

ORIGINAL ARTICLE

A Citywide Protocol for Primary PCI in ST-Segment Elevation Myocardial Infarction

Michel R. Le May, M.D., Derek Y. So, M.D., Richard Dionne, M.D.,
Chris A. Glover, M.D., Michael P.V. Froeschl, M.D., George A. Wells, Ph.D.,
Richard F. Davies, M.D., Heather L. Sherrard, R.N., Justin Maloney, M.D.,
Jean-François Marquis, M.D., Edward R. O'Brien, M.D., John Trickett, R.N.,
Pierre Poirier, A.C.P., Sheila C. Ryan, B.Sc., Andrew Ha, M.D.,
Phil G. Joseph, M.D., and Marino Labinaz, M.D.

ABSTRACT

BACKGROUND

If primary percutaneous coronary intervention (PCI) is performed promptly, the procedure is superior to fibrinolysis in restoring flow to the infarct-related artery in patients with ST-segment elevation myocardial infarction. The benchmark for a timely PCI intervention has become a door-to-balloon time of less than 90 minutes. Whether regional strategies can be developed to achieve this goal is uncertain.

METHODS

We developed an integrated-metropolitan-area approach in which all patients with ST-segment elevation myocardial infarction were referred to a specialized center for primary PCI. We sought to determine whether there was a difference in door-to-balloon times between patients who were referred directly from the field by paramedics trained in the interpretation of electrocardiograms and patients who were referred by emergency department physicians.

RESULTS

Between May 1, 2005, and April 30, 2006, a total of 344 consecutive patients with ST-segment elevation myocardial infarction were referred for primary PCI: 135 directly from the field and 209 from emergency departments. Primary PCI was performed in 93.6% of patients. The median door-to-balloon time was shorter in patients referred from the field (69 minutes; interquartile range, 43 to 87) than in patients needing interhospital transfer (123 minutes; interquartile range, 101 to 153; $P < 0.001$). Door-to-balloon times of less than 90 minutes were achieved in 79.7% of patients who were transferred from the field and in 11.9% of those transferred from emergency departments ($P < 0.001$).

CONCLUSIONS

Guideline door-to-balloon-times were more often achieved when trained paramedics independently triaged and transported patients directly to a designated primary PCI center than when patients were referred from emergency departments.

From the University of Ottawa Heart Institute (M.R.L., D.Y.S., C.A.G., M.P.V.F., G.A.W., R.F.D., H.L.S., J.-F.M., E.R.O., S.C.R., A.H., P.G.J., M.L.) and the Ottawa Base Hospital Program (R.D., J.M., J.T.), University of Ottawa; and the Ottawa Paramedic Service (P.P.) —, all in Ottawa, ON, Canada. Address reprint requests to Dr. Le May at the Ottawa Heart Institute, 40 Ruskin St., Ottawa, ON K1Y 4W7, Canada, or at mlemay@ottawaheart.ca.

N Engl J Med 2008;358:231-40.

Copyright © 2008 Massachusetts Medical Society.

SURVIVAL OF PATIENTS PRESENTING WITH ST-segment elevation myocardial infarction is enhanced by rapid, complete, and sustained reperfusion of the infarct-related artery.¹⁻³ Delays in either door-to-needle¹ or door-to-balloon⁴⁻⁷ times are associated with increased mortality. In patients who are treated with primary percutaneous coronary intervention (PCI), each 30 minutes of delay increases the relative risk of 1-year mortality by 7.5%.⁶ It has been recommended that efforts be made to shorten door-to-balloon times for all patients because time-to-balloon strongly correlates with mortality regardless of the baseline risk of mortality.⁷

PCI ensures more complete and sustained restoration of flow to the infarct-related artery than does fibrinolysis. A systematic overview of 23 randomized trials that compared primary PCI with fibrinolysis concluded that primary PCI was superior at reducing death, reinfarction, and stroke⁸; it was also more cost-effective.⁹ Thus, primary PCI is becoming the strategy of choice in most centers equipped with a catheterization facility. However, access to catheterization laboratories is limited, and the transfer of patients for primary PCI from hospitals without such facilities may be associated with substantial delays.¹⁰ Therefore, strategies are needed to allow for earlier identification of patients with ST-segment elevation myocardial infarction and a shorter symptom-to-reperfusion time.

We developed a care delivery model to improve survival of patients with ST-segment elevation myocardial infarction with the use of systematic primary PCI for the 800,000 people living in the Ottawa metropolitan area. This project required a redesign of the traditional care of these patients, the development of new protocols for ambulance transport, changes in physician-referral patterns, and changes in emergency department protocols.

We previously showed that paramedics could be trained to accurately interpret prehospital electrocardiograms (ECGs) for the detection of ST-segment elevation myocardial infarction.¹¹ Since July 2004, these paramedics have been referring patients directly from the field to a designated cardiac care center for primary PCI. In the second phase of our program, we initiated a protocol by which all patients presenting to the city's emergency departments are transferred for primary PCI. As of May 1, 2005, a protocol was approved at all area hospitals that all patients presenting

within the metropolitan area would be referred to the University of Ottawa Heart Institute for primary PCI. In this report, we compare the time to treatment for patients who were referred from the field by advanced care paramedics with those referred by emergency department physicians during the first year of full operation of the program.

