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A Meta-Analysis of Prehospital Care Times for Trauma

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Abstract

Background. Time to definitive care is a major determinant of trauma patient outcomes yet little is empirically known about prehospital times at the national level. We sought to determine national averages for prehospital times based on a systematic review of published literature. **Methods.** We performed a systematic literature search for all articles reporting prehospital times for trauma patients transported by helicopter and ground ambulance over a 30-year period. Forty-nine articles were included in a final meta-analysis. Activation time, response time, on-scene time, and transport time were abstracted from these articles. Prehospital times were also divided into urban, suburban, rural, and air transports. Statistical tests were computed using weighted arithmetic means and standard deviations. **Results.** The data were drawn from 20 states in all four U.S. Census Regions and represent the prehospital experience of 155,179 patients. Average duration in minutes for urban, suburban, and rural ground ambulances for the total prehospital interval were 30.96, 30.97, and 43.17; for the response interval were 5.25, 5.21, and 7.72; for the on-scene interval were 13.40, 13.39, and 14.59; and for the transport interval were 10.77, 10.86, and 17.28. Average helicopter ambulance times were response 23.25, on-scene 20.43, and transport 29.80 minutes. **Conclusions.** Despite the emphasis on time in the prehospital and trauma literature there has been no national effort to empirically define average prehospital time intervals for trauma patients. We provide points of reference for prehospital intervals so that policymakers can compare individual emergency medical systems to national norms. **Key words:** time; trauma; injuries; emergency medical services; aircraft; ambulances.

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Introduction

The concept of time has been a prominent, but incompletely researched, topic in the trauma literature since the Second World War.[1] The widespread idea of the "golden hour" highlights the immense importance of time to the trauma patient.[2–4] However, at the same time, the "golden hour" concept highlights our very limited understanding of what times, or intervals, are actually being used by local, state, and regional EMS systems in ensuring minimum standards of care for trauma patients.[5]

Rapid responses are believed to be surrogates for the quality of care provided to trauma patients.[6] Data demonstrating the need for rapid delivery of prehospital care has been done outside of the trauma population,[7–10] but the trauma literature remains divided on the issue.[3,11–20] Prehospital care is also influenced by public expectations. These expectations can heavily, but arbitrarily, influence the response time targets that any given state or municipality will set for itself. What is more, even small reductions in response time targets may be very costly to taxpayers (potentially in the form of additional vehicles and personnel) while providing uncertain benefits.

Guidelines and standards have been developed in jurisdictions throughout the country which mandate specific response and transport intervals for prehospital emergency responders.[17,18] However, there have been no attempts to estimate average prehospital time intervals. The meta-analysis reported here synthesizes 49 observational studies over a 30-year period to establish national averages for four important time intervals in the prehospital care of U.S. trauma patients. Our goal in doing this is to provide objective guidance to urban, suburban, and rural EMS planners in better assessing their systems' operational goals and performance relative to other, similar areas of the country. These data will guide internal system improvements and will better inform responses to public criticisms.

Methods

We systematically reviewed the English language literature for human studies that reported prehospital transport times for trauma. A total of 474 articles published from August 1975 to January 2005 were obtained from computer-based bibliographic databases and by hand searching the reference lists of included publications, review publications, and the subject indices of prominent journals. Two of the review publications were obtained from the computer-based search, and the remaining 10 were already in our personal files as referenced publications, books, conference proceedings, or government documents. When known and available, fugitive literature sources, such as government reports, were also included.[21] Computer-based searching contributed 436 articles (92.0%) and hand searching added an additional 38 articles (8.0%).

Computer-based bibliographic searches incorporated the MEDLINE, Cumulative Index to Nursing and Allied Health Literature (CINAHL), and Proquest Digital Dissertations automated search engines. For each search engine, medical subject headings (MeSH), abstracts (AB), text words (TW), and article titles (TI) were used to identify articles with the following Boolean search algorithm: ("MeSH: wounds and injuries" AND "AB,TW,TI: time" AND "AB,TW,TI: transport") OR ("MeSH: wounds and injuries" AND "AB,TW,TI: time" AND "AB,TW,TI: prehospital"). A keyword search was used instead of a MeSH search for Proquest. The separate results from MEDLINE, CINAHL, and Proquest were then reconciled for duplicate articles. The same algorithm was followed as closely as possible during hand searching of review publications and journal subject indices.

