Emergency Medical Services Response Time and Mortality in an Urban Setting

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Abstract

Background. A common tenet in emergency medical services (EMS) is that faster response equates to better patient outcome, translated by some EMS operations into a goal of a response time of 8 minutes or less for advanced life support (ALS) units responding to life-threatening events. **Objective.** To explore whether an 8-minute EMS response time was associated with mortality. **Methods.** This was a one-year retrospective cohort study of adults with a life-threatening event as assessed at the time of the 9-1-1 call (Medical Priority Dispatch System Echo- or Delta-level event). The study setting was an urban all-ALS EMS system serving a population of approximately 1 million. *Response time* was defined as 9-1-1 call receipt to ALS unit arrival on scene, and *outcome* was defined as all-cause mortality at hospital discharge. Potential covariates included patient acuity, age, gender, and combined scene and transport interval time. Stratified analysis and logistic regression were used to assess the response time–mortality association. **Results.** There were 7,760 unit responses that met the inclusion criteria; 1,865 (24%) were ≥8 minutes. The average patient age was 56.7 years (standard deviation = 21.5). For patients with a response time ≥8 minutes, 7.1% died, compared with 6.4% for patients with a response time ≤7 minutes 59 seconds (risk difference 0.7%; 95% confidence interval [CI]: −0.5%, 2.0%). The adjusted odds ratio of mortality for ≥8 minutes was 1.19 (95% CI: 0.97, 1.47). An exploratory analysis suggested there may be a small beneficial effect of response ≤7 minutes 59 seconds for those who survived to become an inpatient (adjusted odds ratio = 1.30; 95% CI: 1.00, 1.69). **Conclusions.** These results call into question the clinical effectiveness of a dichotomous 8-minute ALS response time on decreasing mortality for the majority of adult patients identified as having a life-threatening event at the time of the 9-1-1 call. However, this study does not suggest that rapid EMS response is undesirable or unimportant for certain patients. This analysis highlights the need for further research on who may benefit from rapid EMS response, whether these individuals can be identified at the time of the 9-1-1 call, and what the optimum response time is. **Key words:** emergency medical services; ambulance; time factors; outcome assessment; response; mortality

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Introduction

Background

Modern emergency medical services (EMS) is the first level of health care response for out-of-hospital medical emergencies. Historically, one of the first interventions that prehospital personnel performed was rapid response to a scene and rapid return of a patient to hospital by use of lights and siren.[1] As the scope of prehospital clinical practice expanded, emphasis was on rapid response of advanced life support (ALS)-trained paramedics to the scene. In 1979, Eisenberg and colleagues reported that survival from witnessed prehospital cardiac arrest of a medical origin in adults was maximized if the time from collapse to cardiopulmonary resuscitation (CPR) and the time from collapse to definitive care (i.e., defibrillation) were 4 and 8 minutes, respectively.[2] From this study, many EMS systems adopted an 8-minute response time for ALS units responding to life-threatening events.[1,3–5] However, generalizing these results to the response required for all life-threatening events may be problematic.[1,2,4–6] First, there are major differences between the EMS systems of 1979 and present-day systems, most notable of which is the substantially improved access to defibrillation and CPR.[7,8] Second, in EMS patients with conditions other than cardiac arrest, there is no evidence that 8 minutes is an optimal response that will result in improved outcomes, and in cardiac arrest patients, evidence from the past 10 years suggests that 8 minutes may be too long.[4,5,9,10] Finally,

the economic burden of maintaining an 8-minute response time goal is large.[11–13]

Rationale for the Study

A common tenet in modern EMS organizations is that a faster response saves lives.[1,3,12] EMS systems designed to meet these response time goals have a large economic cost of maintaining rapid response.[11] As EMS systems allocate resources to achieve a rapid response, there are financial opportunity costs to other EMS programs such as quality assurance and continuing medical education. EMS medical directors and managers require empirical evidence to assess the effectiveness of present response time goals to inform the future development of response time policy. While there have been many calls for further research into response time,[3,12,14–17] only a few studies have explicitly studied this topic.[2,4–6,9,10,14,18] No contemporary studies, either examining specific diagnoses such as cardiac arrest or trauma or using a pragmatic approach of examining all responses irrespective of diagnosis or patient condition, have found the optimal ALS response time to be based on a cutoff of less than or greater than 8 or 9 minutes.[4,5,9,10] No known study has examined the association between ALS response time and mortality restricted to patients thought to be in a life-threatening condition at the time of the 9-1-1 call—the point at which EMS systems must make the decision to respond rapidly.

The primary objective of this study was to determine whether, in a large urban ALS EMS system, a response time of 8 minutes or longer was associated with an increase in mortality for adult patients identified at the time of the 9-1-1 call as being in a life-threatening condition. Our hypothesis was that there would be no observable difference in all-cause mortality stratified by an 8-minute response time. Secondary objectives focused on the time of death (in the emergency department [ED] or after hospital admission as an inpatient), 4- and 9-minute response times, and response time as a continuous variable. The rationale for assessing a 4-minute cutoff was to examine a previous finding by Pons and colleagues, which suggested a statistically significant difference with a 4-minute dichotomous response time[4]; a 9-minute cutoff was also included because this is a common response time goal for many EMS systems.