METHODS

PARAMEDIC-REFERRED PATHWAY

The portion of the program regarding referral by paramedics in the field was developed for patients dialing 911 within the city of Ottawa. Advanced care paramedics were instructed to evaluate patients with chest pain at the scene and administer chewable aspirin and sublingual nitroglycerin if the pain was attributed to myocardial ischemia. As compared with primary care paramedics, advanced care paramedics had advanced training in cardiac life support. It was routine practice for advanced care paramedics to perform and interpret 12-lead ECGs at the scene and independently triage and transport patients with ST-segment elevation myocardial infarction to the designated center for primary PCI. The farthest point of service was 37 miles away from the cardiac care center.

All patients who had an onset of symptoms 12 hours or less before presentation and an ST-segment elevation of at least 1 mm in two or more contiguous limb leads or of at least 2 mm in two or more contiguous precordial leads during prehospital 12-lead ECGs were eligible for direct transfer by advanced care paramedics to the cardiac care center, thus bypassing the city's four emergency departments. However, patients with absent vital signs, severe hemodynamic instability, or left bundle-branch block were excluded from this protocol and were transported to the nearest hospital. Patients who were initially assessed by primary care paramedics were also excluded and were transported to the nearest hospital. When needed, the advanced care paramedics used a dedicated telephone line to alert a central page operator at the cardiac care center of the impending arrival of a patient. This call activated the code for an ST-segment elevation myocardial infarction, which prompted the cardiology team to assemble in a designated area near the catheterization laboratory.

INTERHOSPITAL TRANSFER PATHWAY

Patients who were transported between hospitals were initially assessed in one of the four emergency departments in the city. The mode of arrival was either self-transport or ambulance. Reasons for not being referred directly from the field to the PCI center are stated above. Patients were initially triaged by a nurse and then evaluated by the emergency-department physician. All patients who had an onset of symptoms 12 hours or less before presentation and an ST-segment elevation of at least 1 mm in two or more contiguous leads on 12-lead ECGs were eligible for direct transfer to the cardiac care center for primary PCI. The cardiac care center was connected through an underground tunnel to one of the four hospitals and provided around-the-clock services of cardiology staff to assess patients in the emergency room of that hospital; this cardiology staff was responsible for activating the team to perform primary PCI through the central paging operator at the cardiac care center.

The other hospital emergency departments were located within 7 miles of the cardiac care center. At these sites, the emergency department physician, without consultation with a cardiologist or an internist, called the ambulance dispatcher to arrange immediate transfer. Fibrinolysis was to be considered if the delay from the dispatch call to the arrival of the paramedic crew was more than 15 minutes. After putting the patient in the ambulance at the community hospital, paramedics immediately notified the central operator at the cardiac care center of the impending arrival of a patient with ST-segment elevation myocardial infarction to activate the appropriate health care team. Before the PCI procedure, all patients received 160 mg of chewable aspirin, 600 mg of oral clopidogrel, and 60 units per kilogram of body weight of intravenous unfractionated heparin (maximum dose, 4000 units).

PRIMARY AND SECONDARY END POINTS

The primary end point was the proportion of patients who had door-to-balloon times within the 90-minute recommended guideline. The door-to-balloon time was defined as the time that had elapsed between arrival at the first hospital and the time of the first balloon inflation. For patients who were referred directly from the field, the first hospital was the cardiac care center.

Times were obtained from the ambulance call reports, emergency department triage sheets, the

electronic time stamp printed on ECGs, computer-generated catheterization reports that used real-time data entry, and medical charts. Values for coronary flow at baseline and after the procedure were reported according to the classification of the Thrombolysis in Myocardial Infarction (TIMI) trial.¹²

Secondary end points included mortality, reinfarction, stroke, cardiogenic shock, and major bleeding. Reinfarction was defined as recurrent chest pain associated with reelevation of the ST segments in association with either reelevation of cardiac enzymes (twice the upper limit of the normal range) or angiographic documentation of reocclusion of the infarct-related artery. A stroke was defined as a new neurologic deficit of more than 24 hours' duration. Episodes of bleeding were defined as major or minor according to the TIMI classification.¹² The study was approved by the institutional review board at the University of Ottawa Heart Institute.

STATISTICAL ANALYSIS

Categorical variables were compared with the use of Fisher's exact test. Normally distributed continuous variables were compared with Student's t-test. Time intervals were analyzed with the Mann-Whitney U test. Analyses were conducted with the use of Systat software, version 11.0 (Systat). A P value of 0.05 or less was considered to indicate statistical significance.

