Emergency Medical Services Out-of-Hospital Scene and Transport Times and Their Association With Mortality in Trauma Patients Presenting to an Urban Level I Trauma Center

C. Eric McCoy, MD, MPH; Michael Menchine, MD, MPH; Sehra Sampson, MD; Craig Anderson, PhD; Christopher Kahn, MD, MPH

Study objective: We determine the association between emergency medical services (EMS) out-of-hospital times and mortality in trauma patients presenting to an urban Level I trauma center.

Methods: We conducted a secondary analysis of a prospective cohort registry of trauma patients presenting to a Level I trauma center during a 14-year period (1996 to 2009). Inclusion criteria were patients sustaining traumatic injury who presented to an urban Level I trauma center. Exclusion criteria were extrication, missing or erroneous out-of-hospital times, and intervals exceeding 5 hours. The primary outcome was inhospital mortality. EMS out-of-hospital intervals (scene time and transport time) were evaluated with multivariate logistic regression.

Results: There were 19,167 trauma patients available for analysis, with 865 (4.5%) deaths; 16,170 (84%) injuries were blunt, with 596 (3.7%) deaths, and 2,997 (16%) were penetrating, with 269 (9%) deaths. Mean age and sex for blunt and penetrating trauma were 34.5 years (68% men) and 28.1 years (90% men), respectively. Of those with Injury Severity Score less than or equal to 15, 0.4% died, and 26.1% of those with a score greater than 15 died. We analyzed the relationship of scene time and transport time with mortality among patients with Injury Severity Score greater than 15, controlling for age, sex, Injury Severity Score, and Revised Trauma Score. On multivariate regression of patients with penetrating trauma, we observed that a scene time greater than 20 minutes was associated with higher odds of mortality than scene time less than 10 minutes (odds ratio [OR] 2.90; 95% confidence interval [CI] 1.09 to 7.74). Scene time of 10 to 19 minutes was not significantly associated with mortality (OR 1.19; 95% CI 0.66 to 2.16). Longer transport times were likewise not associated with increased odds of mortality in penetrating trauma cases; OR for transport time greater than or equal to 20 minutes was 0.40 (95% CI 0.14 to 1.19), and OR for transport time 10 to 19 minutes was 0.64 (95% CI 0.35 to 1.15). For patients with blunt trauma, we did not observe any association between scene or transport times and increased odds of mortality.

Conclusion: In this analysis of patients presenting to an urban Level I trauma center during a 14-year period, we observed increased odds of mortality among patients with penetrating trauma if scene time was greater than 20 minutes. We did not observe associations between increased odds of mortality and out-of-hospital times in blunt trauma victims. These findings should be validated in an external data set. [Ann Emerg Med. 2013;61:167-174.]

Please see page 168 for the Editor's Capsule Summary of this article.

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0196-0644/$-see front matter

http://dx.doi.org/10.1016/j.annemergmed.2012.08.026

INTRODUCTION

Debate continues over the "load and go" versus "stay and stabilize" approach to patient care in the out-of-hospital setting because there is a paucity of supportive data for either argument. The critical factor at the center of this debate is emergency medical services (EMS) out-of-hospital time (response time, scene time, and transport time) and its association with patient outcome, namely, morbidity and mortality. Although the optimal out-of-hospital intervals for EMS personnel have not been defined for major trauma, it has been recommended that the least amount of time required in the out-of-hospital setting be spent, allowing only for performance of essential procedures.[1-3]

Multiple elements compose an EMS system, each with inherent qualities that may be reviewed, analyzed, and improved on if deficient.[4] One component currently in debate and commonly scrutinized by administrators, elected officials, and the public, and one potentially affecting patient care, is the association between out-of-hospital time and mortality in patients presenting to a trauma center.

Editor's Capsule Summary

What is already known on this topic

Uncertainty remains about the relationship between emergency medical services (EMS) on-scene intervals and trauma patient outcomes.

What question this study addressed

What were the associations between EMS on-scene and transport time intervals and inhospital mortality among 19,167 trauma center patients?

What this study adds to our knowledge

When on-scene intervals exceeded 20 minutes, there were increased odds of mortality for patients with penetrating trauma but not for those with blunt trauma. The transport duration did not matter. Potential confounding factors that may have extended on-scene times were not assessed.

