, Tsukuba University Hospital Mito Clinical Education and Training Center, Mito Kyodo General Hospital, Mito, Ibaraki, Japan

ST-elevation myocardial infarction (STEMI) is a fatal condition. Prompt primary percutaneous coronary intervention is associated with lower mortality. However, community hospitals in Japan lack human and medical resources, and implementation of the same strategies as those used in the USA, such as an on-call cardiologist at the hospital, to achieve a door-to-balloon time of ≤ 90 min appears particularly challenging. Therefore, we used Training for Effective and Efficient Action in Medical Service-Better Process (TEAMS-BP) to develop a new process and assessed its effectiveness in reducing door-to-balloon time. TEAMS-BP can optimize the process by making the best use of available materials, machines, facilities and manpower. All processes conducted by physicians, nurses, electrocardiogram technicians, radiological technologists, and clerical staff in the emergency room were reviewed, documented, and standardized using the four steps of TEAMS-BP. The following processes were implemented: setting time goals, calling an electrocardiogram technician beforehand, minimizing tasks before calling a cardiologist, confirming the checklist, and providing data feedback. Forty-four STEMI patients who were treated after TEAMS-BP implementation were compared with 58 who were treated before implementation. Median door-to-balloon, door-to-electrocardiogram and door-to-laboratory times were significantly reduced after TEAMS-BP implementation, decreasing from 106 to 82 min, 14 to 6 min, and 67 to 45 min, respectively. In conclusion, implementation of TEAMS-BP improved the door-to-balloon time of STEMI cases without additional resources or costs incurred by the hospital. TEAMS-BP can be implemented by any hospital wishing to develop a new process that accommodates local working conditions.

Keywords: door-to-balloon time; primary percutaneous coronary intervention; quality improvement; ST-elevation myocardial infarction; Training for Effective and Efficient Action in Medical Service-Better Process
Tohoku J. Exp. Med., 2018 April, **244** (4), 305-315.

Introduction

Although ST-elevation myocardial infarction (STEMI) is a serious condition, mortality has been shown to be decreased by prompt primary percutaneous coronary intervention (PCI) (McNamara et al. 2006). The initial step in management of the STEMI patient is prompt recognition, because the benefit of reperfusion therapy is greatest when it is performed soon after presentation. For patients presenting to the emergency room (ER) with ischemic symptoms that arouse suspicion of an acute coronary syndrome, the diagnosis of STEMI can be confirmed by an electrocardiogram (ECG). Once the diagnosis of STEMI is made in the ER, the STEMI patient should have continuous cardiac monitoring, oxygen, intravenous access, and antiplatelet therapy. Therapy should be started to relieve ischemic pain, stabilize hemodynamic status, and reduce ischemia while the patient is being assessed as a candidate for primary PCI in the ER. Prompt restoration of coronary blood flow is essential to optimizing myocardial salvage and reducing mortality. PCI refers to the nonsurgical procedure used to improve coronary blood flow at the site of occlusion and involves balloon inflation and stent placement.

Clinical guidelines for managing STEMI patients recommend a maximum door-to-balloon (DTB) time, the time between arrival at the hospital and primary PCI, of 90 min

Received November 15, 2017; revised and accepted March 26, 2018. Published online April 13, 2018; doi: 10.1620/tjem.244.305.
Correspondence: Hiroki Isono, M.D., Graduate School of Comprehensive Human Sciences, University of Tsukuba, 1-1-1 Tennodai, Tsukuba, Ibaraki 305-8575, Japan.
e-mail: hirokisono@gmail.com

(O'Gara et al. 2013; Japanese Circulation Society 2013). DTB time is globally regarded as an important quality indicator of STEMI care (Ikemura et al. 2017).

In the USA, the D2B Alliance, a national quality improvement initiative, has disseminated specific strategies to improve DTB time (O'Gara et al. 2013). Although the DTB goal of ≤ 90 min is already achieved in 90% of cases (Krumholz et al. 2011), the recommended first medical contact (FMC)-to-balloon time of ≤ 90 min has not (O'Gara et al. 2013).

In Japan, the proportion of patients treated in ≤ 90 min in tertiary hospitals is 50% (Shiomi et al. 2012; Ikemura et al. 2017), and even lower in community hospitals, at 39% (Nakayama et al. 2009). Japanese community hospitals are hampered in the implementation of the strategies applied in the USA (Bradley et al. 2006) due to limited around the clock access to in-house cardiologists, which requires sufficient human resources, and the introduction of pre-hospital 12-lead ECG, which depends on the cooperation of local governments.

Previous studies in Japan have identified predictors of prolonged DTB time, including presentation during out-of-hours periods, a non-cardiologist as the first-contact physician, and low-volume PCI-capable institutions (Nakayama et al. 2009; Ikemura et al. 2017). These factors mean that a lack of resources at the hospital contributes to prolonged DTB time. However, no study is currently investigating how to reduce DTB time or the time required for its components in these settings (Nakamura et al. 2001; Takakuwa et al. 2009; Takeuchi et al. 2015).

Rather than simply voicing dissatisfaction with the current situation, clinicians must act to reduce the DTB time using our limited resources, without waiting for the implementation of measures by the central or local government. Indeed, individual hospitals have reported reductions in DTB time of 20-40 minutes in other countries (Niles et al. 2010; Lin et al. 2011; Young Hee et al. 2011; Pan et al. 2014).

Development of a new process to reduce DTB time which can accommodate the working conditions of Japanese hospitals is essential. We recently developed a new method that can be used to develop a wide variety of new processes, called Training for Effective and Efficient Action in Medical Service-Better Process (TEAMS-BP) (Isono et al. 2017). As shown in Fig. 1, TEAMS-BP improves the way jobs are done so that continual improve-

HOW TO IMPROVE WORK

TEAMS-BP

A practical plan to help you provide high-quality medical care efficiently by making the best use of the Materials, Machines, Facilities and Manpower currently available

STEP 1- BREAK DOWN THE TASK

1. List **all** details of the task exactly as done in the Current Method section.
2. Be sure to **verbalize concretely** in as much detail as possible.