Methods

Study Design

This was a retrospective study (i.e., both exposure and outcome had occurred prior to the commencement of the study) of a cohort of adult patients who received the highest-priority EMS response between January 1, 2006, and December 31, 2006.

Definitions

Exposure was EMS *response time*, defined as the sum of activation and response intervals (interval of time between receipt of the 9-1-1 call and arrival of the EMS unit on scene), and *outcome* was defined as all-cause mortality at hospital discharge.[13,19]

Population and Setting

The study was set in an EMS system that responds to calls for a population of approximately 1 million. This system has approximately 44 response units, all of which are ALS-equipped and -staffed. Units are staffed with one ALS provider and one basic life support (BLS) provider, or two ALS providers, depending on ALS staff availability. In 2006, this service recorded 107,562 EMS unit responses. Based on information provided by the 9-1-1 caller, and interpreted by a registered emergency medical dispatcher using the Medical Priority Dispatch System (MPDS), life-threatening situations were identified and given the designation of Echo- or Delta-level events. The MPDS is a uniform protocol designed to obtain details on the nature of an emergency from 9-1-1 callers to then determine the appropriate dispatch of resources to each emergency event.[20] The MPDS rates the emergency from least serious (Alpha) to most critical (Echo).[21] The dispatch of EMS units in this jurisdiction using the MPDS is consistent with industry-accepted quality standards. In the jurisdiction for this study, an Echo- or Delta-level event elicited a lights-and-siren response from both the fire department, who provided BLS with defibrillation (BLS-D) first response, and EMS, who provided ALS treatment and all transports if required. The EMS system has been designed for an EMS ALS response of $\leq$7 minutes 59 seconds on Echo and Delta emergency calls.

Human Subject Committee Review

A health research ethics board approved this study and waived the requirement for written informed consent.

Experimental Protocol

The study sample was constructed as follows: EMS unit responses were included if the patient was $\geq$18 years of age and if the unit response resulted in a transport to an acute care facility. EMS data, which were collected from a single computer-aided dispatch database, were linked to health system ED data employing a deterministic linkage strategy using patient care record number (a shared tracking variable), date of service, and first and last names. Linked EMS–ED data were subsequently linked to inpatient data also by a deterministic linkage using unique lifetime

identifier (a health system tracking number), hospital site, and time of ED discharge and inpatient admission. From the EMS–ED and inpatient linked data, the study was restricted to life-threatening events identified at the time of the 9-1-1 call (MPDS Echo- and Delta-level determinants).

Measurements

The exposure for this study was the time interval between receipt of the 9-1-1 call and arrival of the first EMS unit on scene. The start time was automatically created when the 9-1-1 call was answered and the end time was recorded when the EMS crew activated the mobile data terminal in the ambulance. In events where multiple EMS units responded, the fastest time to arrival on scene was used,[13] as the first EMS unit on scene would usually provide the immediate potentially time-sensitive prehospital interventions (e.g., defibrillation).[22] Unfortunately, BLS-D first-response data were not available for this time period and could not be included.

Potential covariates included patient acuity, age, gender, level of prehospital interventions (ALS or BLS), and *combined scene and transport interval time* (i.e., time from arrival of the first EMS vehicle on scene to arrival of the transporting unit at the hospital).[23] Covariates were selected a priori based on clinical plausibility, previous literature on this topic, and availability. Patient acuity was assessed using the Canadian Triage and Acuity Scale (CTAS), which was scored on arrival at the ED by the triage nurse, consistent with published standards (explained in detail in Table 1).[24] Age, gender, and level of prehospital interventions were entered into the EMS database by the paramedic at the termination of the event. Scene and transport intervals were included to assess the effects of time to hospital arrival on the response time and mortality association, as outcome from some conditions may be associated with shorter total prehospital times.[25–28] All time intervals, for example, arrival of the EMS unit on scene, departure of the unit from the scene, and arrival of the unit at the hospital, were captured by the responding crew with a mobile data terminal in the ambulance.

Analytical Methods

A univariable approach compared the risk of mortality in patients who received a response time ≥8 minutes (*exposed*) with that of those who did not (*unexposed*). The *risk of mortality* was defined as the number of patients who died divided by the number of patients in the exposure category. In addition, an odds ratio of mortality with a 95% confidence interval (CI) was reported. Stratified analysis and logistic regression were used to further explore the exposure–outcome association. The potential modifying effects of covariates were assessed by the Mantel-Haenszel test of homogeneity, compared with previous study findings, and considered within the context of clinical significance.[29,30] Confounding was assessed by comparing the crude to adjusted odds ratios, and also considered in the context of previous study findings and clinical significance.[30] Logistic regression was used to report values adjusted for the a priori–determined covariates. The only exceptions to this were the CTAS score and the level of prehospital interventions. The CTAS score was omitted prior to data analysis because of concerns with the timing of the assessment. Since this scale is applied at the time of hospital arrival, it is influenced by exposure and prehospital treatment. It was therefore decided to assess the potential effect of acuity only in the sensitivity analysis. Similarly, level of prehospital intervention may also be influenced by the exposure and was also assessed only in the sensitivity analysis.