How this is relevant to clinical practice

EMS on-scene intervals should be monitored for cases of penetrating trauma. Factors that cause delays and their relationships to outcomes should be determined.

In the United States, trauma is the fifth leading cause of death, claiming more than 121,500 lives annually.[5,6] Unintentional injury is the leading cause of death for people between the ages of 1 and 44 years and is responsible for more years of life lost than stroke, cancer, and cardiovascular disease combined.[6,7] Given these facts and statistics, identifying factors associated with trauma-related mortality is a critical step in the process of medical systems evaluation and improvement.

Although many factors may contribute to mortality in the acutely injured trauma patient, identifying those factors that are associated with mortality that have the potential to be systematically improved on within the EMS structure could have tremendous implications for patient care and outcome. This study is designed to identify the association between out-of-hospital time and mortality in trauma patients presenting to an urban Level I trauma center. This information may provide factors that can be improved on at the systems level to affect change (decrease mortality) at the population level.

MATERIALS AND METHODS

Study Design

We conducted a secondary analysis of a prospective cohort registry of trauma patients presenting to an urban Level I trauma center during a 14-year period (January 1996 to December 2009).

Study Setting and Selection of Participants

This study was conducted in Orange County, CA, which is composed of 34 cities within approximately 800 square miles and is bordered by Los Angeles County to the northwest, San Bernardino County to the northeast, Riverside County to the east, San Diego County to the southeast, and the Pacific Ocean to the west-southwest. This metropolitan county has an approximate population of 3,036,712 million and is composed of 8.35% of the state of California's resident population and more than 1% of the US resident population because fully 1 in 100 US residents resides in Orange County.[8]

Data were prospectively collected as part of the trauma registry at a university teaching hospital, which is the only Level I trauma center servicing the entire county, receiving more than half of the county's trauma patients; 2 Level II trauma centers also receive trauma patients. The trauma registry at the study institution is an American College of Surgeons Level I Trauma Center patient registry and collects data on all trauma activations with mechanism of injury consistent with trauma, all trauma activations with *International Classification of Diseases, Ninth Revision* (*ICD-9*) codes between 800 and 959.9, and all trauma patients without trauma activation who are admitted to the trauma service and have an *ICD-9* code between 800 and 959.9. The primary sample for this study was collected from consecutive data obtained from January 1, 1996, through December 31, 2009. The study protocol was reviewed and approved by the university's institutional review board.

The primary study cohort consisted of consecutive patients sustaining blunt or penetrating traumatic injury and presenting to the Level I trauma center during a 14-year period (1996 to 2009). Exclusion criteria were extrication, missing or erroneous out-of-hospital times, intervals exceeding 5 hours, missing data, and nonblunt or penetrating injury (ie, burns, drowning, hangings). Although the trauma registry at the study institution records patient data on interfacility transfers and times when patients left the sending hospital, these times were excluded from our analysis.

Orange County's EMS system is mostly urban, consisting of 23 paramedic receiving centers, 22 private ambulance companies, 1 air ambulance service, and 13 fire agencies, with total transports of more than 50,000 per year. The system is fire based, with a combination of fire-based and private transportation. Units are dispatched in a tiered fashion through a structured protocol system; all first-in fire department apparatus are staffed with at least 1 paramedic.

Methods of Measurement

EMS intervals were calculated from trauma registry data at the university teaching hospital. Intervals were based on standard EMS definitions and included scene time (time of arrival of first EMS responding vehicle on scene to time leaving the scene) and transport time (time leaving the scene to vehicle arrival at the receiving hospital).[9] EMS call activation times are not recorded in the trauma registry database and therefore response times were not calculated. Thus, "total time" in this study reflects the total scene and transport times and not the "total out-of-hospital time" that describes response, scene, and transport times. We categorized out-of-hospital times into 10-minute intervals a priori with the intent of choosing an interval that is operationally practical, clinically feasible, and politically acceptable.

The additional variables considered in the analysis were those known or thought to be associated with mortality in trauma patients and included age, sex, blunt injury versus penetrating injury, Revised Trauma Score, and Injury Severity Score. The primary outcome was inhospital mortality.

