Association Between Prehospital Time Intervals and ST-Elevation Myocardial Infarction System Performance

Jonathan R. Studnek, PhD; Lee Garvey, MD; Tom Blackwell, MD; Steven Vandeveerter; Steven R. Ward

Background—Among individuals experiencing an ST segment–elevation myocardial infarction, current guidelines recommend that the interval from first medical contact to percutaneous coronary intervention be ≤90 minutes. The objective of this study was to determine whether prehospital time intervals were associated with ST-elevation myocardial infarction system performance, defined as first medical contact to percutaneous coronary intervention.

Methods and Results—Study patients presented with an acute ST-elevation myocardial infarction diagnosed by prehospital ECG between May 2007 and March 2009. Prehospital time intervals were as follows: 9–11 call receipt to ambulance on scene ≤10 minutes, ambulance on scene to 12-lead ECG acquisition ≤8 minutes, on-scene time ≤15 minutes, prehospital ECG acquisition to ST-elevation myocardial infarction team notification ≤10 minutes, and scene departure to patient on cardiac catheterization laboratory table ≤30 minutes. Time intervals were derived and analyzed with descriptive statistics and logistic regression. There were 181 prehospital patients who received percutaneous coronary intervention, with 165 (91.1%) having complete data. Logistic regression indicated that table time, response time, and on-scene time were the benchmark time intervals with the greatest influence on the probability of achieving percutaneous coronary intervention in ≤90 minutes. Individuals with a time from scene departure to arrival on cardiac catheterization laboratory table of ≤30 minutes were 11.1 times (3.4 to 36.0) more likely to achieve percutaneous coronary intervention in ≤90 minutes than those with extended table times.

Conclusions—In this patient population, prehospital timing benchmarks were associated with system performance. Although meeting all 5 benchmarks may be an ideal goal, this model may be more useful for identifying areas for system improvement that will have the greatest clinical impact. (Circulation. 2010;122:1464-1469.)

Key Words: emergency medical services ▶ epidemiology ▶ myocardial infarction ▶ reperfusion

Current guidelines from the American College of Cardiology and American Heart Association recommend that the interval from first medical contact to percutaneous coronary intervention (PCI) be ≤90 minutes among individuals experiencing an ST-elevation myocardial infarction (STEMI).1,2 Local, state, and national programs have aimed to reduce time to PCI by integrating the prehospital and in-hospital care of STEMI patients.3–6 The early acquisition of prehospital 12-lead ECGs and subsequent hospital notification in patients with symptoms of an acute coronary syndrome is a Class I recommendation and has been shown to reduce time to PCI.7–13 However, there is little additional guidance on how emergency medical services (EMS) should optimize their time before hospital arrival.

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The aims of this study were to describe prehospital system time intervals from first medical contact to reperfusion by PCI among STEMI patients, to assess associations between time intervals and achieving PCI in ≤90 minutes, to derive theoretical benchmarks for system time intervals, and to estimate the probability of achieving PCI in ≤90 minutes based on proposed timing benchmarks.

Methods

Design and Setting

This was a retrospective analysis of prehospital patients presenting with an acute STEMI as diagnosed by prehospital ECG in Mecklenburg County, North Carolina. Since May 2007, the Mecklenburg EMS Agency (Medic) has maintained a registry of all prehospital STEMI activations within the county. Outcomes data for this registry were provided through a cooperative agreement with the 3 hospitals that perform PCI in the county. Each STEMI-receiving hospital is an accredited chest pain center with PCI by the Society of Chest Pain Centers14 and participates in the North Carolina statewide system of STEMI care. Reperfusion of Acute Myocardial Infarctions in Carolina Emergency Departments.15 This study was approved by the Carolinas Health-
care System and the Presbyterian Healthcare System Institutional Review boards. Medic is a public-utility EMS agency managed by the 2 local healthcare systems and Mecklenburg County. The agency serves a population of ~867 000 individuals in the city of Charlotte, NC, and the surrounding county. Over the study period, the average yearly call volume was 90 000, resulting in ~69 000 yearly patient transports. The system design is a single-tier, all advanced life support service. First responders are all basic life support providers possessing automatic external defibrillator capability. Prehospital triage, treatment, and transport protocols are uniform within both the county and city limits. Relevant devices at Medic and the PCI centers were referenced to an atomic clock.

