CLINICAL PRACTICE

Response Time Effectiveness: Comparison of Response Time and Survival in an Urban Emergency Medical Services System

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Abstract. Emergency medical services (EMS) administrators seek methods to enhance system performance. One component scrutinized is the response time (RT) interval between call receipt and arrival on scene. While reducing RTs may improve survival, this remains speculative and unreported. **Objective:** To determine the effect of current RTs on survival in an urban EMS system. **Methods:** The study was conducted in a metropolitan county (population 620,000). The EMS system is a single-tier, paramedic service and provides all service requests. The 90% fractile RT specifications required for county compliance include 10:59 minutes for emergency life-threatening calls (priority I) and 12:59 minutes for emergency non-life-threatening calls (priority II). All emergency responses resulting in a priority I or priority II transport to a Level 1 trauma center emergency department over a six-month period were evaluated to determine the relation between specified and arbitrarily assigned RTs and survival. **Results:** Five thousand, four hundred twenty-four transports were reviewed. Of these, 71 patients did not survive (1.31%; 95% CI = 1.04% to 1.67%). No significant difference in median RTs between survivors (6.4 min) and nonsurvivors (6.8 min) was noted ($p = 0.10$). Further, there was no significant difference between observed and expected deaths ($p = 0.14$). However, mortality risk was 1.58% for patients whose RT exceeded 5 minutes, and 0.51% for those whose RT was under 5 minutes ($p = 0.002$). The mortality risk curve was generally flat over RT intervals exceeding 5 minutes. **Conclusions:** In this observational study, emergency calls where RTs were less than 5 minutes were associated with improved survival when compared with calls where RTs exceeded 5 minutes. While variables other than time may be associated with this improved survival, there is little evidence in these data to suggest that changing this system's response time specifications to times less than current, but greater than 5 minutes, would have any beneficial effect on survival. **Key words:** prehospital; emergency medical services; response time; effectiveness; standards. ACADEMIC EMERGENCY MEDICINE 2002; 9:288–295

EMERGENCY medical services (EMS) administrators and managers continually seek innovative methods to enhance system performance. Like any service, multiple elements comprise an emergency medical response system, each with inherent qualities that may be reviewed, analyzed, and improved if deficient. One component commonly scrutinized by administrators, elected officials, and the public, and one potentially affecting patient care, is the response time interval between call receipt and arrival of medical care on the scene. Various times and response intervals intrinsic to EMS systems have been previously described.[1–3] Further, the Utstein criteria for cardiac arrest data were proposed in an attempt to report uniform data collection with reference to clinical and time criteria.[4] Despite these attempts for achieving consistent data reporting, definitions continue to vary between systems depending on design, performance specifications, or data collection limitations. Such designs may limit the ability to adequately scrutinize response times and to make comparisons between EMS systems.

Intuitively, reducing the response time would potentially decrease morbidity and improve survival for many categories of illness and injury. The benefit associated with a standardized, quantitative time reduction, however, remains speculative.

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The International Guidelines 2000 Conference on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care, while not advocating a specific response time objective, did recommend that EMS systems attempt to achieve a response and shock time of 8 to 10 minutes from collapse to provide the maximum potential for successful cardiac and cerebral resuscitation.[5] It was further emphasized that performing defibrillation within 5 minutes would be preferable. To decrease the time from illness or injury onset to emergency medical care, considerable resources (communication system, ambulances, equipment, and personnel) may be expended. Therefore, the costs of building and maintaining an EMS infrastructure that meets arbitrary response time criteria should be supported only if reasonable patient benefit is realized.

The purpose of this study was to estimate the effect of current response time specifications established for an advanced life support (ALS), municipal county EMS provider on survival to hospital discharge. Further, survival rates were stratified by response times to determine whether differences in mortality existed between strata, and to determine whether a time interval threshold was associated with improved survival. Out-of-hospital and hospital clinical data from nonsurvivors were then further analyzed in an attempt to establish whether survival might have been possible given a quicker response.

