SPECIAL ARTICLE

Strategies for Reducing the Door-to-Balloon Time in Acute Myocardial Infarction

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ABSTRACT

BACKGROUND
Prompt reperfusion treatment is essential for patients who have myocardial infarction with ST-segment elevation. Guidelines recommend that the interval between arrival at the hospital and intracoronary balloon inflation (door-to-balloon time) during primary percutaneous coronary intervention should be 90 minutes or less. However, few hospitals meet this objective. We sought to identify hospital strategies that were significantly associated with a faster door-to-balloon time.

METHODS
We surveyed 365 hospitals to determine whether each of 28 specific strategies was in use. We used hierarchical generalized linear models and data on patients from the Centers for Medicare and Medicaid Services to determine the association between hospital strategies and the door-to-balloon time.

RESULTS
In multivariate analysis, six strategies were significantly associated with a faster door-to-balloon time. These strategies included having emergency medicine physicians activate the catheterization laboratory (mean reduction in door-to-balloon time, 8.2 minutes), having a single call to a central page operator activate the laboratory (13.8 minutes), having the emergency department activate the catheterization laboratory while the patient is en route to the hospital (15.4 minutes), expecting staff to arrive in the catheterization laboratory within 20 minutes after being paged (vs. >30 minutes) (19.3 minutes), having an attending cardiologist always on site (14.6 minutes), and having staff in the emergency department and the catheterization laboratory use real-time data feedback (8.6 minutes). Despite the effectiveness of these strategies, only a minority of hospitals surveyed were using them.

CONCLUSIONS
Several specific hospital strategies are associated with a significant reduction in the door-to-balloon time in the management of myocardial infarction with ST-segment elevation.

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Prompt treatment increases the likelihood of survival for patients who have myocardial infarction with ST-segment elevation.[1-3] Hospitals can therefore influence the outcomes for such patients by developing and implementing systems and processes that minimize the interval between arrival at the hospital and the administration of reperfusion therapy. Since percutaneous coronary intervention (PCI) has become the preferred approach for treating myocardial infarction with ST-segment elevation,[4] hospitals are seeking ways to reduce the door-to-balloon time, defined as the time between arrival at the hospital and the first balloon inflation during PCI.

The importance of the door-to-balloon time is highlighted by its inclusion as one of the core quality measures collected and reported by the Centers for Medicare and Medicaid Services (CMS) and the Joint Commission on Accreditation of Healthcare Organizations. Concomitant with national efforts to improve the care of patients with acute myocardial infarction have been substantial improvements in performance on many core measures (such as the use of aspirin and beta-blockers). However, performance with respect to the door-to-balloon time continues to lag behind national standards,[4-6] which recommend an interval of 90 minutes or less. A minority of hospitals treat patients who present with myocardial infarction with ST-segment elevation within 90 minutes after their arrival,[7-10] and hospital performance has not improved substantially in recent years.[7]

Previous qualitative work has identified some common approaches among hospitals that have achieved a rapid door-to-balloon time.[11,12] However, it is not clear which strategies are most effective or how great their effect might be. We sought to identify operational and clinical processes for treating patients who have myocardial infarction with ST-segment elevation and to quantify the association of these measures with hospital door-to-balloon times.

METHODS

STUDY DESIGN

We conducted a cross-sectional study of acute care hospitals in the United States with the use of a Web-based survey to determine the internal processes for identifying and treating patients with myocardial infarction with ST-segment elevation who undergo PCI. Eligible hospitals were those that reported the door-to-balloon time as a CMS performance measure and had reported an annualized volume of at least 25 PCI cases during 2004. From the 818 eligible hospitals, we randomly selected 500 hospitals and contacted the chief executive officer, first by letter and then by e-mail, to explain the goals and procedures of the study and to request the hospital's participation. The chief executive officer provided the contact information for the person in the organization whom they deemed to be the most appropriate respondent for the Web-based survey. This protocol was approved by the institutional review board at the Yale School of Medicine.