Analyses were repeated while stratifying the data set by those who were only cared for in the ED versus those who were admitted as an inpatient, and at 4-minute (≤3 minutes 59 seconds vs. ≥4 minutes) and 9-minute (≤8 minutes 59 seconds vs. ≥9 minutes) cutoffs. Logistic regression only was used to assess response time as a continuous variable. All analyses were performed in Stata version 8.0 (StataCorp LP, College Station, TX).

A simple sensitivity analysis was used to assess the potential effects of selection bias, misclassification bias, and uncontrolled confounding on the crude 8-minute effect estimate. There were two possible sources of selection bias in this study: 1) the exclusion of unit responses that did not result in transport of the patient to an acute care facility (i.e., because of death at the scene) and 2) the exclusion of subjects whose EMS and outcome data could not be linked. To assess the potential effect of selection bias, we evaluated the change in the crude risk estimate if we incorporated field deaths from cardiac arrest of a medical origin or unit responses that were excluded because of missing data or inability to link. In the unit responses excluded because of missing data or inability to link, several scenarios were assessed, which included increasing the mortality by 50% in those with a response time ≥8 minutes while decreasing it by 50% in those with a response time ≤7 minutes 59 seconds, and vice versa. The primary area for misclassification bias was the determination of response time. It was possible that an EMS unit was "held back" from a scene because of a safety concern; if this occurred, the reported response time would underestimate true response time. Several scenarios were assessed to determine the influence on the crude effect estimate. It is possible that there was uncontrolled confounding by acuity; therefore, the CTAS score and the level of prehospital interventions (i.e., ALS or BLS) were assessed using stratified analysis and logistic regression to determine

TABLE 1. Patient Characteristics

Variable	≥8 minutes (n = 1,865)	≤7 minutes 59 seconds (n = 5,895)	Total (n = 7,760)
Gender			
Female	822 (44.1%)	2,708 (45.9%)	3,530 (45.5%)
Male	1,043 (55.9%)	3,187 (54.1%)	4,230 (54.5%)
CTAS*			
Level 1	150 (8.0%)	519 (8.8%)	669 (8.6%)
Level 2	975 (52.3%)	3,025 (51.3%)	4,000 (51.6%)
Level 3	686 (36.8%)	2,203 (37.4%)	2,889 (37.2%)
Level 4	54 (2.9%)	146 (2.5%)	200 (2.6%)
Level 5	0 (0.00%)	2 (0.03%)	2 (0.03%)
Age—mean (±SD), years	55.4 (21.2)	57.2 (21.6)	56.7 (21.5)
18 to 39 years	488 (26.2%)	1,479 (25.1%)	1,967 (25.4%)
40 to 64 years	670 (35.9%)	1,919 (32.6%)	2,589 (33.4%
≥65 years	707 (37.9%)	2,497 (42.4%)	3,204 (41.3%)
Combined scene and transport interval time—median (IQR), minutes	39.1 (16.5)	36.1 (14.1)	36.7 (14.7)
MPDS priority			
Delta	1,821 (97.6%)	5,708 (96.8%)	7,529 (97.0%)
Echo	44 (2.4%)	187 (3.2%)	231 (3.0%)
Level of care†‡			
ALS	917 (49.3%)	2,904 (49.5%)	3,821 (49.4%)
BLS	943 (50.7%)	2,968 (50.5%)	3,911 (50.6%)

*The Canadian Triage and Acuity Scale (CTAS) is used to prioritize patient care in Canadian emergency departments (EDs). It is applied on arrival at the ED by the triage nurse. CTAS level 1 is defined as resuscitation, level 2 as emergent, level 3 as urgent, level 4 as less urgent, and level 5 as nonurgent.
†All City of Calgary emergency medical services (EMS) response units are ALS-capable, but patient condition does not always warrant ALS-level care. ALS-level care criteria include patient's prehospital index ≥4, medication administered, including fluid bolus, endotracheal intubation or attempted intubation, electrical countershock, and surgical intervention; all other patients are categorized as BLS.
‡Total N = 7,732 (≥8 minutes = 1,860; ≤7 minutes 59 seconds = 5,872).
ALS = advanced life support; BLS = basic life support; IQR = interquartile range; MPDS = Medical Priority Dispatch System; SD = standard deviation.

whether including them would have changed the conclusions of this study.