TABLE 1. Pre Out-of hospital and Clinical Data Elements*

Out-of-hospital	Hospital
Call type (dispatch signal)	Disposition
Response time	Length of stay in ED and in hospital
Transport priority	Initial vital signs
Transport problems	Intubation
Initial vital signs	Orotracheal
Intravenous access	Nasotracheal
Total IV fluid infused	Rapid-sequence induction
Intubation	Needle cricothyrotomy
Orotracheal	Surgical cricothyrotomy
Nasotracheal	Intravenous access
Initial ECG rhythm	Peripheral
Medications	Central
Significant scene or patient information	Cutdown
	Total IV fluid and blood infused
	Surgical procedures
	Thoracostomy tube
	Open thoracotomy
	Initial ECG rhythm
	Medications
	Past medical history

*Demographic information was obtained for all patients. IV = intravenous; ECG = electrocardiogram; ED = emergency department.

METHODS

Study Design. A consecutive sample of retrospective data including EMS patient care reports and hospital medical records was collected from March 1, 1998, through August 31, 1998. Only emergency responses (use of warning lights and siren) that resulted in a priority I (emergency life-threatening) or priority II (emergency non-life-threatening) transport to Carolinas Medical Center Emergency Department were included in the analysis. Data records from Mecklenburg EMS Agency were linked by computer algorithm to patient information from the emergency department through identifiers contained in billing records. This study, which met the criteria for expedited review, was approved by the Institutional Review Board at Carolinas Medical Center.

Study Setting and Population. This study was conducted in Mecklenburg County, located in the southern Piedmont region of North Carolina. This is a metropolitan county with a population of approximately 620,000 within an area of 550 square miles. Mecklenburg EMS Agency, managed by two hospital systems within the county, is an all–advanced life support (ALS) paramedic service, and is the exclusive provider for all 9-1-1 requests for EMS. First-responder services are provided throughout the county by a combination of paid and volunteer fire and rescue departments, all functioning at the emergency medical technician–defibrillation (EMT-D) level. All first responders are trained to use and are equipped with automated external defibrillators. The primary public safety answering point (PSAP) for the enhanced 9-1-1 system is located at the Charlotte-Mecklenburg Police Communications Center. Requests for medical assistance are immediately routed to the Central Medical Emergency Dispatch (CMED) Center at the EMS Agency. The CMED Center incorporates a computer-aided dispatch and Medical Priority Dispatch System (Medical Priority Consultants, Inc., Salt Lake City, UT). Call screening, priority and response mode assignment, and dispatching are performed by telecommunicators who are all certified as emergency medical technician–basics (EMT-Bs) and emergency medical dispatchers. A systems status management plan exists such that fluid redeployment of ambulances places resources in areas of high call demand based on historical data. All posting locations and assignments are updated every six months. The receiving hospital is a Level I trauma center and teaching hospital whose emergency department has an annualized census of approximately 100,000 patients.

A contractual agreement between the Mecklenburg EMS Agency and the county specifies that for at least 90% of calls dispatched (90% fractile re-

TABLE 2. Response Time Distributions (Minutes) for all Calls, Survivors, and Nonsurvivors

Centile	All Calls	Survivors	Nonsurvivors
1%	1.1	1.1	2.2
5%	2.9	2.9	4.0
10%	3.6	3.6	5.0
25%	4.9	4.9	5.5
50%	6.5	6.4	6.8
75%	8.3	8.3	8.3
90%	10.5	10.6	9.8
95%	12.3	12.4	10.3
99%	19.6	19.8	11.5

sponse time), ambulances must arrive at the scene of the incident in 10:59 minutes or less for priority I calls, and 12:59 minutes or less for priority II calls. An 80% fractile time of 20:59 minutes exists for the non-emergency (priority III) calls. The response time clock for the system begins when the patient's chief complaint and address are determined, or 30 seconds from call pick-up, whichever time is less. While arrival at the patient's side is important for clinical evaluation of a system, the contract specifications call for the clock to stop when the ambulance arrives on the scene.

Study Protocol. Call data and patient outcome information during the study period were extracted from the computer-aided dispatch system, EMS patient care reports, and hospital medical records and placed into the database for evaluation and statistical analysis. For those patients who did not survive to hospital discharge, demographic, clinical, and time course data were retrieved from out-of-hospital and hospital patient records and placed into a database (Table 1). Three emergency physicians were selected to review and analyze this information.

Measurements. Individual call response times were categorized to the nearest whole minute and evaluated to determine the relationship between response time and outcome. The probability of death as a function of response time was crudely estimated by evaluating the proportion who did not survive at each integer response time, and evaluating the number of deaths that would have been expected if the death proportion were uniform across response times.