Seven additional criteria were used to limit the initial 474 articles. Articles involving only military personnel and/or outside the United States were excluded. Patient randomized trials were excluded as our goal was to observe the standard of care delivered rather than studies prospectively and deliberately altering care to test an intervention. Articles that only included nontrauma emergencies, interhospital transfers, and/or nontrauma center patients were excluded. Finally, articles that had no information, very limited information (i.e., only reporting elapsed time from arrival on-scene to administration of some treatment), or only gross information on prehospital transport time intervals (i.e., only reporting time from dispatch to trauma center arrival) were excluded. All systematic searches were conducted by one of our investigators with prior experience in conducting meta-analysis.[22]

Pooled estimates of effects that use different reports from the same study cohort are not independent and therefore violate the statistical assumptions that constitute the basis of the procedures for aggregating data.[21] To prevent this problem, the article list was sorted by location and study period and inspected for repetitive study populations. When these were found, it was our policy to keep the study with the largest subject population and the longest duration within a group of repetitive studies. This process eliminated no duplicate articles. From the initial article list, a final list of 49 articles (10.3% of the original 474) remained for our analysis.[11–13,18–20,23–65]

Data from the 49 articles were abstracted for specific time intervals, travel speeds, ambulance types, and urban-rural classification. Four smaller time intervals comprising the full prehospital care interval were abstracted: (1) an activation interval defined as the time from call was received to time of alarm; (2) a response time interval defined as the time from alarm to arrival on-scene; (3) an on-scene time interval defined as the time from on-scene arrival to departure; and (4) a transport time interval defined as the time from scene departure to arrival at a trauma center (Figure 1). All time intervals are reported here in minutes. All travel speeds are reported here in miles-per-hour.

Ambulance types were limited to ground ambulances of all reported types and helicopters. Both single response and tiered systems were included in this analysis. No reports of fixed-wing air ambulance

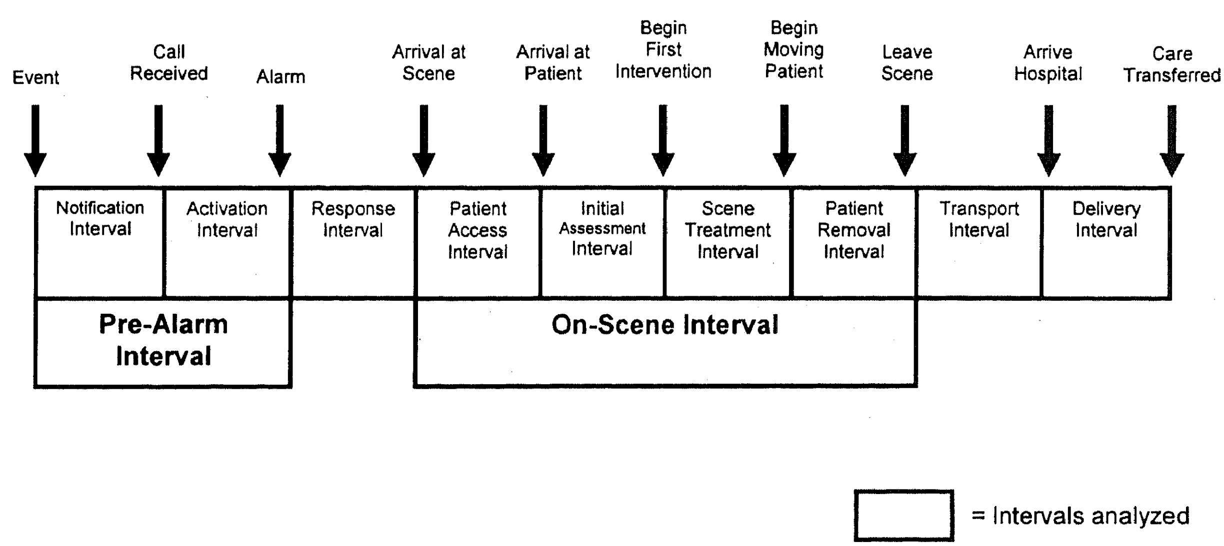

FIGURE 1. Specific intervals and points in time for trauma patients (adapted from Spaite et al.[54]).