Sample Size Determination

Sample size was a convenience sample based on one calendar year of data. The rationale for including one calendar year was to capture the seasonal fluctuations in the amount and type of events, as well as the seasonal differences on time intervals to these events, and to allow direct comparison with the results of the study reported by Pons and colleagues.[4]

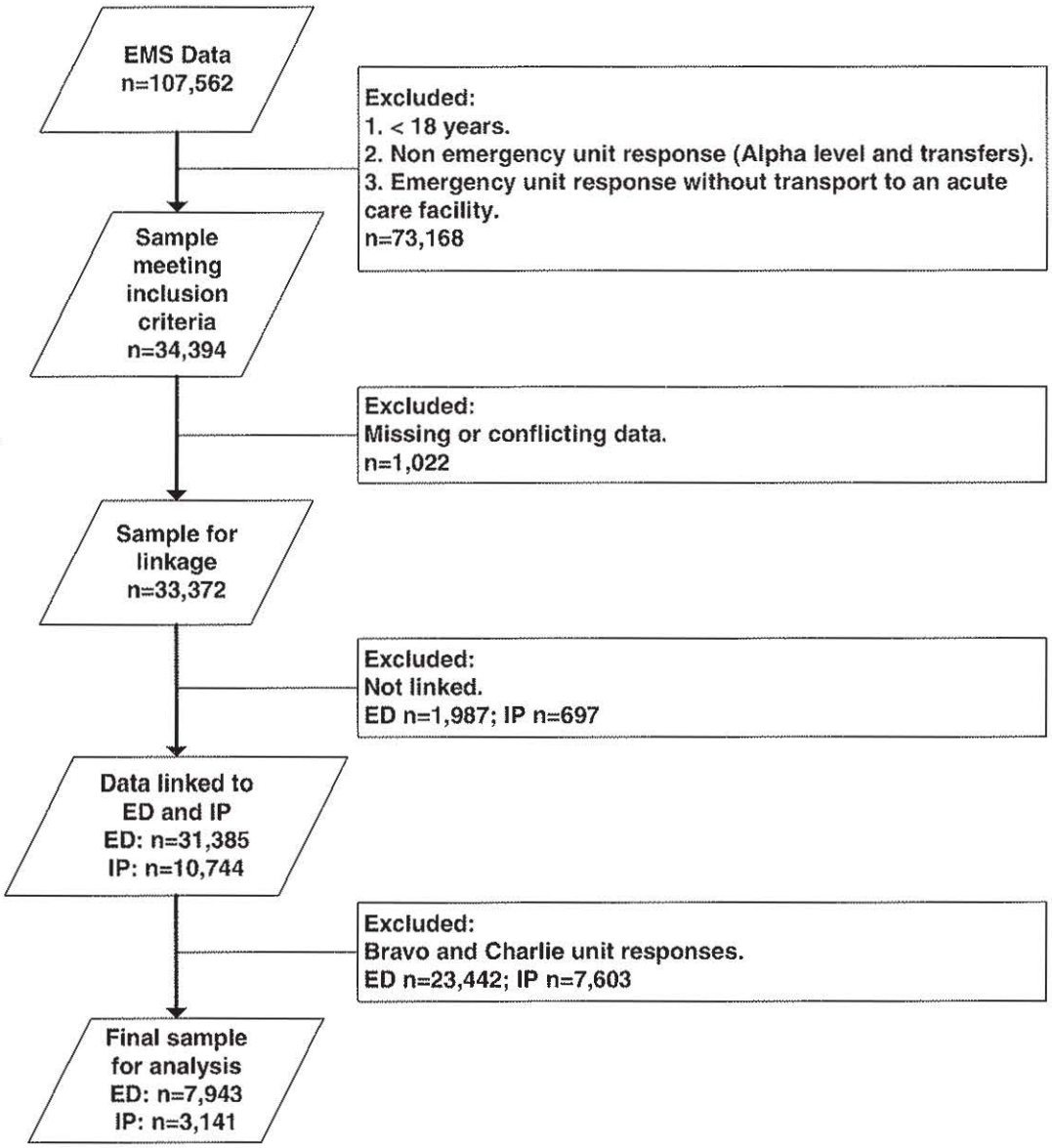
RESULTS

A total of 33,372 EMS unit responses resulted in transport of a patient ≥18 years of age to an acute care hospital; 31,385 such patients (94%) were successfully linked between the EMS and ED databases (Fig. 1). Of the 31,385 linked records, 11,441 patients were identified as being subsequently admitted to hospital, with 10,744 (94%) successfully linked between the ED and inpatient databases. When the sample was restricted to EMS unit responses for Echo- and Delta-level dispatches, 7,943 patients were linked between the EMS and ED databases. A total of 183 of these patients could not be subsequently linked to the inpatient database; therefore, 7,760 unit responses were included in the overall analysis. There were 3,141 unit responses where the patient was admitted to hospital as an inpatient (Fig. 1).

Overall, 1,865 out of 7,760 (24%) patients received a response time ≥8 minutes (exposed). The exposed and unexposed groups did not have clinically significant differences in key characteristics (Table 1). A total of 508 patients died (6.6%), 170 in the ED and 338 after they were admitted to hospital.