MEASURES AND DATA COLLECTION

From the hospital contact person, we obtained information about specific hospital strategies relevant to the door-to-balloon time, using a survey developed from our previous qualitative study[11] (see the Supplementary Appendix, available with the full text of this article at www.nejm.org). We developed closed-ended, multiple-choice questions for each hospital strategy and field-tested the instrument for clarity and comprehensiveness before implementation. The questionnaire asked about strategies in place at the time of the survey (April through October 2005). The final instrument included 32 items concerning 28 key hospital strategies. Response categories included "no standard approach" for cases of partial adoption of certain practices.

The outcome was the door-to-balloon time for patients with myocardial infarction with ST-segment elevation who underwent PCI between April and September 2005. Data on individual patients were obtained from CMS. On the basis of CMS specifications,[13] we included all patients with myocardial infarction with ST-segment elevation who were treated with PCI, except those who were transferred from other hospitals. CMS validates these hospital quality data reports with the use of quarterly validation samples that are abstracted and compared with the reported data.

STATISTICAL ANALYSIS

For each of the 28 hospital strategies, we determined the number and percentage of hospitals in each response category, as well as the average of the median door-to-balloon times of those hospitals. To evaluate the association between specific

Table 1. Characteristics of the Hospitals.*

Characteristic	Completed Survey (N=365)	Did Not Complete Survey (N=135)†	P Value
	number (percent)		
Location			0.02
Urban	342 (93.7)	117 (86.7)	
Rural	23 (6.3)	18 (13.3)	
Teaching status			0.79
Nonteaching	281 (77.0)	105 (77.8)	
Teaching	84 (23.0)	30 (22.2)	
Staffed beds			0.27
<200	48 (13.4)	26 (19.3)	
201–500	226 (63.3)	86 (63.7)	
>500	83 (23.2)	23 (17.0)	
Missing data	8	NA	
Ownership type			0.01
Governmental	43 (11.8)	20 (14.8)	
Nonprofit	279 (76.4)	86 (63.7)	
For profit	43 (11.8)	29 (21.5)	
Geographic census region			0.05
New England	12 (3.3)	4 (3.0)	
Middle Atlantic	44 (12.1)	15 (11.1)	
South Atlantic	56 (15.3)	30 (22.2)	
East North Central	72 (19.7)	15 (11.1)	
East South Central	19 (5.2)	11 (8.1)	
West North Central	32 (8.8)	12 (8.9)	
West South Central	45 (12.3)	18 (12.6)	
Mountain	29 (7.9)	13 (9.6)	
West	56 (15.3)	17 (13.3)	
Annualized number of PCIs performed			0.22
25–40	123 (33.7)	45 (33.3)	
41–60	106 (29.0)	49 (36.3)	
>60	136 (37.3)	41 (30.4)	
CABG capability			
No	32 (8.8)	Unknown	
Yes	333 (91.2)	Unknown	
Part of a multihospital system			
No	128 (35.4)	Unknown	
Yes	234 (64.6)	Unknown	
Missing data	3	NA	
Median door-to-balloon time — min			0.83
≤90	127 (35.1)	47 (34.8)	
91–120	173 (47.8)	64 (47.4)	
121–150	47 (13.0)	20 (14.8)	
>150	15 (4.1)	4 (3.0)	
Missing data	3	NA	
Mean door-to-balloon time — min	100.4±23.5	104.8±24.1	0.08

* Plus–minus values are means ±SD. Percentages may not total 100 because of rounding. NA denotes not applicable, PCI percutaneous coronary intervention, and CABG coronary-artery bypass grafting.
† Data for hospitals that did not respond to the survey were obtained from the CMS.

hospital strategies and the door-to-balloon time, we used hierarchical generalized linear models,[14] which account for the clustering of patients within hospitals. We used the logarithm of the door-to-balloon time in our analysis to reduce skewness. For bivariate comparisons, we constructed a separate model for each hospital strategy.