Three residency-trained, board-certified emergency physicians, all faculty members affiliated with an emergency medicine residency program at the receiving hospital, were arbitrarily selected, blinded to the study objective, and asked to review the data sets obtained for all nonsurvivors. For each case, the physician provided his or her opinion as to whether a 1-, 2-, or 3-minute shorter response time might plausibly have made a clinically significant difference in outcome.

Data Analysis. Observed differentials in the data were analyzed statistically using Stata Statistical Software, Version 6.0 (Stata Corporation, 1999, College Station, TX). A two-sample Wilcoxon rank-sum test was used to test the equality of response time distributions between survivors and nonsurvivors, and Pearson chi-square statistics were used to compare the observed and expected death proportions. "Lowess" (locally-weighted least-squares regression smoothing) kernel smoothing was used to visualize the continuous dose–response function relating response time to probability of mortality over the range of response times in which mortal events were observed. The smoothed values are obtained by estimating predicted values from fitted regressions of mortality as a function of response time using only a subset of the data adjacent to each response time, and weighted to give more in-

TABLE 3. Interval Response Times with Observed and Expected Deaths

Response Time	% Dead	95% CI*	Total Dead	n	Expected Deaths†
0–0.9 Min	0	(0, 7.55)	0	47	0.62
1–1.9 Min	0	(0, 5.13)	0	70	0.92
2–2.9 Min	0.57	(0.01, 3.12)	1	176	2.30
3–3.9 Min	0.48	(0.06, 1.71)	2	419	5.48
4–4.9 Min	0.60	(0.16, 1.52)	4	669	8.76
5–5.9 Min	1.82	(1.04, 2.94)	16	879	11.51
6–6.9 Min	1.52	(0.83, 2.54)	14	921	12.06
7–7.9 Min	1.57	(0.79, 2.79)	11	701	9.18
8–8.9 Min	1.92	(0.92, 3.49)	10	522	6.83
9–9.9 Min	2.02	(0.81, 4.11)	7	347	4.54
10–10.9 Min	1.34	(0.28, 3.86)	3	224	2.93
11–11.9 Min	2.16	(0.45, 6.18)	3	139	1.82
12+ Min	0	(0, 1.18)	0	310	4.06
TOTAL	1.31	(1.02, 1.65)	71	5,424	

*For observed proportions of zero, one-sided, 97.5% confidence intervals (CIs) are reported.
†Expected stratum-specific death counts based on the overall rate of 1.31%.

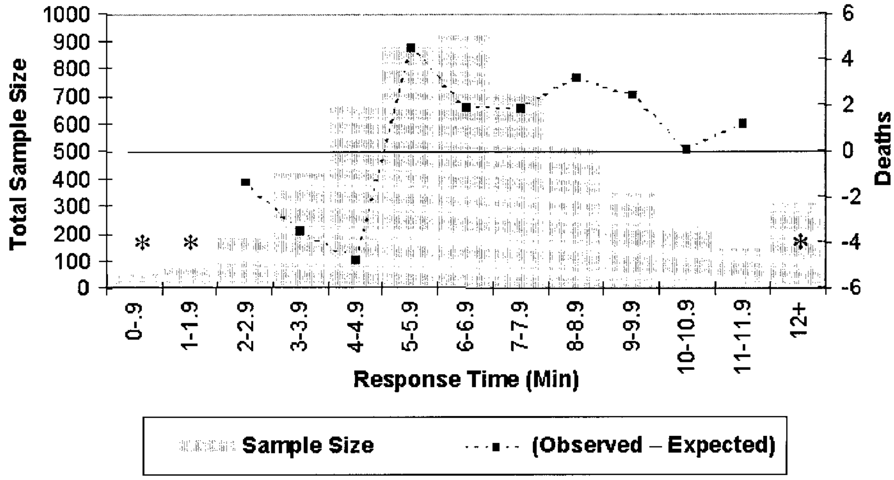

Figure 1. Observed minus expected deaths by response time interval. *No deaths observed in interval.

fluence to observations closest to the estimation point.[6] Results from the physician's clinical evaluation were compiled and analyzed using simple descriptive statistics.

RESULTS

A total of 5,516 consecutive calls were reviewed. Ninety-two (1.7%) records were not linked successfully because of missing or incorrect identifiers, and one of two duplicated calls was deleted. Thus, a final sample size of 5,424 transports was included in the analysis.