The overall risk of mortality in patients who received a response time ≥8 minutes was 7.1%, compared with 6.4% with a response time ≤7 minutes 59 seconds. The difference in the risk of mortality was 0.7% (95% CI: –0.5%, 2.0%). There was no evidence of individual effect measure modification or confounding by age, gender, or combined scene and transport interval time (Table 2). The odds ratio when adjusted for age, gender, and combined scene and transport interval time was 1.19 (95% CI: 0.97, 1.47) (Table 3).

When response time was treated as a continuous variable by minute of response, there was no increased risk of mortality with increasing response time (Table 3). When response time was plotted against the risk of mortality by minute, the risk of mortality appeared to increase up to 8 minutes, then become variable and decline with increasing response time (Fig. 2). When the analysis was restricted to patients who were admitted to hospital as inpatients, there



Note: ED=Emergency Department; IP=In-patient

FIGURE 1. Sample selection. ED = emergency department; EMS = emergency medical services; IP = inpatient.

was an increase in the adjusted odds ratio of mortality at 8 minutes (1.30; 95% CI: 1.00, 1.69). At a 4-minute response time, the difference in the risk of mortality for a response time of ≥4 minutes was 1.9% (0.3%, 3.4%), the crude odds ratio of mortality was 1.41 (1.03, 1.95), and the adjusted odds ratio was 1.35 (0.99, 1.83). The secondary analysis stratified at a 9-minute response showed no association with mortality (Table 4).

A simple sensitivity analysis suggested that sample selection or misclassification of exposure, if present, was unlikely to have affected the observed results (Table 5). Patients with a CTAS level 1 were 20.59 (15.50, 27.33) times, and with a level 2 were 1.64 (1.26, 2.13) times, more likely to die than patients triaged with a level 3, 4, or 5. Therefore, the CTAS score as determined at the time of ED triage did identify a more acutely ill patient population insofar as identifying a population of patients at higher risk of death. There was no effect measure modification or confounding by this scale. When the CTAS score was added to the multiple logistic regression model, the adjusted odds ratio of mortality for those receiving a response time ≥8 minutes was 1.23 (0.98, 1.54). In addition, we also assessed acuity by using the level of prehospital interventions applied to the patient (i.e., ALS or BLS—explained in detail in Table 1). The odds of mortality in patients receiving ALS-level care was 2.26 (1.86, 2.76) times that of those receiving BLS-level care.

TABLE 2. Stratified Analysis of Mortality by 8-Minute Response

Variable	Category	Exposure (min:sec)	Dead	Alive	OR*	95% CI
Age	Crude	≥8:00	133	1,732	1.13	0.91–1.39
		≤7:59	375	5,520		
	18–39 years	≥8:00	4	484	0.57†	0.14–1.71
		≤7:59	21	1,458		
	40–64 years	≥8:00	38	632	1.28	0.84–1.92
		≤7:59	86	1,833		
	≥65 years	≥8:00	91	616	1.22	0.94–1.59
		≤7:59	268	2,229		
	MH pooled	≥8:00	—	—	1.20	0.97–1.48
		≤7:59				
Gender	Female	≥8:00	62	760	1.28	0.93–1.75
		≤7:59	162	2,546		
	Male	≥8:00	71	972	1.02	0.76–1.35
		≤7:59	213	2,974		
	MH pooled	≥8:00	—	—	1.13	0.92–1.39
		≤7:59				
Combined scene and transport interval time	<30 min	≥8:00	26	371	1.04	0.64–1.65
		≤7:59	98	1,456		
	30–35 min	≥8:00	24	315	1.33	0.79–2.18
		≤7:59	74	1,296		
	36–44 min	≥8:00	33	519	1.17	0.75–1.79
		≤7:59	86	1,581		
	≥45 min	≥8:00	50	527	0.96	0.67–1.38
		≤7:59	117	1,187		
	MH pooled	≥8:00	—	—	1.09	0.89–1.34
		≤7:59				

*Odds of mortality given a response time ≥8 minutes over the odds of mortality given a response time ≤7 minutes 59 seconds.
†Although this OR is different from those of the other strata, a reasonable biologically plausible hypothesis could not be found to account for this observation. Likewise, an examination of available literature did not demonstrate a similar finding. In examining the data for the 18-to-39-year-olds, it was observed that the cell comprising deaths in the strata with response time ≥8 minutes was small. To examine the effect of the cell size on the stratum-specific estimate, we moved two individuals from alive to dead in the stratum for ≥8 minutes, and two individuals from dead to alive in the stratum for ≤7 minutes 59 seconds (four individual outcomes were reassigned out of 1,967 observed unit responses). These changes resulted in a movement of the stratum-specific OR for the 18-to-39-year-old group to 0.96. In the absence of a biologically plausible explanation, or previously observed similar phenomenon, it is unlikely that this is effect-measure modification.
CI = confidence interval; MH = Mantel-Haenszel; OR = odds ratio.

