Lack of Association Between Prehospital Response Times and Patient Outcomes

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Abstract

Background. Limited data exist that examine the relationship between prehospital response times (RTs) and improved patient outcomes. **Objective.** We tested the hypothesis that patient outcomes do not differ substantially based on an explicitly chosen advanced life support (ALS) RT upper limit of 10 minutes 59 seconds (10:59 minutes). **Methods.** This case–control retrospective study was conducted in a metropolitan county with a population of 750,000 for the calendar year 2004. The emergency medical services (EMS) system is a single-tiered, ALS paramedic service that includes basic life support (BLS) first responders. The 90% fractile RT specification required by contractual agreement is 10:59 minutes or less for emergency, life-threatening (Priority 1) calls. Cases (study patients), defined as Priority 1 transports with RTs exceeding 10:59 minutes, were compared with controls, which comprised a random sample of Priority 1 calls with RTs of 10:59 minutes or less. Prehospital run reports and hospital outcomes were evaluated using explicit criteria by one observer for the primary outcome of in-hospital death and secondary outcomes of critical interventions performed in the field. We tested the hypothesis of equivalence using the 95% confidence intervals (CIs) for difference in proportions with $\alpha = 0.05$ and $\beta = 0.2$ to show $\Delta = \pm 5\%$. **Results.** Of the 3,270 emergency transports in 2004, we identified 373 study patients (RT >10:59 min) and a random sample of 373 controls (RT ≤10:59 min). Survival to hospital discharge was 80% (76% to 84%) for study patients vs. 82% (77% to 85%) for controls, yielding a 95% CI for the difference of –6 to +4%. ALS procedures were performed in 47.7% (95% CI: 43% to 53%) of study patients vs. 45.4% (40% to 51%) of controls (95% difference in proportions –10 to +5%). The most frequently performed procedures were administration of nitroglycerine and endotracheal intubation. **Conclusions.** Compared with patients who wait 10:59 minutes or less for ALS response, Priority 1 patients who wait longer than 10:59 minutes could experience between a 6% increase and a 4% decrease in mortality, and do not have an increase in critical procedures performed in the field. Our data are most consistent with the inference that neither the mortality nor the frequency of critical procedural interventions varies substantially based on this prespecified ALS RT.

Key words: emergency medical services; reaction time; outcome assessment (health care); ambulances; prehospital.

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Introduction

The provision of optimal emergency medical services (EMS) care in the prehospital environment requires integration of multiple operational and clinical components undertaken by many persons from different sites. Call taking and dispatching, scene response, on-scene patient care, triage and hospital destination decisions, continuing care during transport, and transfer to definitive care are all factors subject to online and off-line medical direction. Ambulance response time represents a high-profile target for potential process improvement. It remains self-evident that response time represents an important performance indicator, but taken alone, it does not completely predict outcome of disease severity or mortality. While prior research has evaluated the effectiveness of response time by various levels of care provision, there are limited studies that have examined the relationship between prehospital response times and patient outcome.[1–4] The purpose of this study was to examine the EMS response times, clinical care provided, and patient outcome for high-acuity 9-1-1 calls that occurred in an urban metropolitan jurisdiction to determine whether the current response time specifications set for the community are safe. As such, this report concerns the relationship between the duration of time defined by the period measured between a call received at the 9-1-1 dispatch center, arrival of an ambulance at the scene, and outcome of the patient. We further tested the hypothesis that patient outcomes do not differ substantially based on an explicitly chosen advanced life support (ALS) response time specification.

Methods

We studied a cohort of EMS-transported patients. The data for this report were obtained by structured, secondary review of explicitly recorded data from EMS transports conducted in an urban setting between

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January 1 and December 31, 2004. We compared two groups, defined by the response time ≤10 minutes 59 seconds (≤10:59 minutes) (controls) or >10:59 minutes (cases, or study patients). This study received approval from the Carolinas Medical Center Institutional Review Board.