We constructed a multivariate model, including independent variables that added significantly to the fit of the overall model (P<0.10 with the use of the likelihood ratio test for nested models), and sequentially excluded the variables that contributed the least to the fit of the model. Although the correlations among variables were modest (Cramer phi coefficient, <0.20 for 92% of the correlations), two variables were particularly strongly correlated (Cramer phi coefficient, 0.87). These variables were the specialty of the physician who was responsible for activating the catheterization laboratory on day shifts and the specialty of the physician who had that responsibility for night-and-weekend shifts. Therefore, we created a separate dummy variable for the multivariate analysis, which indicated whether emergency medicine physicians were responsible for activating the catheterization laboratory on day shifts as well as on night-and-weekend shifts. We also examined the effects of several hospital characteristics (location, teaching status, number of staffed beds, type of ownership, geographic region, capability of performing coronary-artery bypass grafting [CABG], and participation or nonparticipation in a multihospital system). However, none of these variables materially changed the effects of hospital strategies on the door-to-balloon time, and each was removed from the multivariate model. In reporting the data, we used an alpha level of 0.05 as the criterion for the statistical significance of the estimated effects of individual hospital strategies on the door-to-balloon time.

To facilitate the interpretation of the estimated effects, we centered all independent variables on their means, so that the intercept represented the mean of all independent variables.[15,16] Hence, the effect of individual strategies on the door-to-balloon time was calculated as the difference between the door-to-balloon time of hospitals implementing the selected strategy and hospitals not implementing the selected strategy, assuming the average response on all other strategies. We used simulation techniques[17-19] to transform estimated effects and confidence intervals in log units back into their natural units (i.e., minutes). All analyses were performed with the use of SAS software, version 9.1 (SAS Institute) and Stata 9 (Stata).

RESULTS

HOSPITAL SURVEY

We received responses from representatives of 365 of the 500 hospitals contacted (73%) (Table 1). The responding persons for each hospital were typically quality management directors, although cardiovascular nurse managers and medical directors were also involved at many hospitals. Nonrespondent hospitals did not differ significantly from respondent hospitals in terms of the annualized number of PCIs performed, the number of staffed beds, teaching status, geographic region, or median door-to-balloon time; however, rural hospitals were significantly less likely than urban hospitals to respond (P=0.02), and for-profit hospitals were significantly less likely than government or nonprofit hospitals to respond (P=0.01). Among the 365 respondents, 3 hospitals did not report data with regard to door-to-balloon times to CMS during the study period and were excluded from bivariate and multivariate analyses; 2 additional hospitals were missing one or more responses to survey items and were excluded from the multivariate analysis.

HOSPITAL STRATEGIES

Figure 1 shows the frequency distribution of median door-to-balloon times for the hospitals studied. The range of median values was wide, with many institutions having median times that ex-

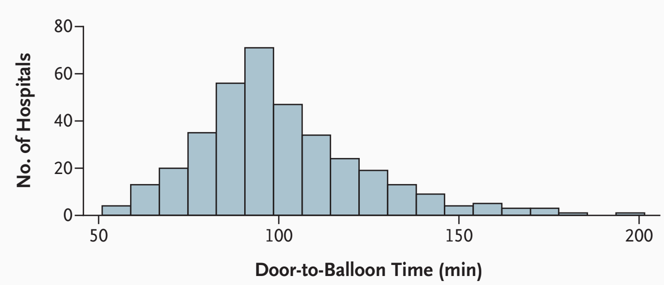

Figure 1. Frequency Distribution for Median Door-to-Balloon Times among Study Hospitals.

The median door-to-balloon time was calculated for each hospital in the study. The mean (±SD) of these median times was 100.4±23.5 minutes, which is considerably longer than the 90-minute interval recommended in the 2004 guidelines of the American Heart Association and the American College of Cardiology.[4]

Table 2. Unadjusted Associations between Hospital Strategies and Door-to-Balloon Time.*