The adjusted odds ratio of mortality for those receiving a response time ≥8 minutes when this variable was added to the multiple logistic regression model was 1.20 (0.97, 1.48), with no effect measure modification or confounding.

DISCUSSION

Our study suggests that for adult patients identified at the time of the 9-1-1 call as having a life-threatening event, an EMS response of ≥8 minutes was not associated with an increase in all-cause mortality at hospital discharge. These results confirm findings reported by Pons and colleagues.[4] These authors examined response time and mortality in a two-tiered BLS-D/ALS system in an American urban setting for all emergency events in which patients were transported to a single receiving facility.[4] The authors reported an odds ratio of survival of 1.06 (0.80, 1.42) for an 8-minute response adjusted for acuity, age, gender, scene, and transport time. Blackwell and Kaufman reported no significant differences ($p = 0.10$) in the median response time between survivors ($n = 5{,}353$; 6.4 minutes) and nonsurvivors ($n = 71$; 6.8 minutes) also in a two-tiered

TABLE 3. Multivariable Models of Mortality and Response Time

	8-Minute Dichotomous Response Time*			Continuous Response Time†		
Variable	OR	95% CI	p-Value‡	OR	95% CI	p-Value‡
Response time	1.19	0.97–1.47	0.103	1.02	0.99–1.05	0.285
Age§	2.87	2.46–3.35	<0.001	2.87	2.46–3.34	<0.001
Gender□	1.22	1.02–1.47	0.033	1.22	1.02–1.47	0.033
Combined scene and transport interval time¶	1.05	0.97–1.15	0.236	1.05	0.97–1.15	0.222

*8-Minute dichotomous response time = ≥8 minutes versus ≤7 minutes 59 seconds.
†Continuous response time = response time by minute from 0 to 20 minutes, with all response times ≥20 minutes collapsed to the 20-minute category.
‡Wald test.
§Age categories are in years: 18 to 39, 40 to 64, and 65 and greater.
□Female is the reference category.
¶Combined scene and transport interval quartile category in minutes: 5 to 29.99, 30 to 35.99, 36 to 44.99, ≥45.
CI = confidence interval; OR = odds ratio.

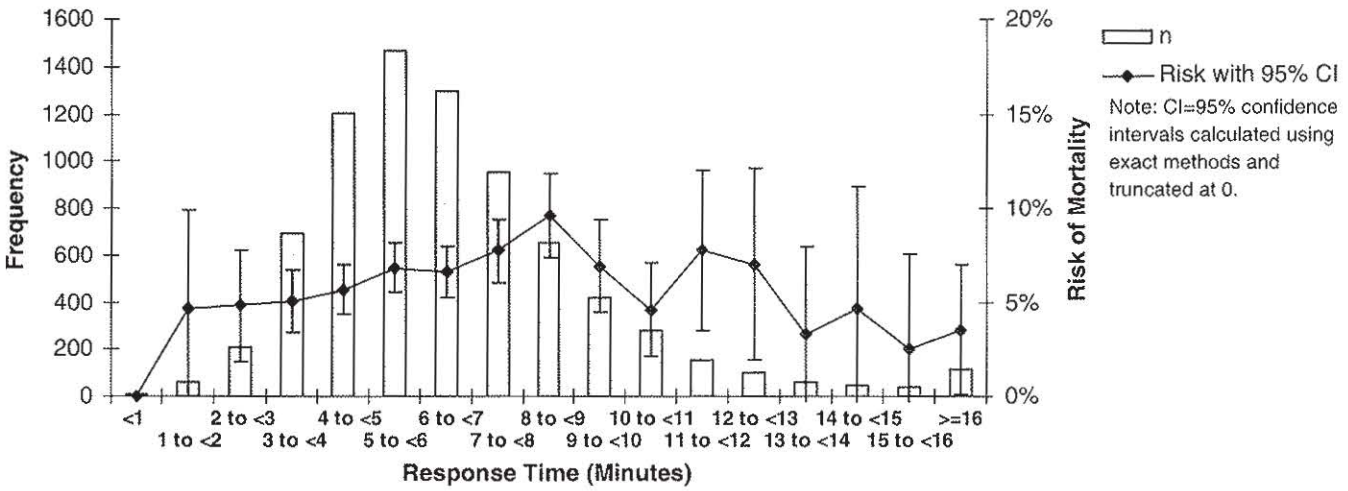


FIGURE 2. Crude risk of mortality by response time, in minutes. CI = confidence interval.

BLS-D/ALS American EMS system.[5] These authors also reported a secondary analysis in which a convenience sample of three physicians reviewed the clinical features of the 71 nonsurvivors from their study. The physicians universally agreed that 59 (83%) nonsurvivors would not have survived with a faster EMS response time. An exploratory analysis in our study suggested a small increase in the odds of mortality for patients who survived to be admitted to hospital and who received a response time ≥8 minutes. A reasonable interpretation of this finding may be that patients who were discharged directly from the ED were going to live, and those who died in the ED were going to die, either because they were too sick or because of some deficiency in care. However, patients who were admitted to hospital may have had a level of acuity at which EMS response time, when combined with other interventions, affected the risk of death.