Primary Data Analysis

Descriptive statistics were used to describe the characteristics of the patient population studied during the 14-year period. The data were downloaded from the trauma database, converted to Stata file format, and analyzed with Stata (version 12.0; StataCorp, College Station, TX). We used logistic regression to assess the association of scene and transport time with mortality, controlling for variables known to influence mortality. A priori, we determined that the intervals 0 to 9 minutes, 10 to 19 minutes, and greater than or equal to 20 minutes would be operationally practical, clinically feasible, and politically acceptable.

RESULTS

Characteristics of Study Subjects

Continuous data were obtained for all patients presenting to the study facility during a 14-year period (January 1996 to December 2009). Twenty-six thousand five hundred sixty-four cases were eligible for review. Excluded cases consisted of 1,515 for extrication, 4,805 missing 1 or more time data items (scene or transport times), 334 with scene or transport time less then zero minutes or greater than 300 minutes, 2 missing final outcome data (ie, mortality report), 418 not listed as "blunt" or "penetrating" (ie, burns), 228 missing Injury Severity Score, 31 missing age, 2 missing sex, and 62 missing Revised Trauma Score. After all exclusions, there were 19,167 cases available for analysis (Figure 1).

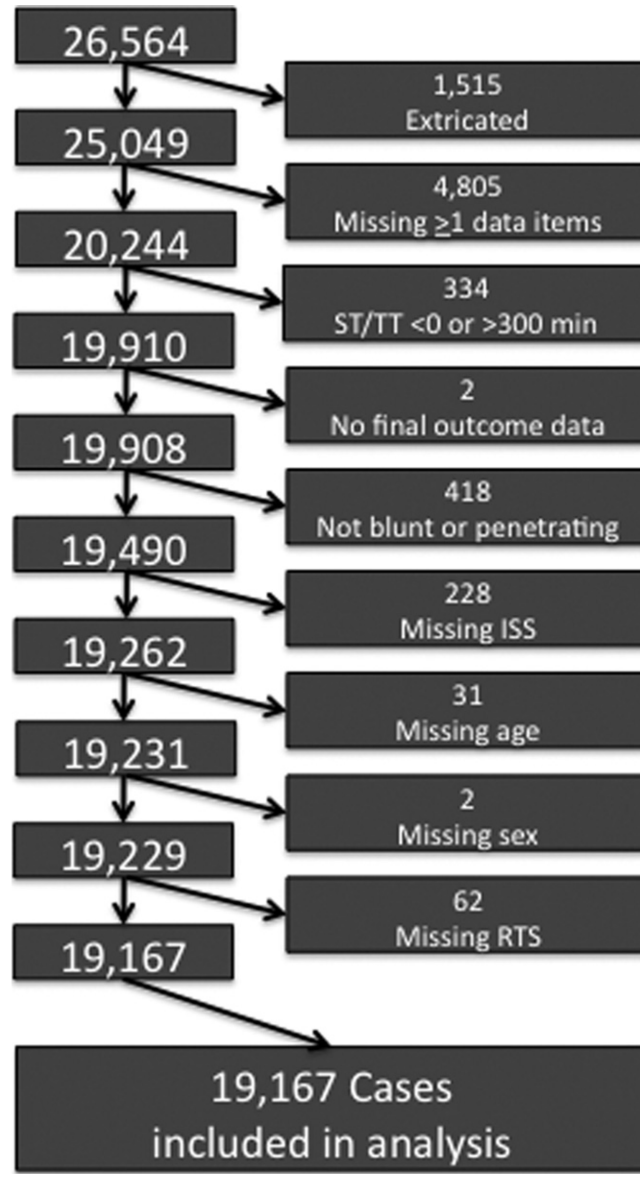

Figure 1. Flow diagram showing of 26,564 cases yielding 19,167 available for analysis. ST/TT, Scene or transport time; ISS, Injury Severity Score; RTS, Revised Trauma Score.