The mean response time for all patients was 6.97 minutes (range 0.2 to 86.2 minutes). The 86.2-minute response represents a call involving multiple casualties where numerous ambulances were dispatched at varying times. This prolonged response was the final unit to arrive on the scene, and represents double the next longest (43.9 minutes) time. Thus, this call was considered an outlier and deleted. The mean response time for survivors was 6.96 minutes and 7.06 minutes for nonsurvivors, or a difference of 0.10 minutes (6 seconds). Table 2 compares the percentile response times between survivors, nonsurvivors, and all calls reviewed. The median response time for all patients was 6.5 minutes (range 0.2 to 86.2 minutes) and 90% of the responses were made within 10.6 minutes. The median response times were 6.4 minutes for survivors and 6.8 minutes for nonsurvivors, or a difference of 0.4 minutes (24 seconds; Wilcoxon rank-sum p = 0.10). Of the 5,424 transports, 71 patients did not survive to hospital discharge, resulting in a mortality proportion of 1.31% (95% CI = 1.02% to 1.65%).

Table 3 demonstrates the probability of mortality as a function of response time, with calls ≥12 minutes collapsed into a single category. 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% was uniform across all times (Fig. 1). There was no strong evidence of a global inequality between observed and expected death counts ($\chi^2_{(df=12)} = 17.35$; p = 0.14). The pattern displayed, however, suggests a systematic differential in that the observed number of actual deaths consistently fell below the expected number for response times less than 5 minutes, but generally exceeded the expected number at response times ranging from 5 to 12 minutes. Similarly, the difference between observed and expected mortality rates exceeded zero for all response time categories ≥5 minutes in which deaths were observed (Fig. 2). A total of 7 deaths occurred among 1,381 transports with response times of <5 minutes (0.51%; 95% CI = 0.20% to 1.04%) versus 64 deaths among 4,043 transports with response times ≥5 minutes (1.58%; 95% CI = 1.20% to 1.97%). Therefore, a post-hoc test for the effect on survival of response time dichotomized at <5 minutes versus times that were ≥5 minutes appears more definitive ($\chi^2_{(df=1)} = 9.23$; p = 0.002), although this should be interpreted cautiously given that the dichotomization point was not specified *a priori*. A smoothed nonparametric dose–response curve generated by locally weighted kernel smoothing with a bandwidth of 0.60 is shown in Figure 3. Smoothing was run from the 1st to the 99th percentile of the data, and the display is truncated at 11–11.9 minutes, the bin in which the last death was observed. The vertical axis represents the odds of mortality [*Pr(mortality)/(1 − Pr(mortality)*] on the natural log scale.

Three conveniently selected emergency physicians from the receiving hospital reviewed clinical data for all 71 nonsurvivors and provided opinions as to whether they believed survival could have been possible given a 1-, 2-, or 3-minute earlier

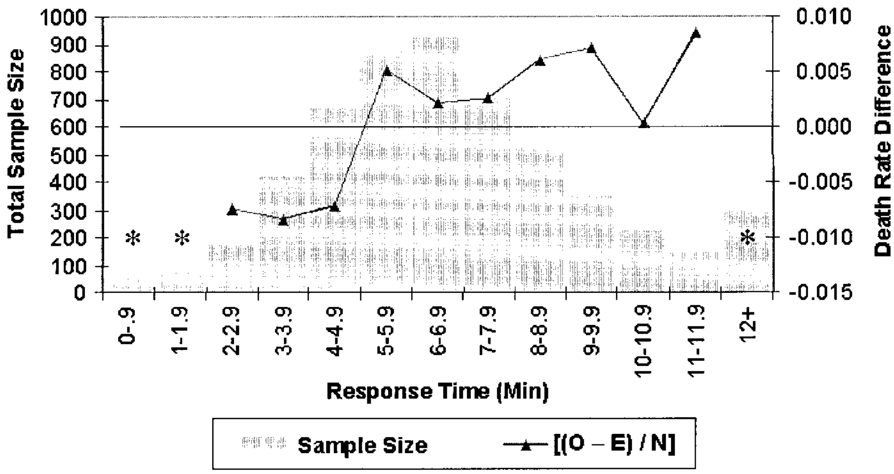

Figure 2. Observed (O) versus expected (E) death rates by response time interval. N = sample total. *No deaths observed in interval.

paramedic response. While each individual physician determined that 64, 68, and 69 patients, respectively, would not have benefited, all physicians universally agreed that 59 (83%) of the 71 nonsurvivors would not have benefited from an earlier response (Table 4). For the remaining 12 patients, 2 of the 3 physicians agreed in only 4 cases, and there was no case where all 3 physicians agreed that an earlier response would have affected outcome. Of interest, 4 of the 12 cases involved patients who were alive on EMS arrival, but progressed into cardiac arrest during hospital transport, thus reflecting minimal to no delay in treatment. It is important to note that the physicians based their opinions on the paramedic response and not that of first responders.