transports were considered. Ground ambulance times were broadly divided into urban, suburban, and rural classifications. These classifications were based on statements made within the articles themselves (i.e., "our study setting was a suburban area") as well as on the reported study areas themselves for articles in which locations were reported by name. Named locations were assigned a classification using the U.S. Census Bureau's urban-rural classification criteria.[66]

All data were abstracted from the final articles by two of the study's investigators. Data collection forms were developed before the data abstraction began and were subsequently revised based on the results of pilot testing. Similar procedures have been previously used to enhance data reliability.[21,67]

A study identification number, date of publication, start and end years of study, median study year (the midpoint between start and end years), location of study, number of subjects, ambulance types, time intervals, and travel speeds were recorded for each final article. One primary reviewer abstracted data from all 49 articles. In an effort to assess interabstractor reliability before the final data were analyzed, each article was then independently reabstracted by the second investigator.[21] The authors, institutional affiliations, journal of publication, and funding sources for each study were removed and replaced with a number for identification. The initial proportion of agreement between the primary and secondary reviewers was 81.6%. Differences between reviewers were discussed, and abstracted data were reconciled before the final analysis was performed.[68] After reconciling differences, the primary and secondary reviewers agreed on 100% of the numbers abstracted from the 49 articles.

Information for a specific time interval from a specific article was not recorded if it was collectively determined by both abstractors that none was ascertainable. Cumulative statistics were calculated for numbers of articles and numbers of subjects within ambulance and time interval categories as well as within ambulance categories by travel speed. Means, weighted by the number of study subjects, were calculated within ambulance and time interval categories as well as within ambulance categories by travel speed. We calculated weighted arithmetic means,[69] as opposed to standard arithmetic means, since the article lists in every category demonstrated highly variable numbers of study subjects. Weighted means allowed studies with greater patient experience to more heavily influence our pooled time interval and travel speed estimates. We correspondingly calculated weighted variances and standard deviations.[70] Weighted means and weighted standard deviations were then used to perform statistical comparisons with Student's t tests.

Weighted means and standard deviations were calculated for the overall study period as well for two 15-year subperiods, 1975–1989 and 1990–2005. Fifteen year subperiods were selected because they were the midpoint of the data. An article's study cohort was assigned to one of the two time periods based on its median study year. All data were managed with the use of Microsoft Excel 2002 (Microsoft Corporation; Redmond, WA). Descriptive and comparison statistics were calculated using SPSS for Windows Release 11.1 (SPSS, Incorporated, Chicago, IL). The study was approved by our Institutional Review Board.

RESULTS

The 49 articles involved in this meta-analysis represent over 30 years of prehospital care time interval data, from August 1975 to January 2005. The data include 25 articles from the surgical literature, 12 articles from the emergency medicine literature, eight articles from the prehospital care literature, and four remaining articles from other sources including general medicine, operations research, rural health, and government publications.

In total, the 49 articles included in the final analysis represented the prehospital care experience of 155,179 patients. Some of the 49 articles reported only one time interval whereas others reported multiple time intervals as part of their analyses. A total of 11 (22.5%) articles provided data on activation intervals, 22 (44.9%) provided data on response intervals, 38 (77.6%) provided data for on scene intervals, and 29 (59.2%) provided data on transport intervals. Most of the articles reported time intervals for urban ground transport followed in order by helicopter transport, suburban ground transport, and rural ground transport (Table 1).