STEP 2- QUESTION EVERY DETAIL

1. Use these types of questions:
   - ✧ **WHY**: Is it really necessary?
   - ✧ **WHAT**: What is its purpose?
   - ✧ **WHERE**: Where is the best place to do this?
   - ✧ **WHEN**: When is the best time to do this?
   - ✧ **WHO**: Who is the best qualified to do it, e.g. occupation and number of workers?
   - ✧ **HOW** is the "best way" to do this?
2. Question the following at the same time:

Materials, Machines, Equipment, Workplace layout, Movement, Safety, Housekeeping, Standard medical care, Patient perspective

STEP 3- DEVELOP THE NEW PROCESS

1. **ELIMINATE** unnecessary details.
2. **COMBINE** details when practical.
3. **REARRANGE** details for better sequence.
4. **SIMPLIFY** all necessary details.

To make the task easier and safer to do:

- Put materials, machines, equipment into the **best position** and **within convenient reach** for the operator.
- **Prevent** risks.
- Use **better tools**.

5. **DISCUSS** with a multidisciplinary team.
6. **WRITE UP** the proposed new method.

STEP 4- APPLY THE NEW PROCESS

1. **SELL** your proposal to the boss, colleagues, and subordinates.
2. Promote **UNDERSTANDING** and **COOPERATION** of other professionals in different departments.
3. Get **FINAL APPROVAL** of all concerned on Safety, Cost, Procedure, and Medical aspects.
4. **PUT** the new method **TO WORK**. Use it until a better way is developed.
5. Give **CREDIT** where credit is due.

Fig. 1. The TEAMS-BP card.
The left side shows the front of the card and the right side shows the back.

ment is achieved. It consists of four steps that teach users how to break each task down into its individual components, scrutinize the details, and develop and implement a new process. We previously demonstrated the strengths of the steps and concept of TEAMS-BP in improving the workflow of nursing assistants at a general hospital in Japan (Isono et al. 2017). In particular, Steps 1 and 2 of TEAMS-BP are simple but unique. In Step 1, we were able to outline the current procedure in detail and discover additional information beyond the perspective of conventional work; and in Step 2, we obtained the optimal route to improvement by asking the basic questions of who, what, when, where, why and how. Second, regarding the concept, TEAMS-BP optimizes the process by making the best use of available materials, machines, facilities and manpower, so that additional resources are not required and the hospital is not burdenend with additional costs.

Here, we developed a new process using TEAMS-BP and assessed whether it was effective in reducing DTB time for STEMI patients receiving primary PCI.

Methods

Study design and setting

This was a before and after study conducted at Mito Kyodo General Hospital in Ibaraki, Japan. The hospital has 320 beds and accepts 4,000 ambulance transfers annually. A total of 400 elective PCIs are performed annually, but the hospital does not conduct coronary artery bypass grafting. The hospital had only one attending emergency physician and four attending cardiologists. There were no attending emergency physicians during out-of-hours periods, and physicians who were not specialists in emergency medicine attended to patients who presented to the ER during these times. Moreover, the on-call attending cardiologist required 30-60 min to travel to the hospital.

The pre-implementation period for TEAMS-BP was from April 1, 2013 to April 30, 2015. TEAMS-BP was subsequently implemented and new processes were introduced in May 2015. The post-implementation period was from May 1, 2015 to October 31, 2016. Data for the study were collected retrospectively in the pre-implementation period and prospectively in the post-implementation period. The study was reviewed and approved by the ethics committee of Mito Kyodo General Hospital.

Patients and data collection

We recruited consecutive STEMI patients aged ≥ 20 years who visited the ER between April 1, 2013 and October 31, 2016, and received primary PCI. STEMI was diagnosed when patients exhibited ischemic symptoms and the 12-lead ECG revealed ST-elevation ≥ 0.2 mV in two contiguous precordial leads, ≥ 0.1 mV in at least two limb leads, or a new left bundle branch block, based on the cardiologist's review. Patients were excluded if they refused PCI, went into cardiopulmonary arrest on arrival, had unsuccessful PCI, were diagnosed with STEMI in the second or a later 12-lead ECG, or were transferred to another hospital without PCI. Patients who presented to the outpatient clinic first were also excluded.

Data collected from medical records included patient demographics and clinical information such as clinical presentation, cardiac risk factors, physical examination findings, laboratory data, imaging results, treatment strategy, and clinical outcome. Regular hours were defined as the period from 8:30 to 17:00 from Monday to Friday and from 8:30 to 12:30 on Saturdays in odd weeks. Out-of-hours was defined as all other times and public holidays.

The time of first medical contact (FMC), "ECG time", "door time", "laboratory time", and "balloon time" were also collected from medical records. FMC time was defined as the time of arrival of the ambulance service provider at the patient's side. Door time was defined as the time of patient arrival at the hospital. ECG time was defined as the time at which the first 12-lead ECG was performed at the hospital. Laboratory time was defined as the time of patient arrival at the catheterization laboratory. Balloon time was defined as the time of first device deployment (first balloon dilation or insertion of thrombus aspiration device). Each time was recorded in the medical records in a timely manner.

Data on time of calling the cardiologist, time of activation of the catheterization laboratory, time of arrival of the cardiologist at the catheterization laboratory, and false activation cases could not be collected from the medical records. Time of symptom onset could not be definitely determined. Data on whether the cardiologist was at the hospital or elsewhere when he was called during out-of-hours periods were only collected in the post-implementation period.

Process improvement design

We developed TEAMS-BP at the University of Tsukuba in 2012 with the co-operation of the Japan Industrial Training Association (Maeno 2016; Isono et al. 2017). It is based on the Japanese Training Within Industry-Job Method (TWI-JM) (Graupp and Wrona 2006). Although TEAMS-BP differs from TWI-JM in presentation, program lectures and format, the basic concept of the four steps is the same. TEAMS-BP allows the breakdown of each task into its individual components, scrutinization of specific details, and development and implementation of a new process in four simple steps as shown in Fig. 1. We planned the process improvement with TEAMS-BP according to steps 1-4, outlined below.