RESULTS

CHARACTERISTICS OF THE PATIENTS

Between May 1, 2005, and April 30, 2006, a total of 344 patients with confirmed ST-segment elevation myocardial infarction were referred for primary PCI to the cardiac care center. Of those patients, 135 (39.2%) were referred directly from the field by paramedics, and 209 (60.8%) were referred from hospital emergency departments. Among patients who needed interhospital transfer, 104 (49.8%) initially presented to the emergency department by ambulance, and 105 (50.2%) arrived by self-transport. Reasons for not being referred directly from the field to the cardiac care center included the absence of an advanced care paramedic in the ambulance, nonqualifying results on prehospital ECG, and the presence of severe hemodynamic instability.

The baseline characteristics of the patients

Table 1. Baseline Characteristics of the Patients.*

Variable	All Patients (N=344)	Field Transfers (N=135)	Interhospital Transfers (N=209)	P Value
Age — yr	62.5±13.2	63.7±12.9	61.8±13.3	0.19
≥75 — no. (%)	73 (21.2)	33 (24.4)	40 (19.1)	0.28
Male sex — no. (%)	249 (72.4)	98 (72.6)	151 (72.2)	1.00
Coexisting conditions — no./total no. (%)				
Hypertension	151/344 (43.9)	60/135 (44.4)	91/209 (43.5)	0.91
Diabetes mellitus	60/344 (17.4)	17/135 (12.6)	43/209 (20.6)	0.06
Current smoker	130/343 (37.9)	54/135 (40.0)	76/208 (36.5)	0.57
History of hyperlipidemia	144/343 (42.0)	62/135 (45.9)	82/208 (39.4)	0.26
Previous myocardial infarction	51/343 (14.9)	19/135 (14.1)	32/208 (15.4)	0.76
Previous cardiac procedure — no. (%)				
Angioplasty	34 (9.9)	18 (13.3)	16 (7.7)	0.10
Bypass surgery	13 (3.8)	7 (5.2)	6 (2.9)	0.39
Anterior myocardial infarction — no. (%)	145 (42.2)	58 (43.0)	87 (41.6)	0.82
Heart rate — bpm	75±19	74±17	76±21	0.53
Blood pressure — mm Hg				
Systolic	132±29	129±24	134±32	0.10
Diastolic	79±18	78±15	81±20	0.17
Killip class 1 — no. (%)	280 (81.4)	107 (79.3)	173 (82.8)	0.48
Height — cm	170±9	170±10	170±9	0.94
Weight — kg	79±17	77±16	80±17	0.08
Creatinine clearance — ml/min	84±40	78±33	87±43	0.03

* Plus-minus values are means ±SD.

are shown in Table 1. The mean (±SD) age of the patients was 62.5±13.2 years, and 21.2% were at least 75 years old. Anterior-wall infarction was present in 42.2% of patients, and Killip class 1 was noted in 81.4%. The baseline characteristics of patients who were transferred directly from the field were similar to those of patients needing interhospital transfer, except for a higher estimated creatinine clearance in the latter group.

TREATMENT

All 344 patients who were referred for PCI underwent cardiac catheterization: selective angiography of both coronary arteries was achieved in 343 patients (99.7%), and PCI was performed in 322 patients (93.6%). Facilitated PCI with tenecteplase was performed in seven patients (2.0%) because of anticipated delays before the catheterization procedure. No patient was treated with fibrinolysis alone. Two patients (0.6%) were treated with immediate bypass surgery, and one patient re-

quired emergency bypass surgery because primary PCI failed.

TIME TO TREATMENT

Time intervals are shown in Table 2. The median door-to-balloon time for all patients was 101 minutes (interquartile range, 76 to 133). The median door-to-balloon time was shorter in patients who were referred from the field (69 minutes; interquartile range, 43 to 87) than in patients needing interhospital transfer (123 minutes; interquartile range, 101 to 153; $P<0.001$). The median time between ECG and PCI and the median time between the onset of symptoms and PCI were also significantly shorter in patients referred from the field. The cumulative percentages of patients' door-to-balloon, ECG-to-balloon, and symptom-to-balloon times as a function of time are shown in Figure 1.

Door-to-balloon times of less than 90 minutes were achieved in 79.7% of patients transferred

Table 2. Critical Time Intervals in Minutes.*

Variable	All Patients (N=344)	Field Transfers (N=135)	Interhospital Transfers (N=209)	P Value
Time from onset of symptoms to arrival at first hospital				0.21
Median	90	81	104	
Interquartile range	53–180	53–163	53–209	
Time from onset of symptoms to ECG				<0.001
Median	86	52	120	
Interquartile range	45–184	29–145	65–235	
Time from ECG to arrival at cardiac care center				<0.001
Median	38	23	51	
Interquartile range	25–58	18–28	39–70	
Time from arrival at cardiac care center to first balloon inflation				<0.001
Median	57	69	51	
Interquartile range	40–76	43–87	39–67	
Time from ECG to first balloon inflation				<0.001
Median	104	91	108	
Interquartile range	83–123	66–113	91–129	
Time from arrival at first hospital to first balloon inflation				<0.001
Median	101	69	123	
Interquartile range	76–133	43–87	101–153	
Time from onset of symptoms to first balloon inflation				<0.001
Median	201	158	230	
Interquartile range	143–294	116–207	173–351	