A total of 3 articles provided average speed for helicopter transport, and 4 articles provided average speed for ground transport. Based on these articles,

TABLE 1. Cumulative Numbers of Articles and Study Subjects for Prehospital Care Intervals of Helicopter and Ground Ambulance Transport of Trauma Patients

	Helicopter Ambulance	Urban Ground Ambulance	Suburban Ground Ambulance	Rural Ground Ambulance
Activation interval				
Articles	9	3	3	4
Subjects	2,281	105,145	105,145	6,846
Response interval				
Articles	3	15	6	9
Subjects	1,347	111,203	106,073	8,698
On-Scene interval				
Articles	11	25	8	10
Subjects	4,047	139,866	127,850	30,047
Transport interval				
Articles	5	21	8	11
Subjects	2,093	132,806	127,409	30,055
Totals				
Articles	17	30	12	14
Subjects	5,626	143,462	129,418	31,443

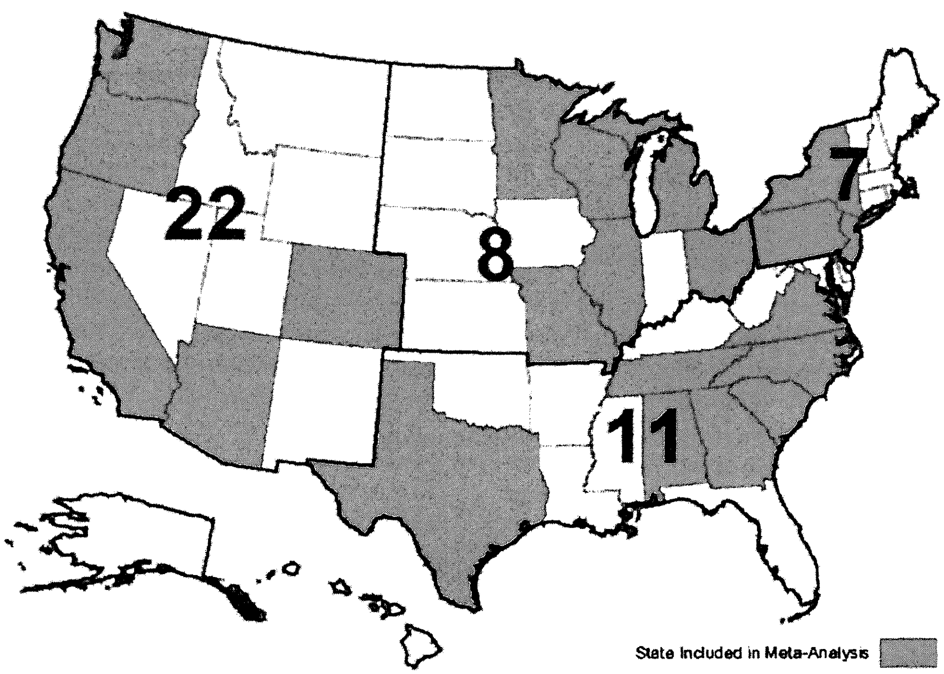

FIGURE 2. State and regional representation as well as the number of articles per Census region (one article was countrywide and is not included here).

we estimated an average helicopter transport speed of 142.6 miles-per-hour, an average urban ground transport speed of 20.1 miles-per-hour, an average suburban ground transport speed of 47.5 miles-per-hour, and an average rural ground transport speed of 56.4 miles-per-hour.

The articles involved in the analysis were widely distributed around the United States. The 20 states from which the articles were drawn encompassed 69.2% of the U.S. population. These states are generally illustrative of the overall U.S. population demographic; all four census regions, northeast, midwest, south, and west, are represented in the analysis (Figure 2).

All helicopter ambulance time intervals (activation, response, on-scene, and transport) were significantly longer, on average, than those for urban, suburban, and rural ground ambulances ($p < 0.01$). No statistically significant differences were noted between urban and suburban intervals with the exception of the transport interval where the mean urban time, 10.78 minutes, was significantly less than the mean suburban time, 10.89 minutes ($p < 0.05$). All urban and suburban ground ambulance time intervals (activation, response, on-scene, and transport) were significantly shorter, on average, than those for rural ground ambulances ($p < 0.01$). (Table 2)

Total prehospital care time intervals for helicopter ambulances increased from the first time period, 1975–1989, to the second, 1990–2005. In contrast, total prehospital care time intervals for all three categories of ground ambulances (urban, suburban, and rural) decreased from the first time period to the second. Response and transport intervals demonstrated significant reductions in time from the first period to the second from urban, suburban and rural ground ambulances ($p < 0.01$). On-scene time intervals also significantly decreased among helicopter as well as urban, suburban, and rural ground ambulances from the first time period to the second ($p < 0.01$).