STEP 1. Break down the task: The tasks of physicians, nurses, ECG technicians, radiological technologists, and clerical staff in the ER were observed or staff were interviewed. Each staff member's tasks were broken down in detail and recorded. Differences in how each task was performed among staff were also noted.

STEP 2. Evaluate every step in detail: Once the tasks were separated into components, wasteful tasks were identified and eliminated. We discussed each task according to six basic questions (who, what, where, why, when, and how?) and recorded the answers to these questions.

STEP 3. Develop a new process: We developed a new process after having analyzed the answers generated in STEP 2. Task details were individually evaluated according to the actions of eliminate, combine, rearrange, and simplify, in that order. If the task detail could be eliminated, this was a 100% improvement and no further investigation was required.

STEP 4. Implement the new process: We shared the new process developed in STEP 3, its objective, and its predicted effects with the manager, colleagues, and subordinates in the relevant departments. Approvals for the safety, cost, procedure, and medical aspects required for task changes were obtained from the appropriate committees before implementation. If a process changed, meetings with the relevant departments were conducted to examine whether there were problems related to the new process.

Outcome measurement

The primary outcome was the median DTB time. Secondary outcomes included the proportion of DTB time that meets the clinical guidelines (≤ 90 min) (O'Gara et al. 2013; Japanese Circulation Society 2013) and that which is > 120 min, signifying delay. It also included the subdivided components of DTB time, such as door-to-ECG time, door-to-laboratory time, laboratory-to-balloon time, FMC-to-balloon time, and FMC-to-door time. In addition, it also included the DTB time that was stratified by arrival time (regular hours and out-of-hours) and transportation mode (ambulance, self-transport, or transfer from another hospital). The outcome assessor was not blinded to the implementation of TEAMS-BP.

Sample size calculation

We expected to detect a reduction in median DTB time of 20 min from a baseline of 100 min with a standard deviation (SD) of 30 min, with a power of 0.80 and alpha of 0.05. From this, we calculated that a sample size of 35 STEMI patients in both pre- and post-implementation periods was needed. However, our study did not have enough power to show differences in secondary outcomes.

Statistical analysis

Time intervals are presented as median (25th-75th percentiles), other continuous variables are presented as mean ± SD, and categorical variables are presented as numbers (%). Intra-group differences were compared using the Mann-Whitney U test for time intervals, unpaired t test for other continuous variables, and Chi-square or Fisher's exact test for categorical variables. All statistical assessments were two-tailed, and $p < 0.05$ was considered statistically significant. Data were analyzed using SPSS 24.0 for Mac.

Results

Structure

During the study period, several staff members were transferred, but the systems for physicians and nurses in the ER and Cardiology Department remained the same. Additionally, there were over 2 STEMI cases per month, which remained the same before and after the implementation of TEAMS-BP (Fig. 2). Fig. 2 shows the number of cases every three months (quarter), but the final quarter of the pre-implementation period (from January to April in 2015) included one extra month because the length of the pre-implementation period was 25 months in total.

Process improvement

The processes conducted by physicians, nurses, ECG technicians, radiological technologists, and clerical staff were reviewed, documented, and standardized to facilitate prompt transfer of STEMI patients from the ER to the catheterization laboratory using TEAMS-BP.

The previous process is shown in Fig. 3. The following processes, introduced in May 2015, were implemented without additional resources or incurred costs: setting time goals, calling an ECG technician beforehand, sharing information about STEMI among all staff members, minimizing tasks before calling a cardiologist, confirming the checklist, and providing feedback on data. We also created checklists detailing the new process for each physician, nurse, and ECG technician. The process improvement is shown in Table 1.

Outcome

In total, 117 patients were diagnosed with STEMI during the study period, 15 of whom were excluded from the study due to having first visited an outpatient clinic, transfer to another hospital, or unsuccessful PCI. Consequently, the number of STEMI patients in the pre- and post-implemen-

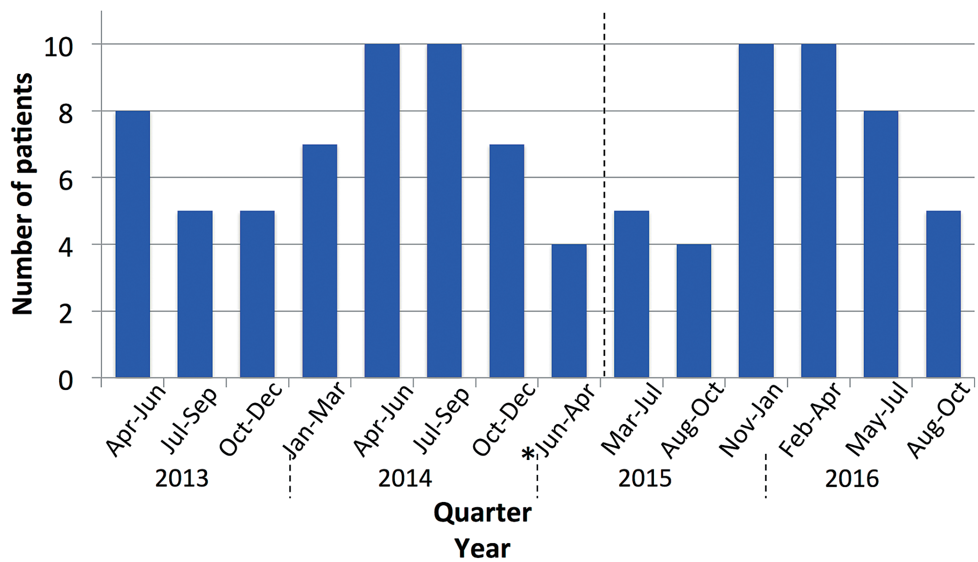

Fig. 2. Number of STEMI patients per quarter.
The number of STEMI patients who visited the ER between April 1, 2013 and October 31, 2016, and received primary PCI.
*The final quarter of the pre-implementation period (from January to April, 2015) included one extra month because the length of the pre-implementation period was 25 months in total.