* ECG denotes electrocardiography.

from the field and in 11.9% of patients transferred from emergency departments ($P<0.001$). Door-to-balloon times of less than 120 minutes were achieved in 95.9% of patients transferred from the field and in 44.9% of patients transferred from emergency departments ($P<0.001$). There was no statistical difference in door-to-balloon times between patients presenting to the emergency department at the on-site catheterization facility (126 minutes; interquartile range, 98 to 153) and patients needing interhospital transfer by ambulance (122 minutes; interquartile range, 101 to 153; $P=0.88$). The median time from the arrival of patients in the emergency department to the request of an ambulance for transfer was 26 minutes (interquartile range, 17 to 48).

ANGIOGRAPHIC RESULTS

The angiographic results are shown in Table 3. The initial proportion of patients with TIMI grade 3 flow at baseline was 23.1% among patients who were referred by paramedics and 21.5% among patients who needed interhospital transfer; this proportion reached 91.8% and 87.1%, respectively, after the procedure.

CLINICAL RESULTS

In-hospital mortality was 4.7% for all patients: 3.0% for patients who were referred directly from the field and 5.7% for patients who were transferred from emergency departments ($P=0.30$) (Table 4). A PCI to a non-infarct-related artery was performed later during the initial hospitalization in 46 patients (13.4%); 1 of these patients

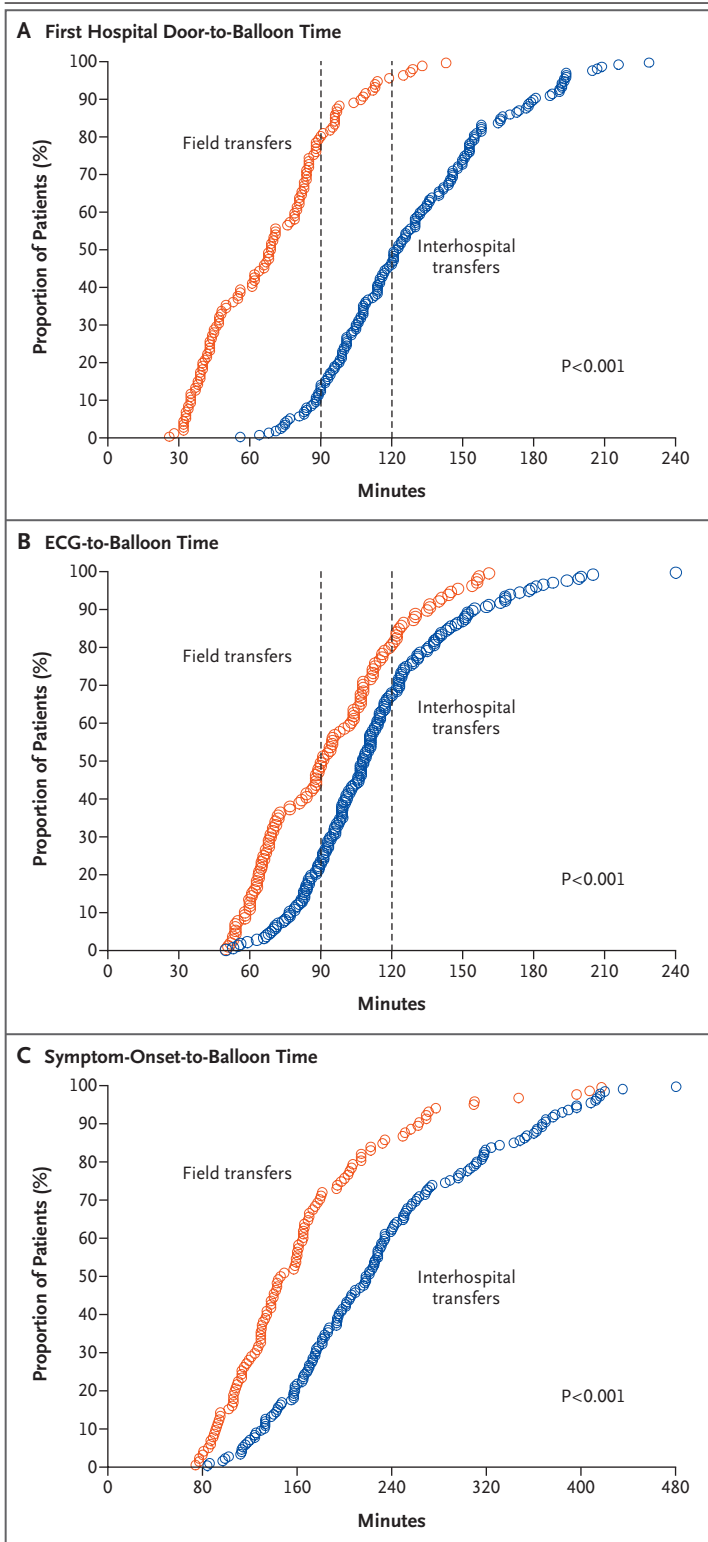


Figure 1. Cumulative Time-to-Balloon Intervals.