DISCUSSION

The idea of rapid transport of trauma patients to definitive care facilities has its roots in military medicine. From Napoleon's "ambulances volantes" to the use of helicopter ambulances in the Korean and Vietnam war, there has long been an emphasis on decreasing prehospital time.

The National Academy of Sciences and the National Research Council stimulated the passage of the Emergency Medical Services (EMS) Systems Act (PL 93-154) in 1973.[71] At that time, coronary artery disease and trauma were responsible for a significant number of preventable deaths as patients who required time sensitive treatments were receiving delayed care.[72] The EMS Act of 1973 set several standards in emergency care but made no specific recommendations with respect to prehospital time intervals.[73] In 2003 a National Association of EMS Physicians position paper acknowledged that response and transport time intervals have regional variability and, therefore, must be locally determined, but likewise offered no standards.[74]

The first definitive mention of a standard for prehospital care time grew out of the recognition that cardiac arrest victims have improved outcomes if they receive

TABLE 2. Weighted Means and Standard Deviations for Prehospital Care Intervals of Helicopter and Ground Ambulance Transport of Trauma Patients

	Helicopter Ambulance	Urban Ground Ambulance	Suburban Ground Ambulance	Rural Ground Ambulance
Activation interval (mins)				
Overall	3.53 ± 3.81	1.40 ± 1.41	1.40 ± 1.41	2.89 ± 1.64
1975–1989	4.15 ± 2.53	na	na	na
1990–2005	3.26 ± 5.15	1.40 ± 1.41	1.40 ± 1.41	2.89 ± 1.64
Response interval (mins)				
Overall	22.27 ± 29.01	5.28 ± 7.46	5.23 ± 20.04	7.86 ± 7.35
1975–1989	18.39 ± 20.17	6.48 ± 4.88	7.20 ± 7.48	9.02 ± 8.97
1990–2005	23.25*	5.25 ± 8.98	5.21 ± 28.32	7.72 ± 7.82
On-Scene interval (mins)				
Overall	21.60 ± 18.90	13.50 ± 3.71	13.45 ± 21.80	15.06 ± 16.80
1975–1989	23.03 ± 21.45	18.10 ± 6.65	21.08 ± 25.49	28.57 ± 33.67
1990–2005	20.43 ± 20.98	13.40 ± 3.56	13.39 ± 22.02	14.59 ± 16.16
Transport interval (mins)				
Overall	25.50 ± 30.29	10.78 ± 4.29	10.89 ± 17.89	17.37 ± 19.40
1975–1989	14.16 ± 12.63	11.19 ± 3.34	14.24 ± 15.64	19.81 ± 22.21
1990–2005	29.80 ± 57.48	10.77 ± 4.44	10.86 ± 18.20	17.28 ± 19.70
Totals (mins)				
Overall	72.91	30.96	30.97	43.17
1975–1989	59.73	35.76	42.51	57.40
1990–2005	76.74	30.81	30.86	42.48

All mean differences between time periods were statistically significant ($p < 0.01$); na = no articles available; * one article available.

Basic Life Support (BLS) within 4 minutes and Advanced Life Support (ALS) within 8 minutes.[7] The association between shorter response time intervals and improved cardiac arrest survival rates has been repeatedly demonstrated and has subsequently become an international standard for urban EMS systems.[8,9,75]

Unlike cardiac arrest victims, the impact of response time intervals on morbidity and mortality for trauma patients is less clear. The available literature inconsistently grades different types of trauma and the idea of the golden hour remains largely unsubstantiated.[5] There also remains debate about the degree to which trauma patients should be stabilized by prehospital emergency medical providers prior to transport to a trauma center. The American College of Surgeons Advanced Trauma Life Support manual strongly encourages rapid transport to a trauma center and specifically calls for minimizing the on-scene time interval.[76] Evidence exists to suggest that decreased on-scene time leads to improved outcomes for trauma victims.[3,11–16,77] Evidence also suggests that patients receiving aggressive out-of-hospital resuscitation and stabilization may do better but often require longer on-scene time intervals.[17–20]

Time Intervals

Sorting out different subintervals within the overall prehospital time interval is important in all time-sensitive illnesses, both nontraumatic and traumatic. Whereas the time to defibrillation is the most important interval in unstable cardiac rhythms, the relative importance of time intervals to trauma patients is less clearly understood. Targeted strategies are required to modify the activities that take place during different time intervals. Despite recommendations for the standardization of prehospital time intervals,[51,78,79] their measurement and the manner in which they are reported in the literature has not been standardized.