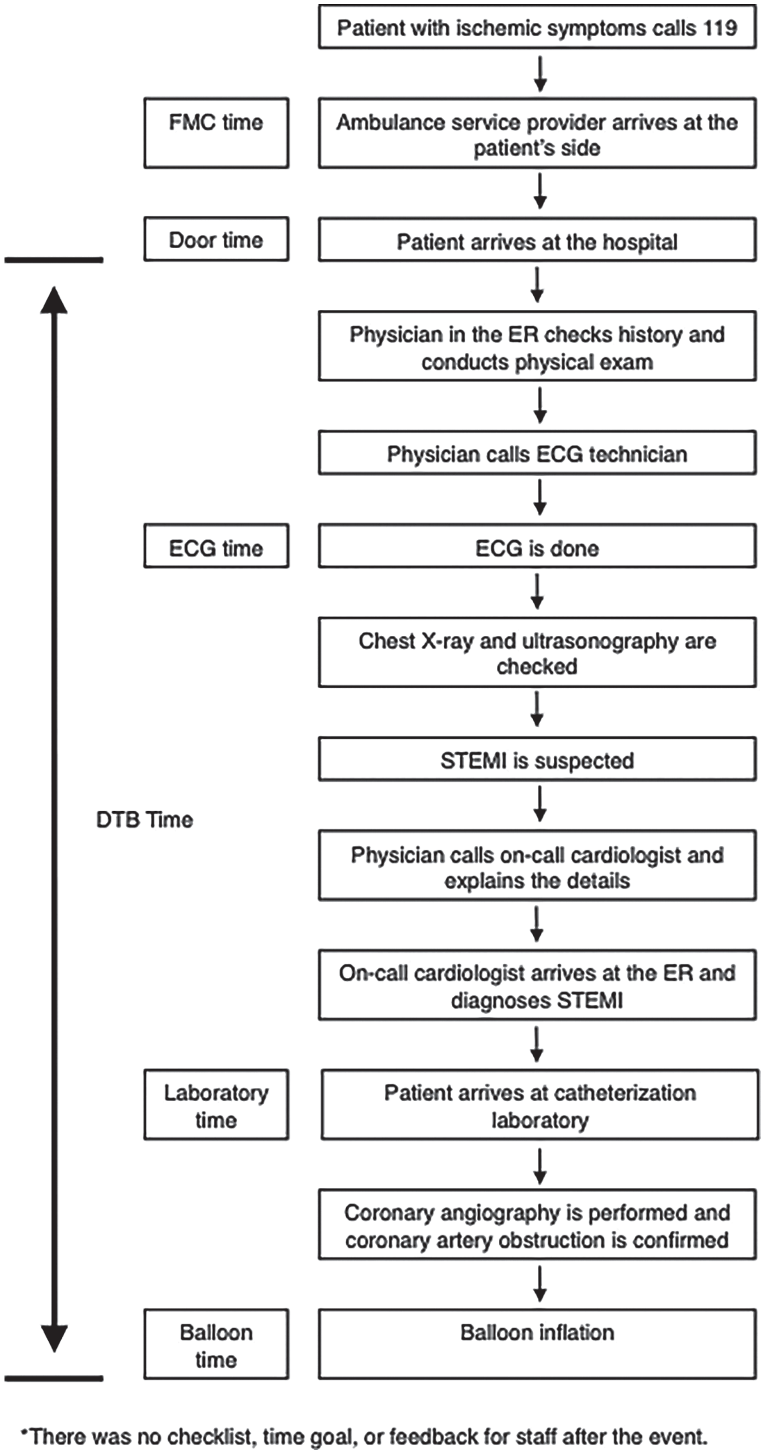

Fig. 3. A baseline process for STEMI patients who were transferred by ambulance.

tation periods were 58 and 44, respectively (Fig. 4).

Patient demographics and characteristics in the two groups were similar (Table 2).

The median DTB time was significantly reduced from 106.0 min (range, 71.0-129.0) to 81.5 min (range, 65.0-108.5) after implementing TEAMS-BP ($p = 0.037$) (Table 3). Median door-to-ECG and door-to-laboratory times were also significantly reduced from 14.0 min to 6.0 min ($p < 0.001$) and 67.0 min to 44.5 min ($p = 0.003$), respectively, after implementing TEAMS-BP. Moreover, 86.4% of patients received 12-lead ECG within 10 min after implementing TEAMS-BP. However, no significant difference was observed in laboratory-to-balloon time (from 32.0 min to 32.5 min, $p = 0.951$).

Upon implementing TEAMS-BP, the overall proportion of patients treated in ≤ 90 min significantly increased

Table 1. Process improvement.

The processes for physicians, nurses, ECG technicians and clerical staff were **reviewed, documented, and standardized** to enable prompt transfer of STEMI patients to the catheterization laboratory.
The following processes were implemented **without** additional resources or incurred costs:
Time goals for vital steps in the ER:
Door-to-ECG time < 10 min.
Door to call a cardiologist time < 15 min.
Door to laboratory arrival time < 50 min.
Prior to arrival of the ambulance:
Calling the ER **for an ECG technician** for patients with suspected STEMI.
Sharing information about STEMI among all staff in the ER, and reviewing the checklist.
For self-transported patients with suspected acute coronary syndrome, ordering 12-lead ECG based on the judgment of the first-contact nurse.
Minimizing tasks before calling a cardiologist.
A **brief patient history and ECG are sufficient** before calling a cardiologist.
"STEMI" is the first thing we say to the cardiologist.
ECG data can be sent to the on-call cardiologist **via e-mail.**
Once STEMI is diagnosed, staff should **review the checklist** to ensure every step has been taken, e.g., laboratory activation, administration of medication, and obtaining written consent.
Data feedback: Target time, data postings and findings are placed on bulletin boards in the ER, catheterization lab and medical office.

ECG, electrocardiogram; STEMI, ST-elevation myocardial infarction; ER, emergency room.