Study Population
Patients transported by Medic to 1 of the 3 PCI centers in Mecklenburg County were eligible for enrollment. Patients must have been ≥18 years of age, met the current protocol guidelines for prehospital cardiac catheterization laboratory (CCL) activation, and had a PCI performed between May 2007 and March 2009. Beginning in May 2007, Medic and the 3 PCI-capable hospitals instituted a “code STEMI” protocol allowing the prehospital diagnosis of STEMI, CCL activation, and bypass of hospitals not PCI capable. To be considered a code STEMI, patients must have signs and symptoms consistent with cardiac ischemia, computer interpretation of the prehospital 12-lead ECG must indicate acute MI, and paramedic overread must confirm this interpretation as ≥1-mm ST-segment elevation in ≥2 contiguous limb leads or ≥2 mm in ≥2 contiguous precordial leads. Paramedics communicated their findings and ECG information via radio to emergency physicians at the PCI centers. ECG images were not transmitted. Emergency physicians activated the PCI center and CCL and notified the interventional cardiologists of incoming patients via a paging system. The CCLs were staffed Monday through Friday from 7 AM to 6 PM, and on-call staff was required to be available within 30 minutes of notification at other times. During the course of the study period, ~16% of patients classified by EMS as having a STEMI were determined to be false-positive activations because paramedics incorrectly applied the above algorithm.

Variable Description
The outcome variable in this analysis was STEMI system performance, defined as first medical contact to reperfusion. First medical contact was defined as the time of 9-1-1 call receipt. Reperfusion time was defined as first device deployment. System performance was analyzed as a dichotomous variable and defined as acceptable in patients with first medical contact to first device deployment ≤90 minutes. The system time intervals analyzed were 9-1-1 call receipt to ambulance on scene (response time), ambulance on scene to 12-lead ECG acquisition (ECG time), ambulance on scene to ambulance departure (on-scene time), prehospital ECG acquisition to STEMI team notification (notification time), and scene departure to patient on CCL table (table time). All variables were initially collected as continuous and reported in minutes and seconds. Two variables related to patient demographics were also available for analysis. These variables were age, gender, and race.

Data Analysis
System time intervals were initially analyzed with descriptive statistics such as means, medians, and SDs. To assess associations between time intervals and the outcome, t tests and χ² tests were used when appropriate. To derive theoretical timing benchmarks, independent variables were assessed for linearity against the outcome variable (PCI in ≤90 or >90 minutes) using lowess plots and individually analyzed with logistic regression. Lowess plots indicated that a curvilinear relationship existed between the system time intervals and the outcome. To set benchmark interval times that were easy to understand and implement, all variables were dichotomized and presented as whole minutes. Time intervals were created on the basis of analysis of measures of central tendency (means, medians, and SDs), results of lowess plots, and expert opinion on realistic time targets. Univariate logistic regression was then performed to identify the measure of effect of each benchmark time on the outcome.

To estimate the probability of achieving PCI in ≤90 minutes in the presence of prehospital system time intervals, benchmark times were defined as response time ≤11 minutes, ECG time ≤8 minutes, on-scene time ≤15 minutes, notification time ≤10 minutes, and table time ≤30 minutes. To further demonstrate the relationships between the derived benchmark times and the outcome variable, multivariable logistic regression analysis was completed. With the results from the univariate models as a starting point, a forward stepwise model building process was undertaken. Model building began with the variable most significantly associated with the outcome in univariate analysis as the initial independent variable in the model. At each step, all remaining variables were assessed, and the variable with the lowest Wald P value was added to the model. This process was repeated until variables failed to reach statistical significance at the 0.05 level. To adjust for important patient characteristics, age, gender, and race were forced into the final multivariable model.