Among patients who were transferred to a specialized center for primary percutaneous coronary intervention, door-to-balloon times of less than 90 minutes were achieved in 79.7% of patients who were transferred directly from the field and in 11.9% of patients who were transferred from emergency departments; door-to-balloon times of less than 120 minutes were achieved in 95.9% of patients transferred from the field and in 44.9% of patients transferred from emergency departments (Panel A). The ECG-to-balloon time (Panel B) and symptom-onset-to-balloon time (Panel C) were also shorter in patients who were referred directly from the field.

rin, 95.7% for clopidogrel, 93.9% for a beta-blocker, 84.1% for an angiotensin-converting-enzyme inhibitor, and 96.0% for a lipid-lowering medication.

The results of clinical follow-up were available for 341 patients (99.1%). At 30 days, 6 of 135 patients who had been referred from the field had died (4.4%), as had 12 of 209 patients (5.7%) who had been referred from emergency departments (P=0.81); at 6 months, 8 patients (6.0%) and 16 patients (7.7%), respectively, had died (P=0.67).

DISCUSSION

Our study reports on the systematic application of primary PCI for an entire metropolitan area with the use of standardized protocols. Recommended guidelines for door-to-balloon times were achieved more often when patients were identified in the field by trained paramedics and transported directly to a designated center for primary PCI than when patients were evaluated by physicians in emergency departments.

Because primary PCI is now considered to be the optimal reperfusion strategy, there has been a movement to transfer patients who initially present to hospitals that do not have an on-site catheterization facility to centers equipped with such a facility. Five randomized trials concluded that interhospital transfer for primary PCI was better than fibrinolysis.¹³⁻¹⁷ In a quantitative overview of these trials, transfer for primary PCI prevented 70 major cardiac adverse events (death, stroke, or reinfarction) for every 1000 patients who were treated.¹⁸

These trials were mostly conducted in Europe, where the ambulance system is highly sophisticated, and consequently randomization-to-balloon times were relatively short. Current guidelines

died during the initial hospitalization. Major bleeding occurred in 6.1% of patients, and blood transfusion was required in 4.1%. At discharge, 99.4% of patients received a prescription for aspi-

Table 3. Procedural and Angiographic Results.*

Variable	All Patients (N=344)	Field Transfers (N=135)	Interhospital Transfers (N=209)	P Value
Procedural results				
Catheterization performed — no. (%)	344 (100)	135 (100)	209 (100)	1.00
Femoral access established — no. (%)	293 (85.2)	111 (82.2)	182 (87.1)	0.22
PCI performed — no. (%)	322 (93.6)	123 (91.1)	199 (95.2)	0.18
Stenting performed — no. (%)	312 (90.7)	119 (88.1)	193 (92.3)	0.18
Stents per patient — no.	1.4±0.9	1.4±1.0	1.4±0.8	0.75
Peak activated clotting time — sec	197±46	199±45	185±51	0.21
Angiographic results†				
Multivessel disease — no. (%)	230 (67.1)	86 (64.2)	144 (68.9)	0.18
Infarct-related artery — no. (%)				0.75
Left main coronary	1 (0.3)	0	1 (0.5)	
Left anterior descending	137 (39.9)	51 (38.1)	86 (41.1)	
Left circumflex	49 (14.3)	19 (14.2)	30 (14.4)	
Right coronary	150 (43.7)	62 (46.3)	88 (42.1)	
Bypass graft	5 (1.5)	1 (0.7)	5 (2.4)	
Coronary flow at baseline				0.57
TIMI grade — no. (%)				
0 or 1	217 (63.3)	86 (64.2)	131 (62.7)	
2	50 (14.6)	17 (12.7)	33 (15.8)	
3	76 (22.2)	31 (23.1)	45 (21.5)	
Coronary flow after procedure				0.58
TIMI grade — no. (%)				
0 or 1	22 (6.4)	6 (4.5)	16 (7.7)	
2	16 (4.7)	5 (3.7)	11 (5.3)	
3	305 (88.9)	123 (91.8)	182 (87.1)	
Stenosis — % of luminal diameter				
Before procedure	96±45	96±12	97±7	0.19
After procedure	8±27	9±28	8±26	0.67

* Plus–minus values are means ±SD.