System Description

As the sole EMS provider, Mecklenburg EMS Agency is a public-utility, single-tiered paramedic service that provides all emergency and nonemergency transports in the county. The service area encompasses 550 square miles, which includes a population of approximately 785,000 with an additional commuter influx of approximately 1.2 million during business hours. The EMS system has an annualized call volume of approximately 82,500, with 63,000 resulting in hospital transport. First-responder services, provided by the Charlotte Fire Department within the city limits of Charlotte and 14 volunteer agencies in the incorporated and unincorporated areas of the county, provide basic life support (BLS) services. All providers operate under a unified set of patient care protocols under the direction of the medical director. First responders have equipment and training to perform automated external defibrillation and bag–valve–mask ventilation. Paramedics provide ALS care in accordance with the American Heart Association standards and trauma care following standard basic trauma and prehospital trauma life support guidelines. All transports terminate at one of two hospital systems: Carolinas HealthCare System, which owns and operates four hospitals, or Presbyterian Health Care System, which owns and operates three hospitals. All facilities reside in Mecklenburg County. The combined emergency department annualized census of all seven emergency departments during the study period was approximately 340,000.

Time Interval Description

Calls received from the enhanced 9-1-1 system are processed using a computer-aided and priority-based dispatch system and categorized depending on the critical nature. Patients transported to the hospital are also categorized depending on clinical condition. The EMS agency is governed by the Mecklenburg Board of County Commissioners, which has mandated response time specifications for each category of call prioritization (Table 1). Thus, the primary study question focuses on the benchmark of 10:59 minutes for emergency, life-threatening calls. The response time clock to measure compliance begins when the address and chief complaint are verified or at 30 seconds after call receipt, whichever is less. The clock stops when the transport ambulance arrives on the scene.

TABLE 1. Description and Fractile Response Time Specifications for Each Level of Call Category

Description	Fractile Response Time Specification
Emergency, life-threatening	10:59 minutes or less for 90% of calls
Emergency, non–life-threatening	12:59 minutes or less for 90% of calls
Nonemergency	20:59 minutes or less for 80% of calls

Data Analysis

The study group consisted of Priority 1 hospital transports with response times exceeding 10:59 minutes. The control group consisted of a random sample of emergency, life-threatening or Priority 1 transports with response times of 10:59 minutes or less during the same time period. The random sample was produced by a computer macro (Microsoft Visual Basic 6.3 v. 1024, Microsoft Corp., Redmond, WA) programmed to select at random a number of controls equal to the number in the study group. Outcomes were assessed by a physician (JJW) using written prehospital run reports and hospital medical records. The primary outcome of interest was in-hospital death, with secondary outcomes consisting of medications administered and critical interventions performed in the field (Table 2). We tested the hypothesis that response time would predict outcome by plotting and comparing (with a Mann-Whitney U statistic) the median (and associated interquartile ranges) response times between patients who died in hospital after transport and patients who survived to discharge, and then by constructing a receiver-operating characteristic (ROC) curve using the response times. We compared frequencies and proportions using the 95% confidence intervals (CIs) for difference in proportions for each outcome; the sample size was estimated to show a 5% difference in mortality rate between study and control groups with $\alpha = 0.05$ and $\beta = 0.2$.

TABLE 2. Emergent Prehospital Interventions

Medication administration
Nitroglycerine
Aspirin
ACLS medications
Albuterol
Naloxone
Diazepam
Dextrose
Magnesium
Procedures performed
Intubation intent
Intubation attempt
Needle cricothyrotomy
Defibrillation/synchronized cardioversion
Cardiac pacing
Continuous positive airway pressure

ACLS = Advanced Cardiac Life Support.

Statistical analyses were performed using StatsDirect (v. 2.6.2, Cheshire, England).

RESULTS

In 2004 3,270 emergency hospital transports were categorized as Priority 1, including 373 study patients (11%, 95% CI: 10.4% to 12.5%) with response times that exceeded the 10:59-minute benchmark and 2,897 with transport times of 10:59 minutes or less. When the 373 study patients were compared with 373 controls (chosen at random from 2,897), no significant differences in gender or age of patients transported were revealed. Female subjects comprised 148 of the 373 study patients and 165 of the 373 controls (95% CI for difference of 4.8%: –12% to 2%). The mean ± standard deviation (SD) age for the study patients was 55 ± 25 years compared with 55 ± 23 years for the controls ($p = 0.72$, unpaired t-test). First responders were dispatched and responded to 14 calls in the study patients (six interfacility transports, one police standby, and seven low-priority calls) and to all but three calls in the controls (two interfacility transports and one low-priority call). Table 3 lists the mean and median response times and Table 4 lists the mean, median, and 90th fractile transport times for the study patients and controls. In both groups, the most frequent reasons (in descending order) for transport included breathing problems, unconsciousness or fainting, chest pain, motor vehicle crashes, strokes, and gunshot wounds. Medical illnesses constituted 268 (72%) of the study patients and 298 (80%) of the controls. Figure 1 lists the types and frequencies of calls received.