DISCUSSION

In the Charlotte-Mecklenburg community, response time specifications were assigned when the EMS system underwent a new management structure. Calls were assigned to one of three categories: emergency life-threatening, emergency non-life-threatening, and non-emergency. The compliance specifications were set for each level as described earlier. To determine the effectiveness of the emergent time standard, we reviewed all calls that were categorized and dispatched as emergency-life-threatening or emergency non-life-threatening, and in which the patient was transported to the specified hospital as a priority I or II. This subgrouping of patients would likely capture acutely ill or injured patients. When response times were compared with outcomes, the overall mortality risk was determined to be 1.31%, and there was no significant difference in median response times between survivors and nonsurvivors. Comparing actual and expected survival rates based on arbitrarily assigned response times, there was no statistically significant difference for times between 5 and 10 minutes, and no evidence to sug-

TABLE 4. Physicians' Opinions for Patients Potentially Benefiting from a 1-, 2-, and 3-minute Earlier Response Time

Patient Age	Injury/Illness*	Actual Response (Minutes:Seconds)	Number of Physicians 1 Min	2 Min	3 Min
48 yr	Witnessed asystole arrest	10:20			1
47 yr	VF arrest	5:24	1	1	2
51 yr	†Bradycardia to asystole arrest	8:15			2
68 yr	Bradycardia to asystole arrest	7:51		1	1
80 yr	†Witnessed PEA arrest	7:15		1	1
24 yr	†Gunshot wound to back	6:06			1
47 yr	Witnessed VF arrest	6:26		1	1
34 wk	Stillborn	8:01			2
76 yr	Witnessed asystole arrest	8:02			1
66 yr	Witnessed VT arrest	7:55			1
29 yr	†Asthma and witnessed VT arrest	6:53		1	2
44 yr	†Witnessed PEA arrest	6:20		1	1

*VF = ventricular fibrillation; VT = ventricular tachycardia; PEA = pulseless electrical activity.
†Witnessed arrest in the presence of emergency medical services (EMS) personnel.

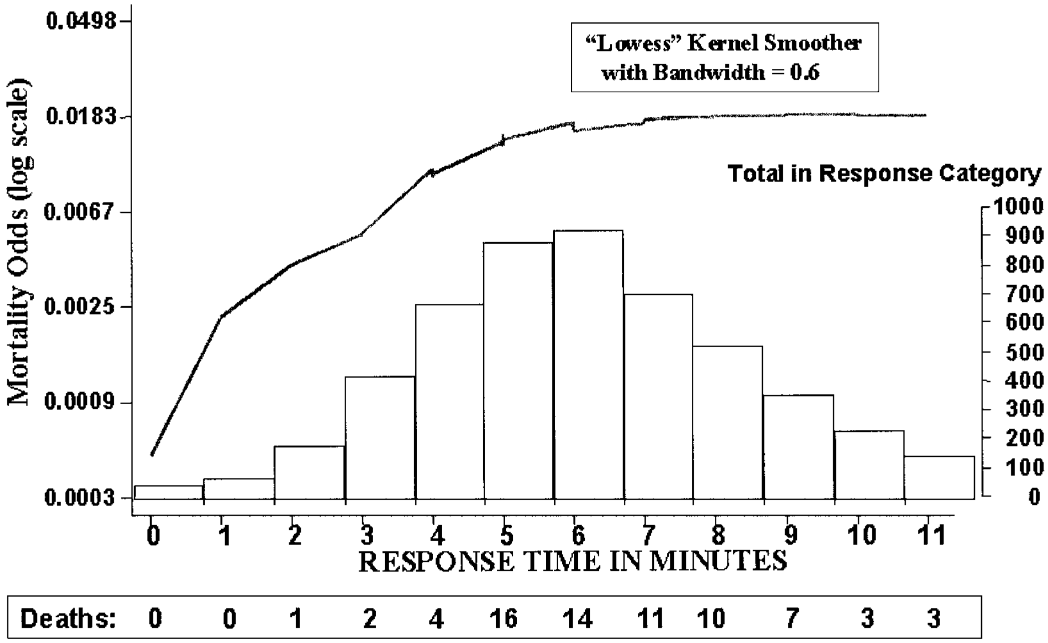

Figure 3. Smoothed mortality odds by emergency medical services (EMS) response time (Call to Scene): 71 deaths in 5,424 transports.