Main Results

Of the 19,167 trauma cases available for analysis, 865 (4.5%) resulted in mortality. Of all injuries, 16,170 (84%) injuries were blunt, with 596 (3.7%) deaths, and 2,997 (16%) were penetrating, with 269 (9%) deaths. Mean age and sex for blunt and penetrating trauma were 34.5 years (68% men) and 28.1 years (90% men), respectively. Of those with Injury Severity Score less than or equal to 15, 0.4% died, and 26.1% of those with a score greater than 15 died; 15.5% of patients with blunt trauma had an Injury Severity Score greater than 15 compared with 19.4% of patients with penetrating trauma with a score greater than 15. Among patients with blunt trauma, 0.2% of those with Injury Severity Scores of 0 to 15 died and 22.6% of those with a score of 16 to 75 died. Among patients with penetrating trauma, 1.3% of those with Injury Severity Score 0 to 15 died and 40.9% of those with a score of 16 to 75 died. Mean Revised Trauma Scores for blunt and penetrating traumas were 7.5 and 7.1, respectively (Table 1).

Blunt trauma accounted for approximately 85% of all cases. The median scene time for blunt trauma was 13 minutes, with an interquartile range (IQR) of 10 to 18 minutes. Median transport time for blunt trauma was 12 minutes (IQR 8 to 17 minutes), and the median total time for blunt trauma was 26 minutes (IQR 21 to 33 minutes).

Penetrating trauma accounted for approximately 15% of all cases. The median scene time for penetrating trauma was 11

Table 1. Characteristics of patient population studied during a 14-year period.

Patient Characteristics	Blunt (n=16,170)	Penetrating (n=2,997)
Mean age, y	34.5	28.1
Male, %	68.2%	90.5%
ISS, %		
0–15	84.5	80.7
16–75	15.5	19.4
Mean RTS (SD)	7.5 (1.13)	7.1 (1.90)
Death (ISS 0–15), %	0.2	1.3
Death (ISS 16–75), %	22.6	40.9

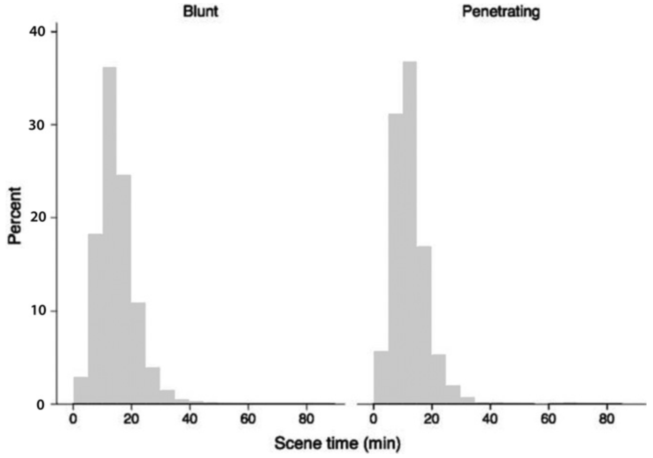

Figure 2. Histogram of scene time for blunt and penetrating injuries.

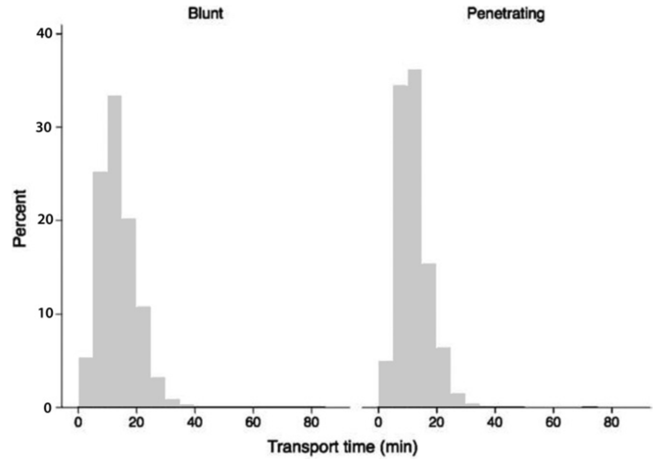

Figure 3. Histogram of transport time for blunt and penetrating injuries.