Survival to hospital discharge was 80% (95% CI: 76% to 84%) for the study patients versus 82% (95% CI: 77% to 85%) for the controls. This yielded a 95% CI for the 2% difference in proportions of –6% to +4%. Figure 2 provides box plots of the median transport times with interquartile ranges for patients who died in hospital versus patients who survived to discharge. The median values were not significantly different by the Mann-Whitney U test ($p = 0.685$).

Figure 3 plots the ROC curve for the ability of the response time to distinguish between patients who died in hospital versus those who survived. The resulting curve does not produce a significant improvement over random assignment, represented by the straight diagonal line in the plot, in the ability to discriminate the primary outcome (area under the curve 0.515, 95% CI: 0.443 to 0.587).

Advanced life support procedures were performed in 47.7% (95% CI: 43% to 53%) of the study patients versus 45.4% (95% CI: 40% to 51%) of the controls. This yielded a 95% CI for the 2.3% difference in proportions of –10% to +5%. The most frequent interventions performed were 1) administration of nitroglycerine and 2) endotracheal intubation.

TABLE 3. Mean and Median Response Times between Study Patients and Controls

Variable	Response Time* >10:59	Response Time* ≤10:59	p-Value
Mean time	14:02	06:29	<0.001†
Median time	12:40	06:32	<0.001‡

*Response times are shown in minutes:seconds.
†Unpaired t-test.
‡Mann-Whitney U test.

TABLE 4. Mean, Median, and 90th Percentile Fractile Transport Times between Study Patients and Controls

Variable	Transport Time* >10:59	Transport Time* ≤10:59	p-Value
Mean time	17:47	15:03	<0.001
Median time	16:04	13:03	<0.001
90th percentile fractile time	29:29	27:15	NA

*Response times are shown in minutes:seconds.
NA = not applicable.

DISCUSSION

In this comparison sample, patients categorized as being critically ill or injured with prolonged response times in excess of a set standard for the community were compared with a similar group whose times were within the standard to determine whether such times posed a substantial risk or threat to the public. The 95% CI analysis suggests that when compared with patients who wait 10:59 minutes or less for ALS response, Priority 1 patients who wait longer than 10:59 minutes could experience between a 6% increase and a 4% decrease in mortality, and do not have an increase in interventions or critical procedures performed prior to hospital arrival.

One of the first studies that promoted a response time specification was conducted by Eisenberg et al., who demonstrated that patient survival was improved for nontraumatic cardiac arrest when BLS cardiopulmonary resuscitation was received within 4 minutes and defibrillation and other ALS interventions were performed within 8 minutes after collapse.[5] Since this publication, several documents and organizations have supported similar response time specifications for EMS system design.[6,7] Unfortunately, such specifications are not based on measured data. Several studies, however, have addressed outcome as a result of response time.

Perrse et al. conducted a retrospective, observational study designed to determine the difference in survival from witnessed ventricular fibrillation between systems using a targeted (tiered ALS and BLS) and uniform (all-ALS) response strategies in an urban EMS system.[8] Of the 205 cases (181 targeted and