Strategy	Hospitals	Average Median Door-to-Balloon Time	P Value	Wald P Value†
	no. (%)	*minutes*		
Written criteria for immediate ECG in emergency department				
No	42 (11.5)	105.1		
Yes	323 (88.5)	99.8	0.34	
Formal training of triage staff for assessing acute coronary syndrome				
No	150 (41.1)	100.8		
Yes	215 (58.9)	100.2	0.75	
Dedicated ECG technicians in emergency department				0.20
No	90 (24.7)	102.6		
Yes, only some shifts	31 (8.5)	100.4	0.36	
Yes, always	244 (66.8)	99.7	0.07	
Dedicated space in triage area for immediate ECG				
No	121 (33.2)	103.2		
Yes	244 (66.8)	100	0.70	
Activation of catheterization laboratory on weekdays				<0.001
Emergency medicine physician with cardiologist	218 (59.7)	102.6		
Cardiologist alone	65 (17.8)	105.8	0.44	
Emergency medicine physician alone	82 (22.5)	90.5	<0.001	
Activation of catheterization laboratory at night and on weekends‡				<0.001
Emergency medicine physician with cardiologist	200 (54.9)	104.3		
Cardiologist alone	65 (17.9)	104.8	0.99	
Emergency medicine physician alone	99 (27.2)	90.2	<0.001	
Process for activating catheterization team‡				<0.001
After communicating with the emergency department, interventional cardiologist activates catheterization laboratory by calling staff or a central page operator	147 (40.4)	108.1		
Emergency department makes at least two calls: one to the interventional cardiologist and another to a central page operator, who pages catheterization laboratory staff	135 (37.1)	96	<0.001	
Emergency department makes a single call to a central page operator, who then pages interventional cardiologist and catheterization laboratory staff	50 (13.7)	89.2	<0.001	
No standard approach	1 (0.3)	119.5	0.37	
Other	31 (8.5)	99	0.04	
Activation of on-call staff for catheterization laboratory‡				0.23
Page operator is not used	90 (24.7)	97.5		
Page operator is used; confirmation of page receipt is required	205 (56.3)	102.2	0.47	
Page operator is used; no confirmation of page receipt is required	23 (6.3)	90.4	0.19	
No standard approach	46 (12.6)	102.1	0.34	

Table 2. (Continued.)

Strategy	Hospitals	Average Median Door-to-Balloon Time	P Value	Wald P Value†
	no. (%)	*minutes*		
First physician notified after STEMI diagnosis in emergency department				0.01
Cardiologist	239 (65.5)	101.0		
Interventional cardiologist	93 (25.5)	97.3	0.04	
Patient's primary care physician	7 (1.9)	117.9	0.01	
Other or variable	26 (7.1)	101.9	0.87	
Laboratory and radiographic results are needed to activate catheterization laboratory				0.003
Yes	11 (3.0)	116.7		
No	340 (93.2)	99.1	0.04	
No standard approach	14 (3.8)	119.6	0.81	
Patients with acute coronary syndrome who undergo ECG en route to hospital‡				0.67
0%	91 (25.0)	101.9		
1–10%	39 (10.7)	98.5	0.58	
11–50%	44 (12.1)	99.2	0.63	
51–99%	64 (17.6)	95.5	0.10	
100%	49 (13.5)	101	0.52	
Don't know	77 (21.2)	103.6	0.86	
Emergency medical service routinely calls in or transmits results of ECG				0.03
No	143 (39.2)	102.8		
Yes	144 (39.5)	96.0	0.01	
Not applicable	78 (21.4)	104.3	0.71	
Process after emergency medical service transmits ECG results				<0.001
Emergency department waits for patient to arrive at hospital to determine whether catheterization laboratory should be activated	61 (16.7)	103.6		
Emergency department contacts cardiologist while the patient is en route to determine whether catheterization laboratory should be activated	39 (10.7)	95.7	0.09	
Emergency department activates catheterization laboratory while the patient is still en route to the hospital	33 (9.0)	85.4	<0.001	
No standard approach or variable approach	11 (3.0)	87.8	0.01	
Not applicable because ECG data not transmitted en route	52 (14.2)	104.4	0.97	
Not applicable because ECG never performed en route	91 (24.9)	101.9	0.45	
Unknown or no response	78 (21.4)	104.3	0.43	
Expected interval between page and arrival of staff in catheterization laboratory‡				0.003
≤20 min	39 (10.7)	91.0		
21–30 min	280 (76.9)	99.9	0.16	
>30 min	39 (10.7)	111.1	<0.001	
No expected time	6 (1.6)	110.8	0.20	

Table 2. (Continued.)