† Angiographic results are based on data from only 343 patients (including 134 patients who were transferred from the field) since selective coronary angiography was not successful in 1 patient.

recommend that the door-to-balloon time be less than 90 minutes and that the estimated PCI-related delay be less than 60 minutes.^{19,20} In a real-world setting, the experience has been quite different. Data from the National Registry of Myocardial Infarction revealed that the median door-to-balloon time in 4278 patients undergoing interhospital transfer for primary PCI in the United States was 180 minutes, with only 4% of patients having a door-to-balloon time of less than 90 minutes and 15% less than 120 minutes.²¹

To minimize the effect of transfer on time to

reperfusion and to achieve guideline door-to-balloon times, several authors have suggested developing efficient, coordinated regional strategies similar to the trauma-system model.²²⁻²⁴ Our results suggest that this model may be feasible. The data were collected in a real-world setting in which all patients who presented with ST-segment elevation myocardial infarction were considered for primary PCI. The median door-to-balloon time for patients who were identified by paramedics and transferred directly from the field was within the 90-minute guideline interval for 80% of patients. Before implementation

Table 4. In-Hospital Clinical Outcomes and Bleeding Complications.*

Outcome	All Patients (N=344)	Field Transfers (N=135)	Interhospital Transfers (N=209)	P Value
Death — no. (%)	16 (4.7)	4 (3.0)	12 (5.7)	0.30
Reinfarction — no. (%)	4 (1.2)	2 (1.5)	2 (1.0)	0.65
Stroke — no. (%)	4 (1.2)	1 (0.7)	3 (1.4)	1.00
Death, reinfarction, or stroke — no. (%)	22 (6.4)	7 (5.2)	15 (7.2)	0.51
Cardiogenic shock — no. (%)	27 (7.8)	8 (5.9)	19 (9.1)	0.32
Bleeding — no. (%)				
Major	21 (6.1)	9 (6.7)	12 (5.7)	0.82
Minor	26 (7.6)	3 (2.2)	23 (11.0)	0.003
Blood transfusion — no. (%)	14 (4.1)	8 (5.9)	6 (2.9)	0.17
Intracranial bleeding — no. (%)	1 (0.3)	0	1 (0.5)	1.00
Peak activated clotting time — sec	197±46	199±45	185±51	0.21
Revascularization procedure — no. (%)				
Repeat PCI	3 (0.9)	2 (1.5)	1 (0.5)	0.56
PCI on non–infarct-related artery	46 (13.4)	22 (16.3)	24 (11.5)	0.26
Bypass surgery	13 (3.8)	4 (3.0)	9 (4.3)	0.58
Length of hospital stay — days				
Median	4	5	4	0.007
Interquartile range	3–6	3–6	3–6	

* Plus–minus values are means ±SD.

of this approach, these patients (almost 40% of the entire cohort) would have been brought to the nearest hospital emergency department and considered for fibrinolysis. In this respect, the change in referral practice clearly benefited a substantial proportion of patients. The median door-to-balloon time for patients needing interhospital transfer by ambulance was significantly longer than that for patients referred directly from the field; however, this interval was nearly 60 minutes less than that reported for interhospital transfer in the National Registry of Myocardial Infarction²¹ and approaches the results reported in randomized trials.

These preliminary results are encouraging and could be further improved by reducing the time between presentation at the hospital and a call to a dispatcher for an ambulance. Also, the removal of the consultation process between the adjoining hospital and the on-site catheterization facility should shorten door-to-balloon times. However, presentation to an emergency department is associated with some obligatory logistical delays that are bypassed when patients dialing 911 are

evaluated in the field and transported directly to a cardiac care center for primary PCI.

We have recently shown that a strategy in which paramedics independently referred patients with ST-segment elevation myocardial infarction to a designated center for primary PCI was associated with rapid and effective reperfusion and very low hospital mortality.²⁵ However, that analysis did not include a concurrent comparative PCI group. In this study, we have shown that patients with ST-segment elevation myocardial infarction who are triaged in the field by trained paramedics have significantly shorter door-to-balloon times than do patients who are first evaluated in the emergency department according to the usual standard of care. Before we reengineered our strategies, in-hospital mortality for such patients was 10% for patients presenting to our city's emergency departments between 2002 and 2004.²⁶ With the application of a citywide primary PCI program, in-hospital mortality during the first year of operation fell to less than 5%.

Several factors have probably contributed to this apparently lower mortality. In the past, fi-

brinolysis was the reperfusion strategy of choice for patients presenting to our emergency departments. Switching to primary PCI may have contributed to a lower mortality since this strategy is known to improve survival over fibrinolysis.^{10,27} Second, because of contraindications associated with fibrinolysis, as many as 33% of patients in the real-world setting do not receive any reperfusion therapy despite its availability.²⁸ In our new program, all patients underwent cardiac catheterization, and nearly 94% were treated with primary PCI. Third, patients who were identified in the field were processed quickly and had extremely short door-to-balloon times. Finally, lower rates of death among patients undergoing primary PCI have been reported in centers that have a high volume of PCI procedures.²⁹ In our study, patients were referred to a cardiac care center that performs more than 3000 PCI procedures per year and that is prepared to deal with potential complications associated with ST-segment elevation myocardial infarction.