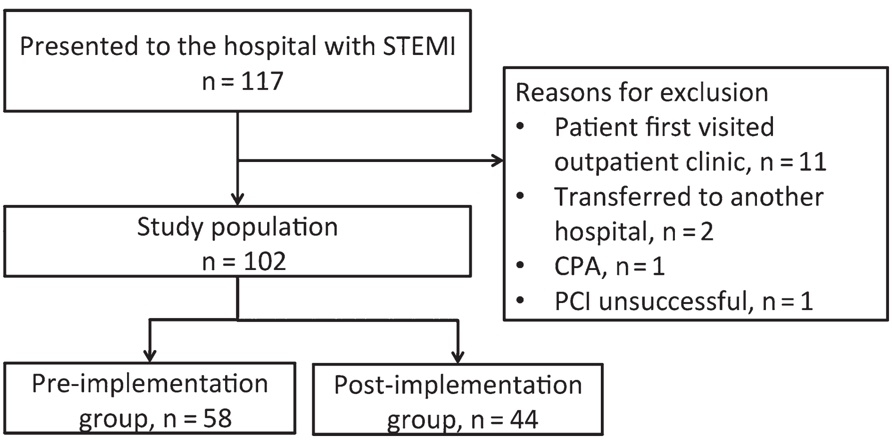

Fig. 4. Study flow diagram and exclusion criteria.
CPA, cardiopulmonary arrest; PCI, percutaneous coronary intervention.

from 39.7% to 61.4% ($p = 0.030$) (Table 4).

The results of DTB time stratified by arrival time and transportation mode are shown in Table 5. DTB time was significantly decreased from 108.0 min to 90.0 min ($p = 0.018$) in patients who presented during out-of-hours periods.

No significant difference was observed for FMC-to-balloon time (from 136.0 min to 120.0 min, $p = 0.272$) or

Table 2. Patient characteristics.

Variable	Before TEAMS-BP (n = 58)	After TEAMS-BP (n = 44)	p value
Age, years	65.0 ± 12.8	66.5 ± 13.6	0.265
Sex, male, n (%)	43 (74.1)	38 (86.4)	0.130
Diabetes, n (%)	25 (43.9)	18 (40.9)	0.708
Hypertension, n (%)	33 (56.9)	32 (72.7)	0.123
Hyperlipidemia, n (%)	25 (43.1)	19 (43.2)	0.946
Smoker, n (%)	26 (44.8)	16 (36.4)	0.318
Previous MI, n (%)	8 (13.8)	6 (13.6)	0.982
Height, cm	165.0 ± 9.7	164.0 ±8.5	0.736
Weight, kg	64.6 ± 12.6	64.1 ± 13.5	0.943
Arrival			
Ambulance, n (%)	38 (65.6)	25 (56.8)	0.371
Transferred from another hospital, n (%)	11 (19.0)	13 (29.5)	0.212
Self-transport, n (%)	9 (15.5)	6 (13.6)	0.791
Presented during out-of-hours period, n (%)	41 (70.7)	29 (65.9)	0.606
Initial Killip class > II, n (%)	3 (5.2)	3 (6.8)	0.726
Anterior ST elevation, n (%)	26 (44.8)	25 (56.8)	0.230
Peak CK	2609.5 ± 1933.6	2455.3 ± 2370.7	0.718
Intra-aortic balloon pump	5 (8.6)	6 (13.6)	0.419
Temporary pacemaker	1 (1.7)	4 (9.1)	0.090
Contrast CT before laboratory arrival	3 (5.2)	3 (6.8)	0.726
In-hospital mortality, n (%)	1 (1.7)	4 (9.1)	0.168
Median length of stay (days)	15.8 ± 6.1	18.8 ± 26.0	0.413

Data are expressed as mean ± SD or n (%). MI, myocardial infarction.

FMC-to-door time (from 34.0 min to 26.0 min, $p = 0.557$) in patients who were transferred by ambulance. We excluded 9 cases with missing data on FMC time in this analysis.

In the post-implementation period, 10 patients presented when a cardiologist was in the hospital, and 19 patients presented when a cardiologist was absent from the hospital during out-of-hours periods. The median DTB time for these patients was 69.0 min and 91.0 min, respectively.

Discussion

Our results revealed a significant reduction in DTB time from 106.0 min to 81.5 min following TEAMS-BP implementation. We demonstrated that the new process is effective for reducing DTB time. A significant reduction in door-to-ECG and door-to-laboratory times contributed to this result.

Table 3. Door-to-balloon (DTB) time and time required for its three components.

Variable	Before TEAMS-BP (n = 58)	After TEAMS-BP (n = 44)	p value
DTB time	106.0 (71.0-129.0)	81.5 (65.0-108.5)	0.037*
Door-to-ECG time	14.0 (10.0-23.0)	6.0 (5.0-7.0)	< 0.001*
Door-to-lab time	67.0 (47.0-94.0)	44.5 (39.0-56.0)	0.003*
Lab-to-balloon time	32.0 (23.0-45.0)	32.5 (27.0-41.0)	0.951

Time intervals (min) are expressed as medians (25^{th}-75^{th} percentiles).
*Statistically significant between-group difference ($p < 0.05$).

Table 4. Proportion of patients with door-to-balloon (DTB) time ≤ 90 or > 120 min.

Variable	Before TEAMS-BP (n = 58)	After TEAMS-BP (n = 44)	p value
DTB time ≤ 90 min	23 (39.7)	27 (61.4)	0.030*
DTB time > 120 min	20 (34.5)	5 (11.4)	0.007*

Data are presented as n (%).
*Statistically significant between-group difference ($p < 0.05$).

After the implementation of TEAMS-BP, 86% of ECGs were performed within 10 min of hospital arrival. A prolonged door-to-ECG time of more than 10 min is associated with an increased risk of poor clinical outcomes in STEMI patients (Diercks et al. 2006).

Furthermore, clinical guidelines for managing STEMI patients recommend performing an ECG within 10 min (Japanese Circulation Society 2013; Anderson and Morrow 2017). We hypothesize that preparations by first-contact physicians prior to ambulance arrival, transfer of self-transport patients with suspected acute coronary syndrome to the treatment room, and ordering 12-lead ECG based on the judgment of the first-contact nurse contributed to our results.