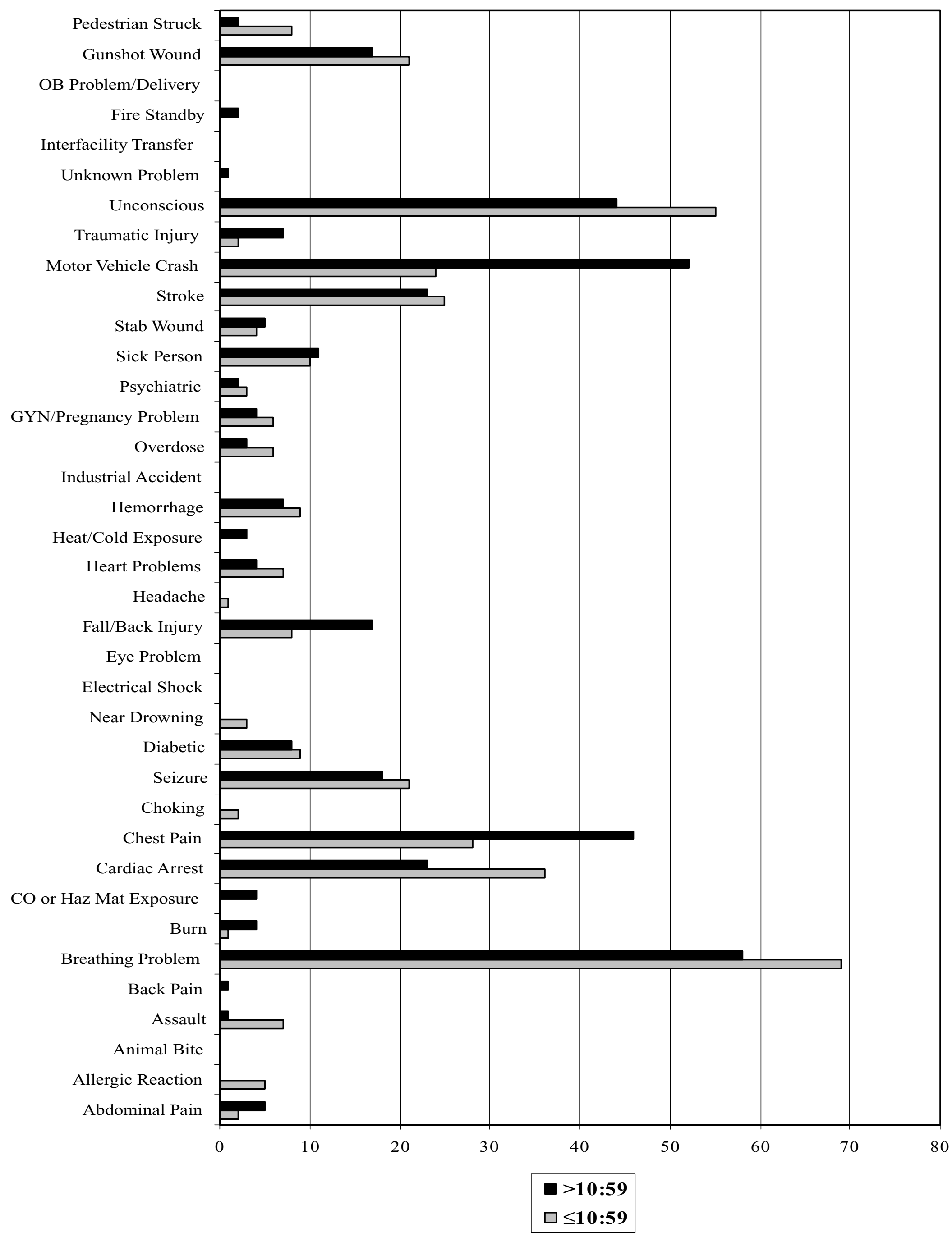

FIGURE 1. Types and frequencies of calls received between the study patients and controls. CO = carbon monoxide; GYN = gynecologic; Haz Mat = hazardous materials; OB = obstetric.

24 uniform), the targeted group had shorter response times, although this was not statistically significant. Outcome variables, including return of spontaneous circulation, survival to admission and discharge, and survival at one year, however, were significantly improved in the targeted group. It was not determined whether the reduced response intervals or other factors such as better paramedic competencies and proficiencies were the reason for improved outcomes.

Pons and Markovchick retrospectively evaluated the effects of exceeding an 8-minute response time guideline on the survival of 3,490 traumatically injured patients in an urban EMS system.[9] The patients were divided into two groups: those with response times >8 minutes and those with response times ≤8 minutes. These patients were stratified by age, mechanism of injury, and Injury Severity Score (ISS). There were no differences in survival between the two groups, except in the >8-minute response time group, where survival