Our results do not apply to areas in which ambulance services are suboptimal or to regions in which transfer distances are unusually long. In our study, the median ambulance transport time between the referring hospitals and the cardiac care center was 10 minutes. It is estimated that 55 to 65% of patients with ST-segment elevation myocardial infarction live within 30

minutes of a PCI center in Ontario.³⁰ In the United States, the median time to the closest PCI hospital is 11.4 minutes, and the median distance is 8.0 miles, with nearly 80% of the adult population living within 60 minutes of activation of the emergency medical system to arrival at a PCI center.³¹

In summary, we developed a program in which all patients within a metropolitan area can be referred for primary PCI. This program was associated with door-to-balloon times recorded in a real-world setting that are encouraging and associated with relatively low rates of death at both early and late follow-up. Guideline door-to-balloon times were best achieved when trained paramedics identified patients in the field and referred them directly to a specialized center for primary PCI. Therefore, effort needs to be devoted to developing emergency medical systems that allow for an expanded role for paramedics to triage and refer patients for primary PCI.

Dr. Le May reports receiving grant support from Pfizer, Sanofi-Aventis, Bristol-Myers Squibb, Medtronic, Schering-Plough, and Hoffmann-La Roche; Dr. Wells, grant support from Bristol-Myers Squibb; and Ms. Sherrard, grant support from Sanofi-Aventis and Bristol-Myers Squibb. No other potential conflict of interest relevant to this article was reported.

We thank all the front-line paramedics and the management team at the Ottawa Paramedic Service for the dedication and enthusiasm that were responsible for the success of this initiative, and the nurses and technical staff working in the catheterization laboratories for their invaluable contribution.

REFERENCES

- Effectiveness of intravenous thrombolytic treatment in acute myocardial infarction: Gruppo Italiano per lo Studio della Streptochinasi nell'Infarto Miocardico (GISSI). *Lancet* 1986;1:397-402.
- The GUSTO Angiographic Investigators. The effects of tissue plasminogen activator, streptokinase, or both on coronary-artery patency, ventricular function, and survival after acute myocardial infarction. *N Engl J Med* 1993;329:1615-22. [Erratum, *N Engl J Med* 1994;330:516.]
- Ohman EM, Califf RM, Topol EJ, et al. Consequences of reocclusion after successful reperfusion therapy in acute myocardial infarction. *Circulation* 1990;82:781-91.
- Berger PB, Ellis SG, Holmes DR, et al. Relationship between delay in performing direct coronary angioplasty and early clinical outcome in patients with acute myocardial infarction: results from the Global Use of Strategies to Open Occluded Arteries in Acute Coronary Syndromes (GUSTO-IIb) trial. *Circulation* 1999;100:14-20.
- Cannon CP, Gibson CM, Lambrew CT, et al. Relationship of symptom-onset-to-balloon time and door-to-balloon time with mortality in patients undergoing angioplasty for acute myocardial infarction. *JAMA* 2000;283:2941-7.
- De Luca G, Suryapranata H, Ottervanger JP, Antman EM. Time delay to treatment and mortality in primary angioplasty for acute myocardial infarction: every minute of delay counts. *Circulation* 2004;109:1223-5.
- McNamara RL, Wang Y, Herrin J, et al. Effect of door-to-balloon time on mortality in patients with ST-segment elevation myocardial infarction. *J Am Coll Cardiol* 2006;47:2180-6.
- Keeley EC, Boura JA, Grines CL. Primary angioplasty versus intravenous thrombolytic therapy for acute myocardial infarction: a quantitative review of 23 randomised trials. *Lancet* 2003;361:13-20.
- Le May MR, Davies RF, Labinaz M, et al. Hospitalization costs of primary stenting versus thrombolysis in acute myocardial infarction: cost analysis of the Canadian STAT Study. *Circulation* 2003;108:2624-30.
- Boersma E. Does time matter? A pooled analysis of randomized clinical trials comparing primary percutaneous coronary intervention and in-hospital fibrinolysis in acute myocardial infarction patients. *Eur Heart J* 2006;27:779-88.
- Le May MR, Dionne R, Maloney J, et al. Diagnostic performance and potential clinical impact of advanced care paramedic interpretation of ST-segment elevation myocardial infarction in the field. *CJEM* 2006;8:401-7.
- The TIMI Study Group. The Thrombolysis in Myocardial Infarction (TIMI) trial: phase I findings. *N Engl J Med* 1985;312:932-6.
- Andersen HR, Nielsen TT, Rasmussen K, et al. A comparison of coronary angioplasty with fibrinolytic therapy in acute myocardial infarction. *N Engl J Med* 2003;349:733-42.
- Grines CL, Westerhausen DR Jr, Grines LL, et al. A randomized trial of