Confounding and effect measure modification were assessed with criteria set forth by Mickey et al. Confounding variables included age, gender, and race and were reported only if the adjusted odds ratios (ORs) for any main effect variable changed by 10%. On completion of the main effects model, plausible interaction terms were created and effect modification was assessed. Only those interaction terms with a value of Wald P ≤0.01 were added to the model. Model fit and discrimination were assessed with the Hosmer-Lemeshow goodness-of-fit test and area under the receiver-operating characteristic curve. Results of this model are presented as β coefficients to facilitate the calculation of probabilities and as ORs to indicate the estimated measure of the effect that timing benchmarks have on the study outcome. All data in this analysis were abstracted from patient records and entered into Microsoft Excel (Redmond, Wash). All statistical analyses were conducted with Stata version 10 (College Station, Tex).

Results
There were 181 patients during the study period who had prehospital CCL activation and received PCI. Complete system time intervals were available for 165 patients (91.2%). The time interval missing most often was prehospital ECG acquisition to STEMI team notification (15 patients, 8.3%). There was no indication that these data were missing because of some nonrandom pattern. The most likely reason for these missing data was a failure to record the time of STEMI team notification.

Of 165 patients with complete data, 110 (66.7%) received PCI ≤90 minutes after 9-1-1 call receipt. The median time to PCI in the study population was 82.9 minutes, with 90% of patients receiving PCI within 118.0 minutes after 9-1-1 call receipt. Briefly, patients had an average age of 60.3 years, 121 (73.3%) were white, and 119 (72.1%) were male.

A descriptive analysis of each system time interval is displayed in Table 1. Among STEMI patients, the shortest average time interval was ECG time at 6.6 minutes. On average, nearly half of the benchmark of 90 minutes was used to transport a patient from the scene to placement on the CCL table (42.6 minutes). Table 1 also displays the average system time interval for patients receiving PCI in ≤90 minutes compared with those receiving PCI in >90 minutes. Analysis indicated that all time intervals were
significantly associated with PCI time, with time intervals being shorter among the individuals who received PCI in ≤90 minutes.

Table 2 presents frequencies of benchmark time intervals, unadjusted ORs, and 95% confidence intervals (CIs) for the occurrence of PCI in ≤90 minutes by each benchmark time interval. Results from these univariate analyses indicated that achieving each benchmark time interval, except notification time, was significantly associated with an increased frequency of having a PCI in ≤90 minutes.

On the basis of the univariate results presented above, a multivariable logistic regression model was constructed using the benchmark time intervals; it is also presented in Table 2. The ORs presented in this model were also adjusted for age, gender, and race. This model demonstrated good fit with the Hosmer-Lemeshow goodness-of-fit test and had good ability to discriminate between subjects who received PCI in ≤90 minutes and those who did not, with an area under the receiver-operating characteristic curve of 0.87.

Table 3. Multivariable Logistic Regression Model for the Occurrence of PCI in ≤90 Minutes

Table 2. Frequencies, Unadjusted ORs, and 95% CIs for the Occurrence of PCI in <90 Minutes by Each Benchmark Time Interval

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Mean, min (95th Percentile)</th>
<th>PCI in ≤90 min (95% CI) (n=110)</th>
<th>PCI in &gt;90 min (95% CI) (n=55)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response time, min</td>
<td>8.0 (7.5–8.7)</td>
<td>9.3 (8.3–10.3)</td>
<td></td>
</tr>
<tr>
<td>ECG time, min</td>
<td>6.6 (5.1–6.5)</td>
<td>8.8 (6.9–10.7)</td>
<td></td>
</tr>
<tr>
<td>Scene time, min</td>
<td>14.8 (14.5–15.4)</td>
<td>17.4 (16.1–18.8)</td>
<td></td>
</tr>
<tr>
<td>Notification time, min</td>
<td>12.8 (11.0–13.9)</td>
<td>16.6 (13.3–15.9)</td>
<td></td>
</tr>
<tr>
<td>Table time, min</td>
<td>42.6 (39.3–45.9)</td>
<td>58.3 (51.3–65.4)</td>
<td></td>
</tr>
</tbody>
</table>

PCI indicates percutaneous coronary intervention; ECG; electrocardiogram.