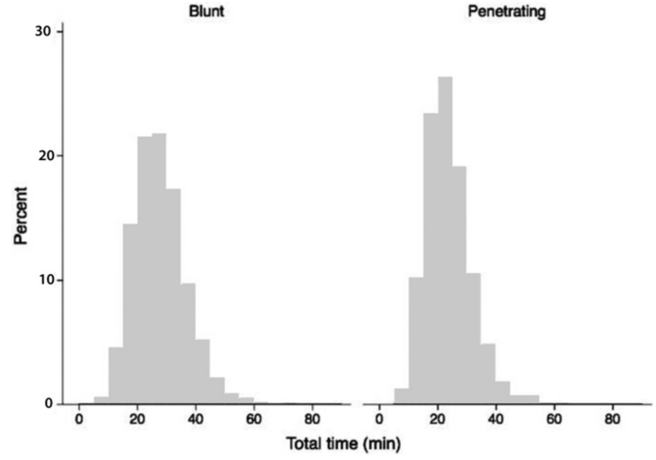

Figure 4. Histogram of total time for blunt and penetrating injuries.

minutes (IQR 8 to 15 minutes). Median transport time for penetrating trauma was 10 minutes (IQR 8 to 14 minutes), and the median total time for penetrating trauma was 22 minutes (IQR 17 to 28 minutes).

For both blunt and penetrating injuries (all cases), the median scene time was 13 minutes (IQR 10 to 17 minutes), median transport time was 12 minutes (IQR 8 to 16 minutes), and the median total time was 26 minutes (IQR 20 to 32 minutes) (Figures 2 to 4).

On multivariate regression of patients with penetrating trauma, we observed that a scene time greater than or equal to 20 minutes was associated with higher odds of mortality than scene time less than 10 minutes, with an odds ratio (OR) of 2.90 (95% confidence interval [CI] 1.09 to 7.74). Scene time of 10 to 19 minutes was not significantly associated with mortality (OR 1.19; 95% CI 0.66 to 2.16). Longer transport times were likewise not associated with increased odds of mortality in penetrating trauma cases; OR for transport time greater than or equal to 20 minutes was 0.40 (95% CI 0.14 to 1.19), and OR for transport time 10 to 19 minutes was 0.64 (95% CI 0.35 to 1.15) (Table 2; Figure 5).

On multivariate regression of patients with blunt trauma, we did not observe any association between scene or transport times and increased odds of mortality. Scene time ORs were 0.88 (95% CI 0.57 to 1.37) for greater than or equal to 20 minutes and 0.88 (95% CI 0.65 to 1.18) for 10 to 19 minutes. Transport time ORs were 1.16 (95% CI 0.76 to 1.78) for greater than or equal to 20 minutes and 1.04 (95% CI 0.78 to 1.40) for 10 to 19 minutes (Table 2; Figure 5).

All of the covariates that we postulated had an effect on mortality showed statistically significant associations with mortality in our sample and were controlled for in the multivariate regression analysis. Men had a 1.31 odds of mortality compared with women (95% CI 1.12 to 1.54). The odds of mortality increased in successive age groups with age greater than 60 years (OR 3.56; 95% CI 2.87 to 4.42), 40 to 59 years (OR 1.46; 95% CI 1.17 to 1.82), and 20 to 39 years (OR 1.27; 95% CI 1.04 to 1.55). The odds of mortality with patients having an Injury Severity Score greater than 15 was 91.06 compared with those with less than 15 (95% CI 70.07 to 118.34) (Figure 6). The mortality associated with Injury Severity Score in our study (specifically that mortality is greater with Injury Severity Score greater than 15 compared with a

Table 2. Multivariate logistic regression evaluating association between out-of-hospital time and mortality.

Covariates	OR (95% CI)	
Scene time, min	Blunt	Penetrating
0–9	Reference	Reference
≥10–19	0.88 (0.65–1.18)	1.19 (0.66–2.16)
≥20	0.88 (0.57–1.37)	2.90 (1.09–7.74)
Transport time, min	Blunt	Penetrating
0–9	Reference	Reference
≥10–19	1.04 (0.78–1.40)	0.64 (0.35–1.15)
≥20	1.16 (0.76–1.78)	0.40 (0.14–1.19)
Men	1.31 (1.12–1.54)	
Age, y		
0–19	Reference	
20–39	1.27 (1.04–1.55)	
40–59	1.46 (1.17–1.82)	
>60	3.56 (2.87–4.42)	
ISS 0–15	Reference	
ISS 16–75	91.06 (70.07–118.34)	
RTS >7	Reference	
RTS ≤7	78.20 (63.00–97.08)	