Before implementation of TEAMS-BP, the first-contact physicians did not make preparations prior to ambulance arrival despite receipt of information from the emergency medical service when the patient was en route to the hospital. The physicians should have activated the STEMI protocol once they knew that the patient had ischemic symptoms. We therefore implemented the following process (Table 1) prior to arrival of the ambulance: calling the ER for an ECG technician for patients with suspected STEMI, sharing information about STEMI among all staff in the ER, and reviewing the checklist.

Of note, the 44.5 min door-to-laboratory time after implementing TEAMS-BP is faster than the 50 min obtained after implementation of a critical pathway in the ER by an urban university hospital in Japan (Nakamura et al. 2001). Clarifying the segregation of duties using a checklist for job type, in addition to optimizing consultation methods and other improvements, also contributed to our results. By setting a target time and gathering feedback, we were able to share the importance of prompt ER treatment among all staff members. As we did not change processes in the catheterization laboratory, there was no change in laboratory-to-balloon time.

The use of TEAMS-BP was particularly easy to monitor during out-of-hours periods, as shown in Table 5. Presentation during out-of-hours periods and non-cardiolo-

Table 5. Comparison of DTB time stratified by arrival time and presentation.

Variable	Before TEAMS-BP	n	After TEAMS-BP	n	p value
Arrival time					
Regular hours	71.0 (63.0-80.0)	17	72.0 (60.5-95.5)	15	0.852
Out-of-hours	108.0 (93.0-135.0)	41	90.0 (73.0-112.0)	29	0.018*
Presentation					
Ambulance	100.0 (74.8-124.8)	38	88.0 (73.0-112.0)	25	0.332
Transfer from another hospital	69.0 (63.0-135.0)	11	65.0 (46.0-103.0)	13	0.459
Self-transport	128.0 (111.0-180.0)	9	87.5 (68.5-135.0)	6	0.066

Time intervals (min) are expressed as medians (25^{th}-75^{th} percentiles).
*Statistically significant between-group difference ($p < 0.05$).

gists as the first-contact physicians are two factors that are significantly associated with a prolonged DTB time in community hospitals (Nakayama et al. 2009). Another study reported that age > 75 years, peripheral artery disease and arrival out-of-hours were predictors of delayed DTB (Ikemura et al. 2017). Prolonged DTB time was also noted in our hospital. The median DTB time of 108.0 min during out-of-hours periods was 37.0 min longer than that observed during regular hours before TEAMS-BP implementation. This was mainly due to the management of STEMI patients by inexperienced physicians and nurses during the cardiologist's absence from the hospital during out-of-hours periods. Following TEAMS-BP implementation, the median DTB time during out-of-hours periods was reduced to 90.0 min, which is equivalent to the time taken in tertiary care referral centers in Japan (Ikemura et al. 2017). There was no difference in DTB time during regular hours between the pre- and post-implementation periods (71 min vs. 72 min, p = 0.852) because a DTB time of ≤ 90 min had already been achieved in 75% of cases before TEAMS-BP implementation, which met the goal set by the D2B Alliance in 2006 (Bradley et al. 2009).

We noted the recommendation of specific strategies by the D2B Alliance to improve DTB time in the USA (O'Gara et al. 2013) when implementing TEAMS-BP. According to these recommended strategies, the catheterization laboratory should be activated by an emergency physician; the emergency department (ED) should make a single call to a central page operator; pre-hospital ECG should be transmitted to the ED; the ED should activate the catheterization laboratory while the patient is en route to the hospital; the interval between paging and the arrival of staff in the catheterization laboratory should be ≤ 20 min; an attending cardiologist should always be present in the hospital; and the hospital should provide real-time feedback to staff (Bradley et al. 2006). We considered the feasibility of these specific strategies when implementing TEAMS-BP. Originally, we proposed that the on-call cardiologist be called when the Emergency Medical Service reports a patient with ischemic symptoms, because it took time for the cardiologist to arrive at the catheterization laboratory due to other ongoing procedures, outpatient clinic duty during regular hours, or absence from the hospital during out-of-hours periods. However, we did not implement this strategy because a lack of ECG findings of ST elevation could create false alarms that would overburden the cardiologist and medical staff. We also chose not to implement the strategy of having a physician at the ER activate the catheterization laboratory without a cardiology review and approval because the rate of false activations is reported to be approximately 15%

(O'Gara et al. 2013), which would be expected to be much higher with physicians who are not specialists in emergency medicine at our hospital.

In the past, we had an incident in which a page regarding a STEMI case to a staff member was forgotten, resulting in a delay in his arrival. As a result of this incident, a protocol had been established prior to the present study to determine who should call whom to activate the catheterization laboratory. Although this did not exactly correlate with the strategy of "a single call to a central page operator activates the PCI team", this protocol worked well. In our hospital, only two clerical staff were available during out-of-hours periods to attend to reception, accounting, and to work as telephone operators. As implementation of the strategy of a single call to a central operator may lead to the risk that a page would be missed or delayed, we retained our old process after implementation of TEAMS-BP.

Because the new process (Table 1) was designed specifically for the working conditions of our hospital, its general applicability might be low; nevertheless, implementing TEAMS-BP allows the development of a suitable process for any hospital.

Further improvements

Although the proportion of cases with a DTB time of ≤ 90 min increased from 39.7% to 61.4% after TEAMS-BP implementation, this was still much lower than that reported in the USA (91.4%) in 2010 (Krumholz et al. 2011). Further analysis of individual cases is required to identify the steps during which the delays occur and why they happen. A previous study of nursing assistants showed that an advantage of TEAMS-BP is its ability to elicit improvement by repeating the four-step cycle, and that improvements will continue to be made (Isono et al. 2017).