- transfer for primary angioplasty versus on-site thrombolysis in patients with high-risk myocardial infarction: the Air Primary Angioplasty in Myocardial Infarction study. *J Am Coll Cardiol* 2002; 39:1713-9.
15. Vermeer F, Oude Ophuis AJ, van den Berg EJ, et al. Prospective randomised comparison between thrombolysis, rescue PTCA, and primary PTCA in patients with extensive myocardial infarction admitted to a hospital without PTCA facilities: a safety and feasibility study. *Heart* 1999;82:426-31.
16. Widimský P, Groch L, Zelizko M, Aschermann M, Bednár F, Suryapranata H. Multicentre randomized trial comparing transport to primary angioplasty vs immediate thrombolysis vs combined strategy for patients with acute myocardial infarction presenting to a community hospital without a catheterization laboratory: the PRAGUE study. *Eur Heart J* 2000;21:823-31.
17. Widimský P, Budesinský T, Vorác D, et al. Long distance transport for primary angioplasty vs immediate thrombolysis in acute myocardial infarction: final results of the randomized national multicentre trial — PRAGUE-2. *Eur Heart J* 2003;24: 94-104.
18. Zijlstra F. Angioplasty vs thrombolysis for acute myocardial infarction: a quantitative overview of the effects of interhospital transportation. *Eur Heart J* 2003;24: 21-3.
19. Antman EM, Anbe DT, Armstrong PW, et al. ACC/AHA guidelines for the management of patients with ST-elevation myocardial infarction: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee to Revise the 1999 Guidelines for the Management of Patients with Acute Myocardial Infarction). *Circulation* 2004;110(9):e82-e292. [Errata. *Circulation* 2005;111:2013-4, 2007; 115(15):e411.]
20. Van de Werf F, Ardissino D, Betriu A, et al. Management of acute myocardial infarction in patients presenting with ST-segment elevation. *Eur Heart J* 2003;24: 28-66.
21. Nallamothu BK, Bates ER, Herrin J, Wang Y, Bradley EH, Krumholz HM. Times to treatment in transfer patients undergoing primary percutaneous coronary intervention in the United States: National Registry of Myocardial Infarction (NRFMI)-3/4 analysis. *Circulation* 2005;111: 761-7.
22. Bradley EH, Curry LA, Webster TR, et al. Achieving rapid door-to-balloon times: how top hospitals improve complex clinical systems. *Circulation* 2006;113:1079-85.
23. Bradley EH, Herrin J, Wang Y, et al. Strategies for reducing the door-to-balloon time in acute myocardial infarction. *N Engl J Med* 2006;355:2308-20.
24. Henry TD, Atkins JM, Cunningham MS, et al. ST-segment elevation myocardial infarction: recommendations on triage of patients to heart attack centers: is it time for a national policy for the treatment of ST-segment elevation myocardial infarction? *J Am Coll Cardiol* 2006;47: 1339-45.
25. Le May MR, Davies RF, Dionne R, et al. Comparison of early mortality of paramedic-diagnosed ST-segment elevation myocardial infarction with immediate transport to a designated primary percutaneous coronary intervention center to that of similar patients transported to the nearest hospital. *Am J Cardiol* 2006;98: 1329-33.
26. So DY, Ha AC, Turek MA, et al. Comparison of mortality patterns in patients with ST-elevation myocardial infarction arriving by emergency medical services versus self-transport (from the prospective Ottawa Hospital STEMI Registry). *Am J Cardiol* 2006;97:458-61.
27. Keeley EC, Boura JA, Grines CL. Comparison of primary and facilitated percutaneous coronary interventions for ST-elevation myocardial infarction: quantitative review of randomised trials. *Lancet* 2006;367:579-88. [Erratum, *Lancet* 2006;367:1656.]
28. Fox KA. An international perspective on acute coronary syndrome care: insights from the Global Registry of Acute Coronary Events. *Am Heart J* 2004;148:Suppl: S40-S45.
29. Canto JG, Every NR, Magid DJ, et al. The volume of primary angioplasty procedures and survival after acute myocardial infarction. *N Engl J Med* 2000;342:1573-80.
30. Labinaz M, Swabey T, Watson R, et al. Delivery of primary percutaneous coronary intervention for the management of acute ST segment elevation myocardial infarction: summary of the Cardiac Care Network of Ontario Consensus Report. *Can J Cardiol* 2006;22:243-50.
31. Nallamothu BK, Bates ER, Wang Y, Bradley EH, Krumholz HM. Driving times and distances to hospitals with percutaneous coronary intervention in the United States: implications for prehospital triage of patients with ST-elevation myocardial infarction. *Circulation* 2006;113:1189-95.

Copyright © 2008 Massachusetts Medical Society

FULL TEXT OF ALL JOURNAL ARTICLES ON THE WORLD WIDE WEB

Access to the complete text of the *Journal* on the Internet is free to all subscribers. To use this Web site, subscribers should go to the *Journal's* home page (www.nejm.org) and register by entering their names and subscriber numbers as they appear on their mailing labels. After this one-time registration, subscribers can use their passwords to log on for electronic access to the entire *Journal* from any computer that is connected to the Internet. Features include a library of all issues since January 1993 and abstracts since January 1975, a full-text search capacity, and a personal archive for saving articles and search results of interest. All articles can be printed in a format that is virtually identical to that of the typeset pages. Beginning 6 months after publication, the full text of all Original Articles and Special Articles is available free to nonsubscribers who have completed a brief registration.