Discussion

The need for establishing and implementing STEMI care systems has been well documented.18–21 To provide the best possible care to STEMI patients, process improvements must occur in both the prehospital and in-hospital settings.22 The American College of Cardiology/American Heart Association guidelines recommend that the interval from first medical contact to PCI be ≤90 minutes.23,24 However, there are no current recommendations on the time intervals that make up the prehospital portion of that 90-minute benchmark.

Describing prehospital system time intervals and deriving theoretical benchmarks for these intervals is one method that may assist in the evaluation of process improvement for STEMI care. This study identified prehospital benchmark time intervals in a STEMI care system and estimated their association with achieving PCI in ≤90 minutes. In addition, a statistical model was created to estimate the probability of receiving PCI in ≤90 minutes. Time to CCL table, scene time, and response time were the intervals most significantly associated with outcome. Yet, these variables have not been adequately studied as components of a STEMI care system. The utility of prehospital 12-lead ECG acquisitions and CCL notification has been associated with improved overall system performance and was included in the multivariable model presented.25–28 However, until this time, the complex interplay between these variables has not been analyzed.

The ability to rapidly transport patients off scene and arrive on the CCL table in ≤30 minutes was the variable most strongly associated with achieving PCI in ≤90 minutes. On average, approximately half of the guideline-recommended 90 minutes was consumed by transporting the patient to the hospital and specifically to the CCL table. Although transport times may vary greatly by region, it has been demonstrated that >40% of the US population lives in an area where a PCI-capable hospital is the closest destination facility.29 A 30-minute benchmark may not be feasible in the rural portions of the country but should be considered in areas with PCI-capable hospitals. It has also been shown that delay to the CCL table can be reduced if prehospital STEMI triage protocols incorporate
bypassing non-PCI facilities and emergency departments within PCI facilities.24–27

Prehospital scene times of ≤15 minutes were associated with a higher probability of achieving PCI in ≤90 minutes in the present analysis. Early recognition of the signs and symptoms associated with a STEMI is critical for both prehospital and in-hospital providers to reduce the time to reperfusion. Current research on prehospital scene times has focused primarily on the treatment and transport of trauma patients.28–30 Further research on expediting scene times while allowing for appropriate patient assessment should be conducted among STEMI patients.

Prolonged response times resulted in a decreased probability of achieving rapid PCI. Although it may seem intuitive that short response times would translate to improved outcomes, this is not always the case. Several studies have evaluated the effect of response time on outcomes among prehospital patients.31,32 These studies demonstrated that after the first 4 minutes, patient outcome was not associated with further delays in prehospital response time. Although all prehospital patients may not require the same EMS response, it appears as though STEMI patients may benefit from early EMS arrival.

Although 12-lead ECG acquisition and hospital notification have previously been studied, there are no current guidelines for prehospital providers on the timeliness of such interventions. Results from this study indicated a significant association between achieving PCI in ≤90 minutes and obtaining a 12-lead ECG in ≤8 minutes. In the statistical model built from the derived timing benchmarks, notification time was not associated with an increased likelihood of early PCI. However, this term remained in the model because previous research has indicated the importance of bundling ECG acquisition and hospital notification together.6

It is important to recognize that not all of these individual components may be feasible for implementation in any 1 EMS system. Focusing on individual components with an overall design for implementation may prove beneficial for EMS systems attempting to improve STEMI care. Although a STEMI care system includes many more components than the benchmarks included in this study, these benchmarks may serve as plausible starting points for EMS systems process improvement in STEMI care.

Limitations
This study has several limitations resulting from the nature of the study design. Limitations included threats to generalizability and the potential for unrecognized confounding and nondifferential misclassification.