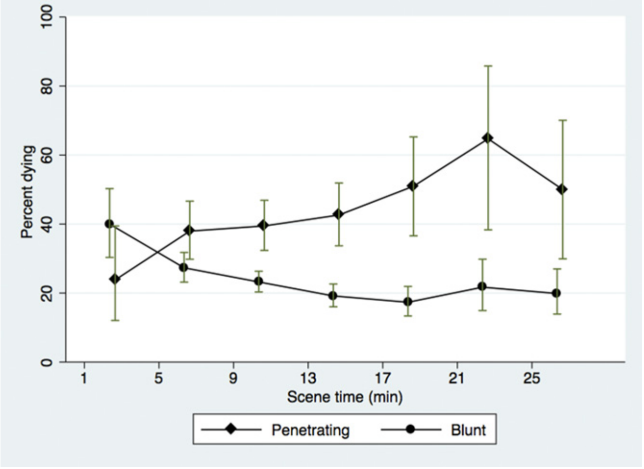

Figure 5. Graph of percentage of patients dying as a function of scene time for blunt and penetrating trauma.

score <15) is consistent with that of current national benchmarks, as well as the prevalent historic association of injury severity and mortality in the trauma literature.[10,11] The odds of mortality with patients having a Revised Trauma Score less than 7 was 78.20 compared with those with a score greater than 7 (95% CI 63.00 to 97.08) (Table 2).

LIMITATIONS

Previous studies have shown an association between increased out-of-hospital times and decreased mortality, as well as an association between increasing Injury Severity Score and decreased scene and transport times.[3,12-17] The association between increased out-of-hospital times and decreased mortality may be in part explained by EMS providers moving with haste for patients thought to have serious injury and taking more time for patients recognized as having minor injuries. The association between increasing Injury Severity Score and decreased scene and transport times may be in part explained by EMS providers recognizing that a patient is critically ill and moving with a greater sense of urgency. Conversely, one can imagine longer out-of-hospital times for patients with greater injury severity and shorter out-of-hospital times for those with lower injury severity. The discrepancy in previous studies with regard to patient injury severity level and out-of-hospital times may be explained by the paramedics' assessment of a "sick" patient and its relation to the rapidity with which they provide care and transport. It is this variable of the paramedics' assessment of the injury severity that likely has a substantial influence on the timeliness of patient care and transport. This variable is practically impossible to quantify and may be a source of omitted variable bias in our study. To date, we have found no studies that have been able to measure this variable.

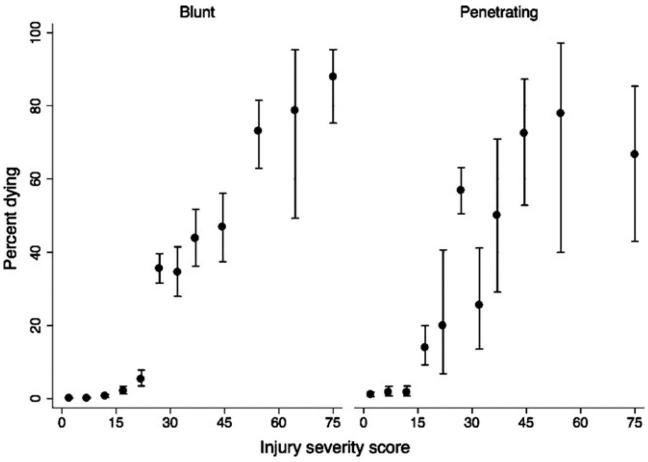

Figure 6. Scatterplot diagram of percentage of patients dying as a function of Injury Severity Score for blunt and penetrating trauma.

Exclusion of patients from the analysis, as well as those with missing data, could have introduced bias to the results. Exclusion of patients extricated in the field was chosen to minimize the effect that prolonged out-of-hospital times in this group would have on skewing the mean out-of-hospital times of the sample being studied. Given that these prolonged out-of-hospital times or reasons for extrication could have an effect on mortality, we also analyzed our data with this subgroup included (data not shown) and found that it did not change our final results. We excluded patients with missing or erroneous out-of-hospital times because we wanted to evaluate a complete data set. We excluded out-of-hospital times exceeding 5 hours because we believed that EMS personnel could travel the entire distance of the county well within 3 to 4 hours, even with maximum traffic. The extra hour was added as a cushion. We chose this timeframe to capture all of the true out-of-hospital times and outliers while excluding out-of-hospital times that were clearly erroneous (eg, a 23-hour transport time). We also did not measure longer-term (eg, >30-day) survival.