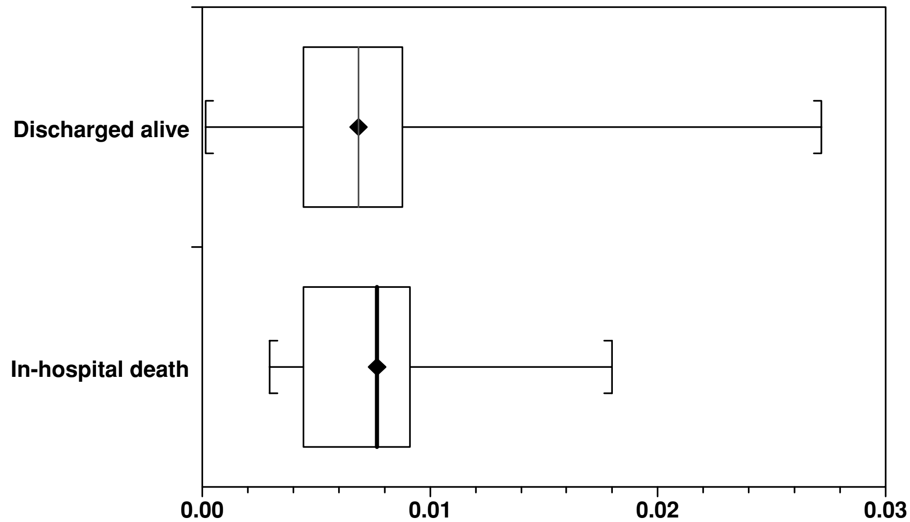

FIGURE 2. Box-and-whisker plots of transport time (denoted as a fraction of an hour) on the x-axis. The median values are represented by the vertical lines within each box and the boxes span the lower to upper quartile ranges, and the whiskers show the minimum to maximum ranges.

was unexpectedly greater for patients with an ISS of >25. When response times were further stratified in 2-minute increments, or when controlling for ISS, age, endotracheal intubation, or type of trauma, there was no difference in survival for any response time interval. Logistic regression also revealed no effect on survival based on response times.

We studied outcomes in relation to response times in patients with medical and trauma etiologies.[10] The purpose of this retrospective study was to determine the effect of a response time specification of 10:59 minutes for emergency life-threatening conditions and 12:59 minutes for emergency non–life-threatening conditions on survival to hospital discharge. We further calculated the probability of mortality as a function of arbitrarily assigned response times to determine whether improved survival would result from reducing current response time standards established for the community. Among the 5,424 patients, there were 71 nonsurvivors, yielding a mortality prevalence of 1.31% (95% CI: 1.02% to 1.65%). The median response times were 6.4 minutes for survivors and 6.8 minutes for nonsurvivors, or a difference of 24 seconds. To further determine the probability of mortality as a function of response time, the proportion of those who did not survive at each integer response time was plotted along with the number of nonsurvivors that would have been expected if the overall observed death proportion of 1.31% had been uniform across all times. There was no inequality between observed and expected death rates. While the number of actual deaths consistently fell below the expected number for response times less than 5 minutes, actual deaths exceeded the number at response times ranging from 5 to 12 minutes. The data supported the inference that survival was sensitive to response time variation only in the first 5 minutes, because the estimated dose–response relation was essentially flat for all response times exceeding 5 minutes. It was concluded that there was little evidence to support reducing the current response time specifications of 10:59 and 12:59 minutes, and that there was evidence to suggest that very low response times (<5 minutes) are associated with a low risk of mortality and may theoretically save as many as 10 lives per year. Pons and colleagues again set out to evaluate the effect of paramedic response time on unselected patient survival to discharge, controlling for certain cofounders.[11] In their retrospective study, a multivariable logistic regression analysis found that

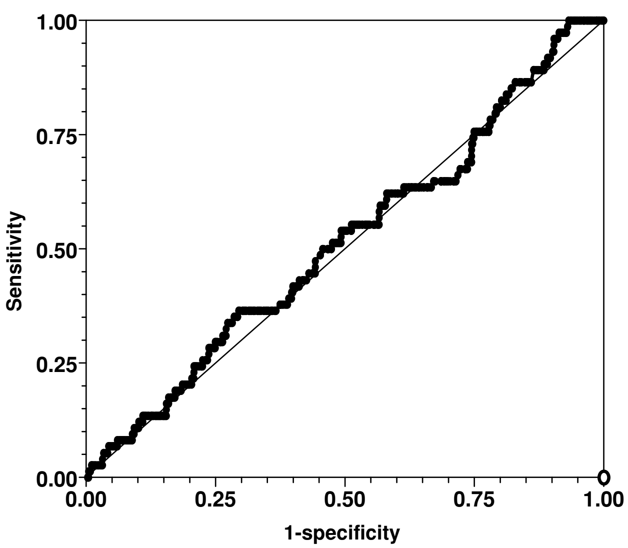

FIGURE 3. Receiver-operating characteristic (ROC) curve demonstrating the ability of response time to predict the primary outcome of in-hospital mortality. The curve is not significantly different from random assignment depicted as the straight diagonal line.