The benchmarks derived in this study were produced using data from within a single EMS agency that has integrated STEMI care with all local PCI-capable hospitals. The generalizability of these results to systems with multiple EMS agencies delivering patients to STEMI-receiving centers operating with various treatment algorithms remains to be seen. This study also used an uncommon definition for first medical contact, the time of 9-1-1 call receipt. This time was specifically chosen to include the entirety of EMS patient contact time. Other definitions of first medical contact are not as aggressive or comprehensive and focus on processes subsequent to paramedic arrival at the scene or at the patient’s side. Therefore, these results may not generalize to systems with varying definitions of first medical contact. Future research should incorporate data from multiple STEMI care systems to validate these findings.

The benchmark table time includes EMS transportation time from the scene to the PCI center, any time spent in the emergency department, and time required for transportation from the emergency department to the CCL. These times were grouped together as an expression of the integration of prehospital and in-hospital services, one of the key elements of successful chest pain evaluation centers.9 With prearrival notification of STEMI patients, the PCI centers in this study prepared the CCL and admitted patients directly to the CCL when possible. In some cases, the CCL was not prepared for patient admission by the time of EMS arrival at the hospital. Therefore, some patients were delivered to the emergency department for a short period of time. Not all hospitals admit EMS patients directly to the CCL from the field; however, the benchmark interval of 30 minutes should allow brief evaluation in the emergency department for those institutions, if that is the preferred method.

Unfortunately, the analytic data set used in this analysis did not include extensive patient demographics and prior medical history. Therefore, there may be some level of unrecognized confounding of the presented results. Further descriptions of patient characteristics may provide opportunities for greater insight into STEMI systems of care. In addition, the impact of first responders was not considered in this evaluation. The contribution of first responders to symptom assessment and patient preparation may influence several of the benchmark times evaluated. The proportion of cases in which first responders participated in this series was not recorded.

Finally, because of the nature of the study design, the potential for misclassification of exposure and outcome variables was present. All variables were initially continuous in nature but were transformed into dichotomous variables. The process of transforming and analyzing continuous data as dichotomous may lead to misclassification bias. However, it is likely that this bias is nondifferential, with misclassification of exposures not related to the outcome and vice versa. Therefore, any bias present in these results would likely be toward the null, indicating that the presented measures of effect may be smaller.

Conclusions
This study was able to describe prehospital system time intervals and to assess their relationship with STEMI system performance. Five theoretical benchmarks were derived from these time intervals that enabled the estimation of the probability of achieving PCI in ≤90 minutes. Although meeting all 5 benchmarks may be an ideal goal, this model may be more useful for identifying areas for system improvement that will have the greatest clinical impact.
Acknowledgments

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Disclosures

None.

References


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Currently, there is little guidance on how emergency medical services should optimize their time before hospital arrival when caring for ST-elevation myocardial infarction patients. This study analyzed the association between 5 prehospital system time intervals and achieving a goal time to percutaneous coronary intervention of ≤90 minutes. Our findings imply that developing prehospital time benchmarks for important patient care–related variables may further enhance quality improvement for ST-elevation myocardial infarction care systems. It is important to recognize that not all of the individual prehospital time components may be feasible for implementation in any 1 emergency medical service system. Focusing on individual components with an overall design for implementation may prove beneficial for emergency medical service systems attempting to improve ST-elevation myocardial infarction care. Although an ST-elevation myocardial infarction care system includes many more components than the benchmarks included in this study, these benchmarks may serve as plausible starting points for emergency medical service systems process improvement in ST-elevation myocardial infarction care.
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급성 심근경색증의 신속한 치료를 위해 치료 전 소요되는 시간간격들에 대한 분석이 필요하다

권준 교수 인하대학교 생명과학

Summary

배경

5T분류 삼성 급성 심근경색증 환자의 최적 치료시간에
서는 최초 의료진 접촉 후 90분 이내의 관심술에 중재시
술을 결정하는 것으로 알려져 있다. 본 연구의 목적
은 환자 분류, 환자에 도
적하기 전까지 소요되는 시간을 및 개의 시간간격들로
나누어 분석하고, 이러한 시간간격들이 최초 의료진 접
촉에서 관심술에 중재를 최적화로 정의하는 5T분류
삼성 급성 심근경색증 치료 시스템 성능에 어떠한 영향
을 미치는지 알아보기 위한 것이다.