Our study has the limitation of any EMS study attempting to evaluate large populations in that the heterogeneity of the population and treatment regimens may make it difficult to draw useful conclusions and it may be that the external validity of any particular EMS study has applicability only within similarly defined geographic populations with similar EMS resources. Each system's response intervals and times may need to be individually tailored to meet the needs of the community within the financial and political constraints inherent to that region. The trauma registry at the study institution is an American College of Surgeons Level I Trauma Center patient registry and collects data on scene and transport times. In our study, we did not know the response times because they are not recorded in the trauma registry, and therefore we were unable to evaluate response time or total time from call to hospital and its association with mortality; however, the lack of this information did not preclude our ability to evaluate the effect of scene and transport times on mortality.

Response time could potentially be a confounder if associated with scene or transport time and also independently associated with mortality. Characteristics of response times that could, if significant enough, introduce bias into the analysis would be response times that are nonuniform, with wide variation. Owing to this, we contacted the county EMS agency to obtain general descriptive information on county response times. For basic life support response, the median 90th percentile for system standard response times is 6 minutes 15 seconds (range 4 to 8 minutes). For advanced life support response, the median 90th percentile for system standard response times is 6 minutes 5 seconds (range 4 minutes 28 seconds to 7 minutes 45 seconds). Although this information is not as comprehensive as having the response times on the 19,167 cases evaluated in our study, we believed it would provide better characterization of the EMS system and allow us to evaluate whether the response times had characteristics that would lead us to believe this variable as a significant confounder. We believe this general information, although limited, does not suggest response time characteristics that would significantly limit our ability to evaluate the association between scene or transport time and mortality.

DISCUSSION

In this secondary analysis of a prospective cohort registry of trauma patients presenting to a Level I trauma center during a 14-year period, we observed an association between longer out-of-hospital times, in particular scene times, and mortality in patients with penetrating trauma and an Injury Severity Score greater than 15. This study is the first to our knowledge to analyze data spanning more than a decade, including close to 20,000 patients, with specific aims to evaluate the association between out-of-hospital times and mortality in the urban setting.

Our results are consistent with those of previous studies supporting the argument that minimizing out-of-hospital times is considered beneficial for survival.[1-2,18,19] Two studies by Sampalis et al[20,21] found that increased out-of-hospital times were associated with increased mortality among seriously injured trauma patients. There are also previous studies not supporting the argument that minimizing out-of-hospital times decreases mortality.[12-14,22,23] A recent study by Newgard et al[24] found no association between EMS out-of-hospital intervals and mortality among injured patients presenting with physiologic abnormality. Among the limitations they observed was the lack of detailed hospital-based information, including measures of injury severity. In the field of out-of-hospital and trauma care, injury severity has been substantially linked, intensively studied, and widely accepted as a significant predictor of mortality and patient outcome. Our study includes Injury Severity Score as one of the variables measured and controlled for in our analysis, thereby allowing the evaluation of the association between out-of-hospital times and mortality irrespective of the degree of injury sustained by the patient.

There are many variables that may determine whether the true association between out-of-hospital times and mortality may be found. Newgard et al[24] reported that it is possible that other factors, such as unmeasured confounders or heterogeneity in the sample, precluded their ability to show such an association. Indeed the heterogeneity of the patient population and EMS system and structure lends to the difficulty of teasing out which exposures or risk factors may have an effect on patient outcome. The North American EMS system developed precipitously in the early 1970s, with significant federal grant support and guidance that defined essential system components; however, that guidance did not include a national organizational model for providing EMS services. That decision was left to local communities, and thus, in contrast with many other countries, local EMS systems in the United States vary considerably in how they are organized and financed.[25,26] Given the challenges of providing out-of-hospital care to heterogeneous populations through a heterogeneous delivery system, it is imperative that the medical community identify patients who may benefit from timely care before abandoning the notion that faster is better for all patients in the out-of-hospital setting.