response time was not a significant independent predictor of survival in an equation that also contained the independent variables age, gender, scene time, transport time, and illness severity. When response times were categorized into two groups (≤4 minutes and >4 minutes), a survival benefit was identified in the ≤4-minute group. However, this benefit was lost when the response time threshold was increased to 8 minutes. No survival benefit was identified for patients with medical cardiac arrest at a threshold of either 4 or 8 minutes. We interpret the results from Pons et al. as consistent with the present data.

The time course to complete an EMS response is dependent on many variables, beginning with the receipt of the 9-1-1 call and ending with the availability of the ambulance for the next response.[12] Each of the component areas may be evaluated for compliance and improvement strategies. Prior to dispatching resources to the scene of an illness or injury, communication functions may include system access by either 9-1-1 and public safety answering point (PSAP) call receiving or standard 7- or 10-digit number calling; identification and transfer to medical call takers (if applicable); EMS call taking, processing, and categorization; and identification and alerting of the closest available unit. Once an ambulance is paged or notified about an assigned call, the mapping function must occur to ensure appropriate routes and access. Responding to the scene may be affected by traffic patterns depending on time of day, inclement weather, road conditions, or other unexpected access impediments, e.g., railroad crossings or drawbridges. Once resources arrive on the incident scene, there may be a time lag until patient contact is made, e.g., in high-rise buildings or airports. On-scene assessment and treatment then ensue, followed by preparation for transport. Hospital transport is subject to conditions similar to those of the initial response, and may be compounded by issues of diversion or specific triage protocol criteria depending on the nature of the complaint (e.g., trauma, cardiac, or stroke). Following arrival at the hospital, the triage process may be prolonged depending on hospital status and current emergency department census. Once the patient is delivered to the specific treatment or triage area, patient report, medical record documentation, and restocking all add to the total prehospital time.

Typically, EMS agencies have inherent system designs that support response time and clinical care targets individualized to the service area, resources, and community needs. Intuitively, response times to urban areas should be shorter than those in suburban or rural areas. Similarly, response times to peripheral points in an urban area may be longer when compared with more centralized zones. Given geographic disparity, these times may appear divergent; however, times may be more homogeneous when other factors are included in the design and reporting matrix, such as fractile specification compliance standards. Certain variables may be introduced into system design features to support or augment either response, such as the incorporation of a system status management process. This strategically places resources at predesignated locations during specific times of the day.[13] System status plans are typically based on historical information or other markers that predict potential call locations.[14,15] Automatic vehicle locators, used by dispatchers to identify the ambulance closest to the patient, or mobile mapping systems to better determine a call location may also be adopted to lessen the impact of response time. Such locators may only reveal distances based on point-to-point, or "as the crow flies," mapping, which does not take into account actual street directions or traffic patterns during critical times of the day.

LIMITATIONS

This study has several limitations. One threat to the external validity of the present findings lies in the method of determining the Priority 1 status. Although these criteria are explicitly defined in written patient care protocols, the designation requires some degree of flexible human thought. The patient care provided by first responders, albeit at the BLS level, was not evaluated and may have contributed to outcome. Our report lacks hard data to quantify illness severity, although we are not aware of any validated metric that applies to both medical and trauma patients in the prehospital setting. Thus, we assess the calibration of the Priority 1 designation only by pointing to the 18% and 20% mortality rates in the control and study groups, respectively, as an indication of an overall high-risk population. Further, this was a retrospective review, so data were extracted from the prehospital patient care report and hospital medical records. Accordingly, the study does not allow us to assess the magnitude or direction of bias that might have been imparted by omissions in documentation.

CONCLUSIONS

The results of this study showed no evidence of increased mortality or increased requirement for critical procedures during transport for Priority 1 patients in association with an ALS response time exceeding 10:59 minutes. Based on the data set from this study, the response time standards set for our community and the system design that includes all ALS with support from BLS first responders appeared to be appropriate and safe. Further research that addresses the association between response time and patient outcomes for BLS versus ALS as first responders and outcome should be considered.

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