Strategy	Hospitals	Average Median Door-to-Balloon Time	P Value	Wald P Value†
	no. (%)	minutes		
Expected interval between page and arrival of interventional cardiologist‡				<0.001
≤20 min	47 (12.9)	94.6		
21–30 min	205 (56.3)	97.9	0.69	
>30 min	31 (8.5)	112.1	0.005	
No expected time	81 (22.3)	105.3	0.11	
Someone is always available to transport patients from emergency department to catheterization laboratory‡				0.93
No	39 (10.7)	103.4		
Yes	325 (89.3)	99.9	0.93	
Initiation of patient transport from emergency department to catheterization laboratory‡				0.012
After catheterization laboratory notifies emergency department it is ready	339 (93.1)	100.6		
A set interval after the decision is made regarding PCI	16 (4.4)	84.9	0.01	
No standard approach	7 (1.9)	117.9	0.04	
Other approach	2 (0.5)	110.5	0.72	
Minimum number of nurses and technicians required in catheterization laboratory before patient is transported from emergency department§				0.66
Interventional cardiologist must be present	88 (24.2)	100.7		
Interventional cardiologist may not be present but need presence of				
1 staff person	8 (2.2)	94.8	0.56	
2–4 staff people	228 (62.8)	101	0.70	
No set number	39 (10.7)	97	0.48	
Elective catheterization cases rescheduled for emergency PCI§				0.65
Yes	353 (97.2)	100.3		
No	5 (1.4)	94.6	0.54	
It depends	5 (1.4)	100.4	0.49	
If interventionalist is present, number of staff required to begin PCI‡				0.64
1	22 (6.0)	109.4		
2	93 (25.5)	99.1	0.25	
3	221 (60.7)	100.0	0.30	
4	28 (7.7)	99.2	0.22	
Catheterization laboratory is left so that next PCI can begin promptly‡				0.76
Yes	321 (88.2)	100.4		
No	30 (8.2)	100.6	0.56	
No standard policy	13 (3.6)	97.5	0.68	
Cardiology fellows participate in performing PCI‡				
No	306 (84.1)	99.2		
Yes	58 (15.9)	106.2	0.31	

Table 2. (Continued.)

Strategy	Hospitals	Average Median Door-to-Balloon Time	P Value	Wald P Value†
	no. (%)	*minutes*		
Staff in critical care area are routinely cross-trained to cover catheterization laboratory‡				
No	345 (94.8)	100.4		
Yes	19 (5.2)	97.9	0.22	
Location of catheterization laboratory‡				0.94
Elevator required to travel from emergency department	204 (56.0)	101.6		
Same floor as emergency department	160 (44.0)	98.7	0.94	
An attending cardiologist is always at the hospital				
No	351 (96.2)	100.8		
Yes	14 (3.8)	92.6	0.01	
Emergency department routinely gives data feedback to emergency medical service‡				
No	289 (79.4)	102.8		
Yes	75 (20.6)	90.7	<0.001	
Hospital gives real-time feedback to staff in emergency department and catheterization laboratory‡				
No	213 (58.5)	104.7		
Yes	151 (41.5)	94.0	<0.001	
Hospital uses root-cause analysis or similar approach for delays‡				
No	99 (27.2)	103.8		
Yes	265 (72.8)	99.0	0.04	

* P values were calculated with the use of a hierarchical generalized linear model of the logarithm of door-to-balloon time with hospital strategy as an independent variable. ECG denotes electrocardiography, PCI percutaneous coronary intervention, and STEMI myocardial infarction with ST-segment elevation. P values are for the comparison between each survey response and the first listed response to each question.
† P values were calculated with the use of the Wald chi-square test.
‡ Data were missing from one survey respondent for this question.
§ Data were missing from two survey respondents for this question.

ceeded the 90-minute interval recommended in the 2004 guidelines of the American Heart Association and the American College of Cardiology.[4] The mean [±SD] of the median door-to-balloon times of all the hospitals was 100.4±23.5 minutes. There was also substantial variation in the prevalence of specific hospital strategies to expedite the door-to-balloon time. A number of strategies had significant unadjusted (bivariate) associations with the door-to-balloon time (Table 2).