When response time at 4 minutes was assessed, the adjusted odds ratio of mortality in this study was 1.35 (0.99, 1.83), whereas Pons and colleagues reported an adjusted odds ratio of survival of 0.70 (0.52, 0.95),[4] and Blackwell and Kaufman reported a statistically significant protective effect with a 5-minute response time.[5] While these results may suggest a small beneficial effect of decreasing response times to below 8 minutes, this study was not designed to answer the question of what the optimum response time is. The financial cost of halving the response time standard would be tremendous, and if this were contemplated it would be beneficial to identify specifically what conditions may benefit from a more rapid response, whether these conditions can be identified at the time of the 9-1-1 call, and the cost-effectiveness of decreased response times on the outcome from these conditions. When response time was treated as a continuous variable, our results are similar to those of Pons and colleagues, i.e., that there was no statistically significant increase in risk of mortality. Mortality appears to increase between 0 and 8 minutes, then become variable and declines with increasing response time (Fig. 2). Pons and Markovchick reported, in an analysis restricted to trauma patients, similar variability in mortality for responses greater than 12 minutes.[10] While the observed variability could be attributed to small numbers within each stratum, it is possible that patients who received longer response times differed with respect to characteristics that could influence risk of mortality. However, our data demonstrated no differences in the proportion of Echo-level events, CTAS score, or number of ALS interventions performed between different time strata.

These analyses may provide further evidence to suggest that the way in which response time is being presently defined by many systems (receipt of 9-1-1 call to arrival of the vehicle at the scene) may not be closely associated with outcome. The present

TABLE 4. Mortality by Different Dichotomous Response Times

Exposure*	Outcome	OR (95% CI) Crude	OR (95% CI) Adjusted†
8 Minutes	Total mortality	1.13 (0.91–1.39)	1.19 (0.97–1.47)
	ED mortality	1.07 (0.73–1.53)	1.07 (0.76–1.53)
	IP mortality	1.24 (0.95–1.61)	1.30 (1.00–1.69)
4 Minutes	Total mortality	1.41 (1.03–1.95)	1.35 (0.99–1.83)
	ED mortality	1.23 (0.73–2.12)	1.14 (0.70–1.87)
	IP mortality	1.44 (0.96–2.20)	1.44 (0.97–2.13)
9 Minutes	Total mortality	0.86 (0.65–1.12)	0.93 (0.72–1.21)
	ED mortality	0.80 (0.49–1.27)	0.83 (0.53–1.31)
	IP mortality	0.94 (0.66–1.30)	1.02 (0.73–1.41)

*8 Minutes = ≥8 minutes versus ≤7 minutes 59 seconds; 4 minutes = ≥4 minutes versus ≤3 minutes 59 seconds; and 9 minutes = ≥9 minutes versus ≤8 minutes 59 seconds.
†Adjusted for age, gender, and combined scene and transport interval time.
CI = confidence interval; ED = emergency department; IP = inpatient; OR = odds ratio.

TABLE 5. Sensitivity Analyses

Scenario	Outcome	Exposed (≥8 min)	Unexposed (≤7 min 59 sec)	OR (95% CI)
Crude	Dead	133	375	1.13 (0.91–1.39)
	Alive	1,732	5,520	
		Selection Bias		
Field deaths included*	Dead	133 + 40	375 + 131	1.08 (0.91–1.31)
	Alive	1,732	5,520	
Scenario 1†	Dead	133 + 15	375 + 35	1.13 (0.93–1.38)
	Alive	1,732 + 190	5,520 + 514	
Scenario 2‡	Dead	133 + 23	375 + 18	1.25 (1.03–1.53)
	Alive	1,732 + 182	5,520 + 531	
Scenario 3§	Dead	133 + 7	375 + 53	1.02 (0.83–1.25)
	Alive	1,732 + 198	5,520 + 496	
		Misclassification Bias		
Scenario 4‖	Dead	133 + 8	375 − 8	1.13 (0.92–1.38)
	Alive	1,732 + 10	5,520 − 10	
Scenario 5¶	Dead	133 + 19	375 − 19	1.11 (0.91–1.36)
	Alive	1,732 + 276	5,520 − 276	

*Includes all nontransported patients who presented or entered cardiac arrest from a presumed medical origin and who received a resuscitation attempt. A resuscitation attempt includes any intervention in addition to cardiopulmonary resuscitation (CPR), which may include defibrillation, intubation, or the administration of medications.

†There were 754 unit responses that were excluded from the study for various reasons, but had exposure data available; 205 were exposed and 549 unexposed. This scenario assumes the same mortality rate as the included unit responses, 7.1% mortality in exposed and 6.4% in unexposed.

‡Assumes that the mortality rate in exposed is 50% increased (7.1% × 1.5 = 11%) and the mortality rate in unexposed is 50% reduced (6.4%/2 = 3.2%).