This work improvement project was conducted at a single hospital without additional resources or incurred costs. Additional reductions in DTB time will require the implementation of measures that involve the local government and hospitals in an entire region. For example, the Tokyo Cardiovascular Care Unit network, a well-organized cardiac care network involving 67 hospitals, has achieved a median DTB time of 60 min (Miyachi et al. 2016). Therefore, we propose two possible measures. First, if the pre-hospital 12-lead ECG system (Nam et al. 2014) is introduced by the local government, cardiologists should arrive at the catheterization laboratory 10-20 min earlier than their current arrival time at our hospital, because FMC-to-door time was approximately 30 min and the DTB time of cases that were transferred from another hospital (65.0 min after implementation of TEAMS-BP) was the shortest in this study. As the 12-lead ECG findings are sent from the referring hospital, the cardiologist can activate the primary PCI process while the patient is en route to our hospital. This flow is similar to that of the pre-hospital 12-lead ECG system. Second, optimizing the distribution of cardiologists in the region will enable hospitals to have a cardiologist present without inducing excessive burden on the cardiologists. We only perform 2 to 3 primary PCIs for STEMI patients per month, which amounts to < 36 per year, consistent with guideline recommendations (Smith et al. 2006). Moreover, as many as 86% of Japanese PCI-capable hospitals treat fewer than 50 acute myocardial infarction patients annually (the number of primary PCIs for STEMI patients would be less) due to the higher number of PCI-capable hospitals in Japan compared with Western countries (Nishigaki et al. 2004; Ikemura et al. 2017).

In cases where these measures have been undertaken but the new workflow does not progress smoothly, the workflow should be improved by re-implementing TEAMS-BP.

Study limitations

This was an uncontrolled before and after study. The significant reduction in DTB time may have been due to general trends and confounding variables. However, previous studies reported that the DTB time was approximately 90 min, and that this has not changed for nearly 10 years (from 2005 to 2013) in Japan (Shiomi et al. 2012; Ikemura et al. 2017). Therefore, implementation of TEAMS-BP greatly contributed to reducing DTB time to less than 90 min. Although patients in the pre- and post-implementation periods had similar baseline characteristics (Table 2), we cannot exclude the potential effect of unrecognized factors.

We could not collect data on whether an attending cardiologist was present in the hospital in the pre-implementation period. The strategy of having an attending cardiologist present at the hospital is effective (O'Gara et al. 2013); therefore, the presence of an attending cardiologist in the hospital might have impacted the difference in DTB time between the pre- and post-implementation periods.

We did not calculate the sample size required to detect a difference in the clinical outcome, and the overall sample size was small. No differences were observed in in-hospital mortality or length of stay.

Conclusions

Implementation of TEAMS-BP improved the DTB time of STEMI cases without the need for additional resources or costs incurred by the hospital.

Conflict of Interest

The authors declare no conflict of interest.

Acknowledgments

The authors would like to thank Kazuto Yamaguchi of the Japan Industrial Training Association; Madoka Tsutsumi, Kazuhiro Nakazawa, Hiroshi Kurihara, Junji Haruta, and Koichi Hashimoto of the University of Tsukuba (for being our mentors); and the staff of Mito Kyodo General Hospital.

References

Anderson, J.L. & Morrow, D.A. (2017) Acute myocardial infarction. *N. Engl. J. Med.*, **376**, 2053-2064.

Bradley, E.H., Herrin, J., Wang, Y., Barton, B.A., Webster, T.R., Mattera, J.A., Roumanis, S.A., Curtis, J.P., Nallamothu, B.K., Magid, D.J., McNamara, R.L., Parkosewich, J., Loeb, J.M. & Krumholz, H.M. (2006) Strategies for reducing the door-to-balloon time in acute myocardial infarction. *N. Engl. J. Med.*, **355**, 2308-2320.

Bradley, E.H., Nallamothu, B.K., Herrin, J., Ting, H.H., Stern, A.F., Nembhard, I.M., Yuan, C.T., Green, J.C., Kline-Rogers, E., Wang, Y., Curtis, J.P., Webster, T.R., Masoudi, F.A., Fonarow, G.C., Brush, J.E. Jr. and Krumholz, H.M. (2009) National efforts to improve door-to-balloon time results from the door-to-balloon alliance. *J. Am. Coll. Cardiol.*, **54**, 2423-2429.

Diercks, D.B., Kirk, J.D., Lindsell, C.J., Pollack, C.V. Jr., Hoekstra, J.W., Gibler, W.B. & Hollander, J.E. (2006) Door-to-ECG time in patients with chest pain presenting to the ED. *Am. J. Emerg. Med.*, **24**, 1-7.

Graupp, P. & Wrona, R.J. (2006) *The TWI Workbook: Essential Skills for Supervisors*, CRC Press, Boca Raton, FL.

Ikemura, N., Sawano, M., Shiraishi, Y., Ueda, I., Miyata, H., Numasawa, Y., Noma, S., Suzuki, M., Momiyama, Y., Inohara, T., Hayashida, K., Yuasa, S., Maekawa, Y., Fukuda, K. & Kohsaka, S. (2017) Barriers associated with door-to-balloon delay in contemporary Japanese practice. *Circ. J.*, **81**, 815-822.

Isono, H., Suzuki, S., Ogura, J., Haruta, J. & Maeno, T. (2017) Improving the workflow of nursing assistants at a general hospital in Japan. *BMJ Open Qual.*, **6**, e000106.

Japanese Circulation Society (2013) Guidelines for the management of patients with ST-elevation acute myocardial infarction.
[*Cited*: July 19, 2017]
http://www.j-circ.or.jp/guideline/pdf/JCS2013_kimura_h.pdf
[*Accessed*: January 9, 2018].

Krumholz, H.M., Herrin, J., Miller, L.E., Drye, E.E., Ling, S.M., Han, L.F., Rapp, M.T., Bradley, E.H., Nallamothu, B.K., Nsa, W., Bratzler, D.W. & Curtis, J.P. (2011) Improvements in door-to-balloon time in the United States, 2005 to 2010. *Circulation*, **124**, 1038-1045.

Lin, J.F., Hsu, S.Y., Wu, S., Liau, C.S., Chang, H.C., Liu, C.J., Huang, H.L., Ho, Y.T., Weng, S.L. & Ko, Y.L. (2011) Data feedback reduces door-to-balloon time in patients with ST-elevation myocardial infarction undergoing primary percutaneous coronary intervention. *Heart Vessels*, **26**, 25-30.