The multivariate model identified six hospital strategies that added significantly to the fit of the model ($P<0.10$ for nested models) and were associated with a significantly lower door-to-balloon time. Some associations were particularly strong, indicating an estimated savings in the door-to-balloon time of 10 to 15 minutes (Table 3). These strategies were generally implemented in a minority of hospitals. Hospitals that implemented a greater number of effective strategies tended to have a shorter door-to-balloon time (Table 4).

Hospital practices regarding activation of the catheterization laboratory had a significant effect on the door-to-balloon time. The intervals were shorter for hospitals in which emergency medicine physicians activated the catheterization laboratory without consulting a cardiologist; those in which the catheterization laboratory was activated with a single call from the emergency department to a central page operator, who then paged both the interventional cardiologist and the catheterization laboratory staff; and those in which staff were expected to arrive in the catheterization laboratory either within 20 minutes or

Table 3. Adjusted Associations between Hospital Strategies and Door-to-Balloon Times.*

Strategy	Door-to-Balloon Time (95% CI) *minutes*	P Value†	Wald P Value‡
Catheterization laboratory is activated by emergency medicine physician			0.01
No			
Yes	−8.2 (−14.3 to −2.0)	0.01	
Process for activating catheterization team			0.01
After communicating with the emergency department, interventional cardiologist activates catheterization laboratory by calling staff or a central page operator			
Emergency department makes at least two calls: one to the interventional cardiologist and another to a central page operator, who pages catheterization laboratory staff	−6.8 (−12.5 to −1.0)	0.03	
Emergency department makes a single call to a central page operator, who then pages interventional cardiologist and catheterization laboratory staff	−13.8 (−21.2 to −6.4)	0.001	
No standard approach	13.2 (−37.8 to 64.2)	0.66	
Other	−5.0 (−14.1 to 4.0)	0.28	
Process after emergency medical service transmits ECG results			0.004
Emergency department waits for patient to arrive at the hospital to determine whether catheterization laboratory should be activated			
Emergency department contacts cardiologist while the patient is en route to determine whether catheterization laboratory should be activated	−8.9 (−17.8 to 0)	0.06	
Emergency department activates catheterization laboratory while the patient is still en route to the hospital	−15.4 (−24.2 to −6.6)§	0.001	
No set protocol or variable protocol	−23.2 (−35.3 to −11.1)¶	0.001	
Not applicable because ECG data not transmitted to emergency department	−6.6 (−15.2 to 2.1)	0.14	
Not applicable because ECG never performed en route	−4.3 (−12.0 to 3.3)	0.27	
Unknown or no response	−5.6 (−13.3 to 2.2)	0.17	
Expected interval between page and arrival of staff in catheterization laboratory			0.01
≤20 min			
21–30 min	3.5 (−4.6 to 11.6)‖	0.40	
>30 min	19.3 (6.0 to 32.7)	0.002	
No expected time	8.8 (−0.7 to 18.3)	0.06	
An attending cardiologist is always at the hospital			0.01
No			
Yes	−14.6 (−25.7 to −3.6)	0.01	
Hospital gives real-time feedback to staff in emergency department and catheterization laboratory			0.001
No			
Yes	−8.6 (−13.6 to −3.6)	0.001	

* All variables are centered at their mean value; therefore, the changes in minutes are relative to those of hospitals with an "average" score on all other items. CI denotes confidence interval, and ECG electrocardiography.
† The reference category is the first listed response to each question.
‡ P values were calculated with the use of the Wald chi-square test.
§ P=0.01 for the comparison with the door-to-balloon time at hospitals reporting that electrocardiography was never performed en route by emergency medical services.
¶ P=0.01 for the comparison with the door-to-balloon time at hospitals reporting that emergency medical services never called in or transmitted electrocardiographic data. Hospitals that reported having no set protocol or a variable protocol could have used a variety of strategies, including activation of the catheterization laboratory before the patient arrived, for expediting the door-to-balloon time.
‖ P=0.003 for the comparison with the door-to-balloon time at hospitals with an expected interval of more than 30 minutes.