§Assumes that the mortality rate in exposed is 50% reduced (7.1%/2 = 3.6%) and the mortality rate in unexposed is 50% increased (6.4% × 1.5 = 9.6).

‖Assumes that 2% of unexposed unit responses are in reality exposed because the emergency medical services (EMS) unit was held back from scene. No data exist to track the number of hold-back situations, but anecdotal evidence would suggest this may be a plausible proportion.

¶Assumes that 5% of unexposed unit responses are in reality exposed because the EMS unit was held back from scene. This is likely an extreme example.

CI = confidence interval; OR = odds ratio.

definition is at best a proxy measure for the more clinically relevant (but also more difficult-to-record) definition of time of injury or illness to time of critical prehospital intervention. Results may also imply that the sample used for this study includes numerous patients for whom an 8-minute EMS response would not make a difference, which suggests that further study is warranted on the effectiveness of using MPDS determinants to triage who is eligible to receive the most rapid response in the EMS system. This study is a pragmatic assessment of an actual EMS response time policy presently used in one urban EMS system. Strengths of this study include that 1) a high linkage success rate was achieved, 2) potential systematic biases were assessed quantitatively, 3) data were manually reviewed for accuracy, and 4) the fastest response time for each event was used, not the individual response times of each responding unit.

Limitations and Future Research

There were numerous limitations to this study. Response time may be viewed as a clinical intervention that can affect patient outcome (clinical perspective) or as a measure of citizen expectation (social perspective). This study focused on the clinical perspective only. The sensitivity analysis suggested that selection and misclassification bias, and confounding by acuity, would not have changed the observed effect of response time on outcome. While one selection bias scenario moved the effect estimate CI within a statistically significant range, the effect estimate itself moved from 1.13 to 1.25. This small change only occurred using extreme assumptions in the sensitivity analysis with excluded unit responses having a 50% increased mortality rate in the exposed group and a 50% decreased mortality rate in the unexposed group. The definition of response time used by many modern EMS systems does not include patient access or assessment intervals. From a clinical perspective, the most valid measure of response time is the interval from illness or injury to the time that a critical prehospital intervention is applied.[2,12,14,31–34] The present definition is at best a proxy measure of this interval.[19] Without data describing the patient access interval and assessment intervals, it is difficult to predict the magnitude and direction this may have on the effect estimate. Fire department response time and interventions were not accessible from available data sources. It is possible that critical interventions such as CPR and defibrillation were performed by the fire department prior to EMS arrival. An unpublished audit from this EMS system that compared the arrival time of EMS and fire department units in 2007 suggested that in 60% of cardiac arrest events the EMS system arrived first.[11] In events where the fire department arrived first, the median time on scene prior to EMS arrival was 80 seconds. Although data from this audit are from 2007, there were no major changes made to the EMS system status management plan that would suggest that

2006 would be different.[11] In addition, in the reported study sample, cardiac arrests made up only 2.2% of all events. This information suggests that there is a small likelihood of uncontrolled confounding by fire department first response prior to EMS arrival. This study was underpowered to detect a 0.7% difference between exposure groups. The sample size is one of convenience (i.e., a calendar year of data). To exclude a type 2 error (i.e., observing no difference when a true difference is present), a sample of 41,000 patients would have been required to exclude a 0.7% difference with 80% power. The MPDS may overtriage acuity of patient complaint, so that patients who do not have a life-threatening situation are designated as such. This may be a valid approach, as it is safer to respond quickly to many calls for which a rapid EMS response is subsequently determined not to be beneficial to ensure that a rapid response *is* provided to a call where it is beneficial. The intent of this study was a pragmatic assessment of the system reflecting patients who are thought to be in a life-threatening condition when the decision to respond rapidly is made. No pediatric patients were included in the sample. These results should be generalized cautiously or not at all to settings outside of the urban environment.

From a clinical perspective, further study could be considered to explore an association of response time in a pediatric population (the causes of life-threatening events, particularly in the very young, are often airway-related and therefore time-sensitive) and to explore the association with morbidity measures. Further studies should also take an etiologic approach to sampling (i.e., identifying a sample of patients who are known to have presented with a life-threatening condition that may benefit from rapid EMS response) and consider a societal perspective (i.e., the expectation of the public, paramedics, and other stakeholders concerning EMS response time).

CONCLUSIONS

These results call into question the clinical effectiveness of a dichotomous 8-minute ALS response time on decreasing mortality for the majority of adult patients identified as having a life-threatening event at the time of the 9-1-1 call. However, this study does not suggest that rapid EMS response is undesirable or unimportant for certain patients. Rather, this analysis highlights clinical limitations in defining response time as the time from 9-1-1 call to arrival on scene, challenges in using the MPDS system to identify who should or should not receive a rapid EMS response, and the need for research on who may benefit from rapid EMS response, whether these individuals can be identified at the time of the 9-1-1 call, and what the optimum response time is.

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