gest any dose–response trend in this region of the data. However, mortality risk appeared sensitive to response times less than 5 minutes in post-hoc analyses. Therefore, because the mortality risk curve flattened as response times exceeded 5 minutes and apparently remained essentially flat at greater response time values, there is no evidence in these data of a benefit associated with reducing response times from 10 to 9 minutes, 9 to 8 minutes, and so forth. There was some apparent evidence for a survival benefit associated only with response times less than 5 minutes.

Analysis of the nonsurvivor clinical information by trained emergency physicians demonstrated that a majority of cases were felt to involve conditions where an earlier response time would not have made a difference in eventual outcome. For the 12 cases where an earlier response of 1 to 3 minutes may have impacted survival, there were inconsistent conclusions obtained by the reviewers. Two of the 3 physicians agreed in only 4 cases. While simply descriptive in nature, this physician evaluation of response time and care provision suggests that the relation observed between higher survival probability and a shorter response time might not correspond to a medically plausible attribution of causality. In nearly all nonsurvivors, medical consensus suggested that the outcome would have been the same, even if the response time had been reduced to less than 5 minutes. Note that first responder data were not included in the analysis, because the purpose of this study was to estimate the effect of current ALS response time specifications on survival. First responders are dispatched for all priority I and priority II calls, thus most if not all calls studied included their response. Functioning at the EMT-D level, first-responder personnel in this community primarily provide basic life support (BLS) care, but are capable of providing some advanced procedures such as automated defibrillation and epinephrine administration via autoinjector. While overall clinical performance was not evaluated, the cases involving those who received early defibrillation by first responders were analyzed. Of the 71 nonsurvivors, 10 received early defibrillatory shocks by first responder personnel; 9 patients received one shock and 1 patient received six. None of the defibrillatory shocks resulted in a perfusing rhythm. Though early defibrillation was unsuccessful in the sample studied, it must be understood that other aspects of clinical care may have contributed to patient survival. Depending on system design, community needs, and resources, first responders may function at the BLS or ALS level. While clinical outcome may be affected by incorporating ALS first responders, this is a separate question, outside the scope of this research investigation. Although the global test for a relation between response time and survival to discharge was not statistically significant, power for this test was low, and post-hoc analyses were suggestive of a trend. Any estimation of lives saved by reducing response times by 1, 2, and 3 minutes would be imprecise due to the very small number of observed deaths in each 1-minute interval. Further, the cost–benefit ratio would clearly be very high compared with most plausible interventions. For example, if it arbitrarily costs $1 million in resources (vehicles, equipment, and personnel) to reduce all system responses by 1 minute, and this optimistically provides a savings of 6 lives per year (3 patients per 6 months), then the cost per life saved is $167,000. The average age of decedents in this study is 53 years, so even if it is assumed that this represents a savings of 20 years of life (the most optimistic estimate one might consider plausible), then the cost is $8,350 per year of life saved. By comparison, many typical medical and public health interventions have lower costs per year of life saved. Influenza vaccinations for all citizens totals $140 and pneumonia vaccination for senior citizens totals $2,200.[7]

Early ambulance services were provided by funeral homes and morticians, mostly as a service to families. Such services were manageable at the time, in that call volumes were much less than they are today. As modern EMS systems have matured over the past 25 to 30 years, the public appears to view services differently. Insomuch that EMS is still a vital necessity for unexpected emergencies, virtually all demographic groups frequently request EMS for diverse complaints.[8–10] Access to the EMS system is considered by some to be the initial entry into the health care system. Therefore, as more demand is placed on the out-of-hospital care system, resources must be augmented to meet the resultant volume expansion. As health care financing and managed care programs surface and continue to trim reimbursements, some providing incentives for care, EMS administrators are finding themselves analyzing all portions of the system to meet new demands of this changing environment. Managing resources with limited assets is the motivation of today's EMS managers. Regardless, patients sustaining unexpected acute injuries or illnesses clearly have a need for emergency medical response and care. Few would argue that rapid response with technically skilled personnel is paramount.