방법 및 결과

2007년 3월부터 2009년 3월까지 병원 도착 이전에 실
행된 심전도에서 5T분류 삼성 급성 심근경색증으로 진
단 받은 환자를 대상으로 하였다. 관심술을 최소시간들로
받은 총 183명의 환자 중에 외과적 관찰로 격리된 환자는
165명(91.1%)이었다. 병원 도착 전 시간간격들로는 평균
10분 이내로 소요되는 9T 신호시간, 10분 이내로 소요
되는 9T 신호시간, 10분 이내로 소요되는 9T 신호시간
의 시간(response time), 8분 이내의 염증은 도착에서
심전도 신호전에 시간(RCG time), 15분 이내의 염증은
도착 후 환자와의 시간(on scene time), 10분 이내
의 임원 전 신호전에 환자 후 급성 심근경색증이 신헌하
지의 시간(notification time), 그리고 30분 이내의 현장
종합 후 관심술적 중재를 최적화 가능성을 시간(time)
등이 있다. 수집된 시장간격들은 로지스틱 회귀분석으
로 분석한 결과 table time, response time, 그리고 on
scene time이 환자가 90분 이내에 관심술에 중재시술
을 받는 것에 가장 중요하게 영향을 미치는 시간간격
들로 나타났다. Table time이 30분 이내인 환자들은 그
이상 소요된 환자들보다 11.1배 더 많이 90분 이내에 관
심술적 중재시술을 받은 것으로 나타났다.

결론

이번 연구를 통해, 급성 심근경색증 환자에서 재판류
치료 전 소요되는 시장간격들이 치료 시스템에 중요한
영향을 미치는 것으로 나타났다. 물론 5개 시장간격들에
대한 기준간격을 모두 만족시키는 것이 이상적이지만,
분석을 통해 가장 영향력 있는 시장간격들로 접근하
는 것이 효과적일 수 있다.
급성 심근경색증 환자에서 지표의 성공 여부는 환자 발병 후 합병증을 최소화하기 위한 환상동맥 재협착 시각의 경과가 얼마나 신속하게 이루어지는가에 달려있다. 특히 60분 이상 급성 심근경색증 환자에서 경제사의 급착화에 따른 신속한 치료 감소를 목표로 점차 임상적 시각을 단단히 고려한 것이 현대 의료학에서 급성 심근경색증 환자에서 최초 의료진 접촉 후 환상동맥 재협착 치료까지 걸리는 시간을 90분 이내로 할 것을 권유하고 있다.

본 연구에서는 5분 간격 상승 급성 심근경색증 환자에서 최초 의료진 접촉 후 90분 이내에 환상동맥 재협착 치료 목표가 이루어지는 것과 관련하여 치료 전 소요되는 전체 시간을 5개의 시간단위로 분류하였다. 그리고 응급처치센터치환 시간은 환상동맥 내 순진 또는 스턴트가 심해지는 시간으로 정의하였다. 연구 결과, 5개 시간단위 중 10분 이내의 response time, 15분 이내의 on scene time, 그리고 30분 이내의 table time은 90분 이내의 환상동맥 재협착 치료 목표를 달성하는 데 있어 가장 큰 영향을 미치는 것으로 나타났는데, 그 중 response time에는 90분 이내의 table time을 염두에 두고 있는 것이 여러 연구에서도 확인된 결과이다. 본 연구에서는 3개의 시간단위의 목표 시간, 즉 10분, 15분, 30분을 설정하여 연구에 활용하였다.