There are subgroups of the population for which the medical community has found survival benefit from decreased out-of-hospital times. Studies by Gervin and Fischer[27] and Ivatury et al[28] found that rapid transport to a trauma center for patients sustaining penetrating thoracic injuries was associated with increased survival. The data in our study are complementary to these findings and support the notion that patients with penetrating injuries may be a subgroup who may benefit from decreased out-of-hospital times. In the literature examining nontraumatic out-of-hospital times, shorter EMS response intervals have been shown to consistently improve survival in nontraumatic cardiac arrest.[29,30] Indeed, this was once a subgroup of a heterogeneous population for which sufficient research was conducted to truly evaluate the association. Similarly, we believe those patients with traumatic injury are a heterogeneous population with subgroups amenable to increased survival with decreased out-of-hospital times. We believe it is prudent for the medical community to identify patients who may benefit from shorter out-of-hospital times.

Our findings support the golden hour concept and are consistent with the previously demonstrated hospital-based beneficial effect on survival.[31] Specifically, our study found that out-of-hospital scene times greater than or equal to 20 minutes were associated with increased odds of mortality in patients with penetrating traumatic injury. Although not stating causation and needing validation in an external data set, this information aids in the identification of patient groups who may benefit from decreasing out-of-hospital times. It is the identification of these patient groups that allows research to further study what specific risk factors or exposures are directly linked to mortality in efforts to make change at the EMS systems level. In particular, scene time is the out-of-hospital interval that EMS systems have the most power to control, given that this interval is composed of evaluation and management that is guided by local EMS policy, procedures, and protocols.

Our study did not find an association between transport times and mortality. Previous studies have demonstrated a survival benefit of treating seriously injured patients in trauma centers, suggesting that the time lost by bypassing nontrauma centers is recouped by the benefits of receiving care at trauma centers.[32-35] One study found that although transport times to trauma centers were higher for patients bypassing other local facilities, longer transport times were not associated with adverse outcomes.[36] Our findings support this conclusion and further substantiate the practice of transporting patients presumed to have serious injury to trauma centers, despite longer transport times.[24,36]

Even as the debate on "load and go" versus "stay and stabilize" continues, there remain public expectation, political pressure, and financial incentives to respond within out-of-hospital times defined by local EMS agencies. Providing EMS services and meeting these expectations takes a considerable amount of human and capital resources and can place EMS providers, patients, and the public at risk.[24,37-39] Accordingly, we believe it is imperative that the medical community continue to research those factors associated with mortality in trauma patients in an effort to use the available resources more effective and efficiently.

In this analysis of patients presenting to an urban Level I trauma center during a 14-year period, we observed increased odds of mortality among patients with penetrating trauma if scene time was greater than 20 minutes. We did not observe associations between increased odds of mortality and out-of-hospital times in victims of blunt trauma. These findings should be validated in an external data set.

Supervising editor: Theodore R. Delbridge, MD, MPH

Author affiliations: From the Department of Emergency Medicine, UC Irvine School of Medicine, Orange, CA.

Dr Menchine is currently affiliated with USC Keck School of Medicine, Los Angeles, CA.

Author contributions: CEM and CK were responsible for synthesizing research questions and overseeing the study. CEM and SS were responsible for researching current literature. CEM was responsible for developing a method for testing the research questions. CEM, CK, and MM were responsible for analyzing the data. CEM and MM were responsible for interpreting the data. CEM, MM, and SS were responsible for writing the article. CK and MM were responsible for editing the article. CA was responsible for statistical analysis. CEM takes responsibility for the paper as a whole.

Funding and support: By *Annals* policy, all authors are required to disclose any and all commercial, financial, and other relationships in any way related to the subject of this article as per ICMJE conflict of interest guidelines (see www.icmje.org). The authors have stated that no such relationships exist.

Publication dates: Received for publication July 28, 2011. Revisions received December 28, 2011, and May 26, 2012. Accepted for publication August 21, 2012. Available online November 9, 2012.

Presented as an abstract at the American College of Emergency Physicians 2010 *Scientific Assembly*, September 2010, Las Vegas, NV.

Address for correspondence: C. Eric McCoy, MD, MPH, E-mail ericmccoymd@gmail.com.

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