Maeno, T. (2016) *Cannot learn from clinical training! Non-technical skills for doctors*, Yodosha, Tokyo.

McNamara, R.L., Wang, Y., Herrin, J., Curtis, J.P., Bradley, E.H., Magid, D.J., Peterson, E.D., Blaney, M., Frederick, P.D. & Krumholz, H.M. (2006) Effect of door-to-balloon time on mortality in patients with ST-segment elevation myocardial infarction. *J. Am. Coll. Cardiol.*, **47**, 2180-2186.

Miyachi, H., Takagi, A., Miyauchi, K., Yamasaki, M., Tanaka, H., Yoshikawa, M., Saji, M., Suzuki, M., Yamamoto, T., Shimizu, W., Nagao, K. & Takayama, M. (2016) Current characteristics and management of ST elevation and non-ST elevation myocardial infarction in the Tokyo metropolitan area: from the Tokyo CCU network registered cohort. *Heart Vessels*, **31**, 1740-1751.

Nakamura, I., Hori, S., Suzuki, M., Asakura, Y., Yoshikawa, T., Ogawa, S. & Aikawa, N. (2001) Critical pathway improves arrival-in-cath-lab interval for patients with acute myocardial infarction in the emergency department. *Jpn. Circ. J.*, **65**, 849-852.

Nakayama, N., Kimura, K., Endo, T., Fukui, K., Himeno, H., Iwasawa, Y., Mochida, Y., Morita, Y., Shimizu, M., Shimizu, T., Takei, T., Yoshida, K., Wada, A. & Umemura, S. (2009) Current status of emergency care for ST-elevation myocardial infarction in an urban setting in Japan. *Circ. J.*, **73**, 484-489.

Nam, J., Caners, K., Bowen, J.M., Welsford, M. & O'Reilly, D. (2014) Systematic review and meta-analysis of the benefits of out-of-hospital 12-lead ECG and advance notification in ST-segment elevation myocardial infarction patients. *Ann. Emerg. Med.*, **64**, 176-186, 186. e171-179.

Niles, N.W., Conley, S.M., Yang, R.C., Vanichakarn, P., Anderson, T.A., Butterly, J.R., Robb, J.F., Jayne, J.E., Yanofsky, N.N., Proehl, J.A., Guadagni, D.F. & Brown, J.R. (2010) Primary percutaneous coronary intervention for patients presenting with ST-segment elevation myocardial infarction: process improvement in a rural ST-segment elevation myocardial infarction receiving center. *Prog. Cardiovasc. Dis.*, **53**, 202-209.

Nishigaki, K., Yamazaki, T., Fukunishi, M., Tanihata, S. & Fujiwara, H. (2004) Assessment of acute myocardial infarction in Japan by the Japanese Coronary Intervention Study (JCIS) Group. *Circ. J.*, **68**, 515-519.

O'Gara, P.T., Kushner, F.G., Ascheim, D.D., Casey, D.E. Jr., Chung, M.K., de Lemos, J.A., Ettinger, S.M., Fang, J.C., Fesmire, F.M., Franklin, B.A., Granger, C.B., Krumholz, H.M., Linderbaum, J.A., Morrow, D.A., Newby, L.K., et al. (2013) 2013 ACCF/AHA guideline for the management of ST-elevation myocardial infarction: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. *Circulation*, **127**, e362-425.

Pan, M.W., Chen, S.Y., Chen, C.C., Chen, W.J., Chang, C.J., Lin, C.P., Weng, Y.M. & Chen, Y.C. (2014) Implementation of multiple strategies for improved door-to-balloon time in patients with ST-segment elevation myocardial infarction. *Heart Vessels*, **29**, 142-148.

Shiomi, H., Nakagawa, Y., Morimoto, T., Furukawa, Y., Nakano, A., Shirai, S., Taniguchi, R., Yamaji, K., Nagao, K., Suyama, T., Mitsuoka, H., Araki, M., Takashima, H., Mizoguchi, T., Eisawa, H., et al. (2012) Association of onset to balloon and door to balloon time with long term clinical outcome in patients with ST elevation acute myocardial infarction having primary percutaneous coronary intervention: observational study. *BMJ*, **344**, e3257.

Smith, S.C. Jr., Feldman, T.E., Hirshfeld, J.W. Jr., Jacobs, A.K., Kern, M.J., King, S.B. 3rd, Morrison, D.A., O'Neill, W.W., Schaff, H.V., Whitlow, P.L., Williams, D.O., Antman, E.M., Smith, S.C. Jr., Adams, C.D., Anderson, J.L., et al. (2006) ACC/AHA/SCAI 2005 guideline update for percutaneous coronary intervention: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (ACC/AHA/SCAI Writing Committee to Update the 2001 Guidelines for Percutaneous Coronary Intervention). *J. Am. Coll. Cardiol.*, **47**, e1-121.

Takakuwa, K.M., Burek, G.A., Estepa, A.T. & Shofer, F.S. (2009) A method for improving arrival-to-electrocardiogram time in emergency department chest pain patients and the effect on door-to-balloon time for ST-segment elevation myocardial infarction. *Acad. Emerg. Med.*, **16**, 921-927.

Takeuchi, I., Fujita, H., Yanagisawa, T., Sato, N., Mizutani, T., Hattori, J., Asakuma, S., Yamaya, T., Inagaki, T., Kataoka, Y., Ohe, K., Ako, J. & Asari, Y. (2015) Impact of doctor car with mobile cloud ECG in reducing door-to-balloon time of Japanese ST-elevation myocardial infarction patients. *Int. Heart J.*, **56**, 170-173.

Young Hee, N., Kwang Soo, C., Jeong Hwan, K., Sun Yi, P., Tae Ho, P., Moo Hyun, K. & Young Dae, K. (2011) Reduction of door-to-balloon time by new performance processes in patients with ST-segment elevation myocardial infarction undergoing primary percutaneous coronary intervention. *Angiology*, **62**, 257-264.