21 to 30 minutes after being paged (P=0.002 for the comparison with an interval of 20 minutes or less and P=0.003 for the comparison with an interval of more than 30 minutes). In addition, hospitals that always had an attending cardiologist at the hospital had a faster door-to-balloon time than did hospitals without an attending cardiologist always on site.

Hospitals that used the results of electrocardiography that were called in or transmitted by emergency medical services to activate the catheterization laboratory while the patient was still en route to the hospital had significantly faster door-to-balloon times than did hospitals that waited for the patient to arrive before activating the catheterization laboratory (P=0.001). The hospitals that activated the laboratory while the patient was still en route also had significantly faster door-to-balloon times than did hospitals reporting that emergency medical services never performed electrocardiography (P=0.01). In addition, hospitals reporting that emergency medical services called in or transmitted the results of electrocardiography but also reporting various methods of handling such information had faster door-to-ballooon times than did hospitals that never received such information (P=0.01). Methods of handling the information may have included activating the catheterization laboratory while the patient was en route to the hospital, but with no set protocol for this procedure at the hospital. Finally, hospitals that provided real-time data feedback on the door-to-balloon time to staff members in the emergency department and catheterization laboratory had faster door-to-balloon times than those that did not (P=0.001).

One item in our survey requested an estimate of how frequently in the previous 6 months the catheterization laboratory had been activated for PCI but then had not been needed. This question was used to evaluate the effect of specific hospital policies on the frequency of such false alarms. The median number of false alarms that was reported among hospitals in which emergency medicine physicians activated the catheterization laboratory was 2 (interquartile range, 1 to 4), as compared with 1 false alarm (interquartile range, 0 to 3) for all other hospitals. Among hospitals using electrocardiographic data obtained en route to activate the catheterization laboratory, the median number of false alarms was 2 (interquartile range, 1 to 4) in the previous 6 months.

Table 4. **Door-to-Balloon Time According to the Number of Key Strategies Used.***

Number of Key Strategies	Hospitals with the Number of Key Strategies (N=362)	Average of Median Door-to-Balloon Times†
	no. (%)	*minutes*
0	137 (37.8)	110
1	130 (35.9)	100
2	56 (15.5)	88
3	31 (8.6)	88
4	8 (2.2)	79

* Since the number of hospitals using three or four strategies was small, the precision of the estimates may be limited.
† P<0.001.

Hospital policies regarding the performance and assessment of electrocardiography in the emergency department did not have a significant effect on the door-to-balloon time, in either bivariate or multivariate analyses. These policies included the use of written criteria for deciding which patients should undergo immediate electrocardiography, provision of formal training in the assessment of acute coronary syndromes for triage staff members in the emergency department, inclusion of dedicated electrocardiographic technicians in the emergency department, and provision of dedicated space for performing electrocardiography in the triage area. In addition, policies and practices related to transporting patients from the emergency department to the catheterization laboratory (e.g., timing and staff required) were not significantly related to the door-to-balloon time in multivariate analysis. Practices in the catheterization laboratory that were surveyed were also not significantly associated with the door-to-balloon time in either bivariate or multivariate analyses. These practices included rescheduling elective PCI cases as emergency PCI cases, leaving the catheterization laboratory prepared for the next PCI to begin promptly, involving cardiology fellows in performing PCI, and locating the catheterization laboratory on the same floor as the emergency department.

DISCUSSION

In a cross-sectional study of 365 acute care hospitals in the United States, we identified several hospital strategies that were strongly associated with the door-to-balloon time in the performance of PCI for patients with acute myocardial infarction with ST-segment elevation. In some cases, specific practices were associated with time savings of 10 to 15 minutes, a clinically important advantage in a group of institutions with a mean value of 100 minutes for median door-to-balloon times. Many of the strategies are not commonly used in hospitals in the United States, which may account in part for the relatively poor performance of such hospitals in meeting guidelines for the door-to-balloon time.