The response time interval, or interval from call receipt to patient care, is perhaps the most important graded component of the EMS system as viewed by hospitals, administrators, elected officials, the media, and the public. Response time standards tend to be publicized and many systems, especially those falling under the aegis of a public authority or utility, have compliance specifications for response. Such specifications may simply be one benchmark, whereas others may break down responses into categories based on acuity. Further, response times may be reported as averages; however, this is a poor reflection of performance. A more accurate description uses fractile response times. This illustrates the percentage of calls where responses were made within a certain time interval. For example, a system that reports a 90% fractile response time of 8 minutes, 30 seconds means that 90% of their responses were made in 8 minutes, 30 seconds or less.

The "perfect" or "standard" response time has yet to be determined, in that a specified response time objective in one location may not be applicable in other areas with diverse characteristics.[11,12] The recommendation of a 4-minute response for delivery of cardiopulmonary resuscitation, coupled with automatic defibrillation capability and 8 minutes for definitive care, has been proposed and continues to be advocated in an effort to achieve increased survival rates.[13–15] A similar philosophy has been adopted for responding to traumatic injuries. Minimizing the entire out of hospital time, including response, scene, and transport times, is considered beneficial for survival.[16–19] As an EMS system is activated, multiple components come into play, each working in concert with intramural (i.e., communications and operations) and extramural (i.e., first responders) system assets. Each of these components has the potential to directly or indirectly influence response times. While delays may occur at any point along a call continuum, several strategies exist for decreasing response times.[20] One simple, albeit costly, solution includes allocating more resources into the community. This proposal mandates a large initial outlay for capital improvements, coupled with the continuing personnel and sustainment costs. Another option may be to incorporate a first-responder tier whose personnel have the ability and capability to provide early defibrillation and airway management, or improving the dispatch component so that calls are prioritized and caller instructions are given.[21–23] Many EMS systems develop plans that strategically position ambulances throughout a response jurisdiction during certain hours of the day and days of the week. Such movement or posting strategies, referred to as systems status management, are typically based on historical call data, and are tailored to increase the probability that resources will be in close proximity to calls within high demand service areas during peak hours. From an operational perspective, while emergency vehicle operators must embrace a working knowledge of the response locality in order to be familiar with exact or proximate call location, vehicle mobile mapping programs are now available to assist in identifying scene locations. Such upgrades would intuitively shorten responses. Ancillary services, such as logistical management and fleet maintenance, must also function in concert to keep the system operational and efficient. In conclusion, any element failing to meet or support system needs increases the potential for prolonging a response and jeopardizing patient care.

LIMITATIONS AND FUTURE QUESTIONS

In addition to the limitations regarding the role of first responders discussed above, other limitations to this study include the retrospective and observational nature of study design and the small six-month sample size. Larger numbers of transported patients would provide more precise estimates of the relation between response time and survival, but would not remove bias due to any unmeasured confounding factors that may exist. The expected number of deaths in each response interval was calculated with the assumption that all transported patients took on the combined mortality risk of 1.31%, and ignored any potential for confounding demographic and geographic characteristics that might affect both response time and survival. Finally, this study included only patients transported to one hospital over a period of six months. Future research over extended periods and including more receiving facilities may reveal diverse results.

CONCLUSIONS

In this particular urban, metropolitan EMS system, there is little evidence to support the putative advantage of reducing the current adopted emergency response times of 10:59 and 12:59 minutes. Various analytic models of these data produce either modest gains or losses in mortality depending on the assumptions about how the intervention would affect the distribution of response times. More complex modeling of the dose–response relation will be possible when more data are available, but introduces further assumptions and caveats. While this study demonstrated a relation between RTs less than 5 minutes and improved survival, achieving this objective for the majority of life-threatening calls, even if it were possible, would incur extraordinary cost expenditure. It is conceivable that ambulances and paramedics could "saturate" a community, but at a cost that would clearly not justify the benefit. Each system's response intervals and times must be individually tailored to meet the needs of the community within the financial and political constraints inherent or imposed.

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