Although implementation of some of the advantageous strategies would require investment in new resources, other strategies that are currently used by only a minority of hospitals could be implemented with existing resources. For instance, having emergency medicine physicians determine whether a myocardial infarction with ST-segment elevation is present and activate the catheterization team without involvement of a cardiologist was strongly associated with a reduced door-to-balloon time but was used in only about 23% of hospitals during weekdays and in 27% of hospitals at night or on weekends. Furthermore, having the catheterization laboratory activated by a single call from the emergency department to a central page operator, who then paged both the interventional cardiologist and the catheterization laboratory staff, was strongly associated with a faster door-to-balloon time, but the single-call process was used in only about 14% of hospitals in this study. Research on the time to fibrinolytic therapy[20] and small, single-hospital studies of the door-to-balloon time[21,22] have also indicated that treatment is more rapid if emergency medicine physicians make the treatment decision without the involvement of a cardiologist. Nonetheless, most hospitals still involve a cardiologist in the decision to activate the catheterization laboratory.

In addition to the strategies that focus on processes within the hospital, the hospital's coordination with emergency medical services was strongly associated with the door-to-balloon time. Previous studies[23-25] have shown that performing electrocardiography en route to the hospital can reduce the door-to-balloon time, and the National Heart Attack Alert Program Coordinating Committee[26] has recommended increased use of such electrocardiographic services. In our study, the percentage of patients with acute coronary syndrome who underwent electrocardiography en route was not associated with the door-to-balloon time. Instead, it was the way that such electrocardiograms were used by hospitals that was important. Hospitals that activated the catheterization laboratory on the basis of electrocardiography performed while the patient was en route and those that had varied strategies to respond to electrocardiographic data transmitted from emergency medical services had an advantage. Determining the optimal approach for incorporating such electrocardiographic data into hospital processes to expedite the door-to-balloon time is an important area for future research.

False alarms were reported to be infrequent in our study, even at hospitals where emergency medicine physicians were responsible for activation of the catheterization laboratory on the basis of electrocardiography performed en route to the hospital. We were not able to obtain independent confirmation of the accuracy of the hospitals' estimates of false alarms. However, we have no evidence to suggest that these data are inaccurate, and we believe that perceptions about the number of false alarms are probably as important as is the true number of false alarms in determining whether noncardiologists are permitted to activate the catheterization laboratory. This issue may be clarified by further study.

Implementation of other strategies that were associated with faster door-to-balloon time may be more complex. The presence of an attending cardiologist at the hospital at all times was associated with a significantly faster door-to-balloon time. These strategies may be impractical or prohibitively expensive to implement in many hospitals.

Several considerations are important in interpreting our results. First, the survey data were reported by a single respondent at the hospital, and the reported policies and practices were not independently confirmed. However, respondents were selected by the chief executive officer of each hospital as the person who was most familiar with activities in this area, and the questions were field-tested before their use to ensure their clarity and completeness.

Second, the hospitals were restricted to those that reported the door-to-balloon time as one of their CMS performance measures. These hospitals may have been more aggressive than others in their efforts to reduce the door-to-balloon time. Therefore, the prevalence of some strategies may be overestimated, but even for this group, the overall rates were low for most of the strategies. In addition, it may not have been possible to detect the influence of some practices because of a high prevalence of the preferred practice (e.g., 97% of surveyed hospitals do not wait for laboratory and radiographic results to activate the catheterization laboratory). Nevertheless, the respondent hospitals did reflect a spectrum of performance in the door-to-balloon time.

Third, with the observational study design, we could not determine whether some of the strategies identified were surrogates for unmeasured care processes that might have been important contributors to a reduced door-to-balloon time. The processes tested, however, emerged from qualitative studies[11,12] and have strong face validity for a causal relationship. In addition, some strategies may be important in particular institutions but not across the full sample, and our results should not inhibit innovations that may be effective in particular settings.

Finally, we were unable to examine efforts that may reduce the time from the onset of symptoms to admission or the time after arrival at the first hospital to balloon inflation for patients who were transferred to a hospital in which PCI is performed. These are important topics for future study, because delays in reperfusion therapy are commonplace for transferred patients.[27]

In conclusion, this study used survey information from 365 acute care hospitals to determine which specific policies and practices were in use for facilitating rapid PCI in patients with acute myocardial infarction with ST-segment elevation. These policies and practices, as reported, were correlated with data on individual patients with regard to the door-to-balloon time, permitting the identification of hospital strategies associated with the most prompt performance of this critical intervention.

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