This paper provides a point of reference for prehospital time intervals across the United States. Our analysis used four time intervals: activation, response, on-scene, and transport time intervals. These time intervals are comprised of discrete activities and were dictated in large part from data provided by the articles included in the meta-analysis.

The activation time interval is primarily determined by dispatchers' training and competence, communication systems, and emergency responder readiness. There is variability among systems as some systems dispatch police or first responder BLS units first and call for ALS units once it is determined that their services are required. This model would artificially increase the time from the initial call until the time the ALS unit was dispatched. To avoid artificially increased activation times it was our practice to report the activation time interval for the first unit dispatched to the scene. We found that urban and suburban units had similar lengths of time during this interval. Rural units and helicopter ambulances had substantially longer time intervals. This difference was likely associated with volunteer crews, off-site personnel, and/or less frequent calls which result in increased preparation time. Comparatively, the increased time required for helicopter transport was most likely related to the additional time required to ensure flight safety and readiness.

The response time interval is directly affected by distance to an incident and the maximum speed at which an ambulance can safely travel including traffic and roadway conditions. Again we found that urban and suburban intervals were similar despite the fact that suburban ambulances traveled at more than twice the average speed of their urban counterparts. Rural ambulances took substantially longer to arrive on scene despite traveling an average of almost 10 mph faster than suburban ambulances.

The on-scene time interval of ambulance crews was similar across urban, suburban, and rural areas. The amount of time spent on-scene is dependent on extrication time, the number of stabilizing maneuvers attempted, the number of responders on scene, and the time required to safely prepare the patient for transport. Again the presence of tiered systems plays a role in this interval. Initial responders awaiting the presence of ALS or helicopter personnel would increase on-scene time intervals. As discussed, there is significant debate over whether the "scoop and run" or the "stay and stabilize" approach is preferred for trauma patients. Our analysis also demonstrates that the amount of on-scene time for helicopter ambulances was significantly longer than for ground ambulances. Moreover, our findings of an average on-scene interval of 13–15 minutes for ground ambulance crews is substantially longer than the short time period generally recommended.[6] It is unknown if this is specific to the trauma patient or if a misunderstanding exists about the amount of time required to stabilize the patient and prepare for transport.

Geographic distribution played an important role in the transport time interval. Urban ground ambulance transport times were shortest, followed by suburban ground ambulances, while rural ground ambulances were found to be substantially longer. Air ambulances had longer transport times than all ground ambulances. The transport time interval is largely controlled by distance, road conditions, and speed. Moreover, despite the importance given to time in the trauma literature, many traumatically injured patients are not transported to the closest available hospital but to the closest available trauma center hospital. This is often clinically indicated as many trauma patients require a level of care that can not be provided in local, nontrauma center hospitals.[80] However, it is often unknown if patients who are correctly triaged to regional trauma centers suffer from the prolonged transport time intervals associated with bypassing the nearest hospital.

The discussion of the importance of time in the EMS system would not be complete without an analysis of how prehospital times have evolved over the development of organized prehospital and trauma care systems. Based on our analysis, in the post-1990 period, total prehospital care time intervals decreased for all categories of ground ambulances. Comparatively, for helicopter ambulances total prehospital care time increased in the post-1990 period while the on-scene interval decreased. We suspect that the increased utilization and range of helicopter ambulances for transport to regional trauma centers both helped to decrease average suburban and rural ground transport times, and account for the increase in their overall time.

Limitations

A barrier in discussing prehospital care intervals is the varied geography and population of the United States. In terms of generalizability, the articles included here represent a reasonable cross-section of regions, states and demographics in the United States. More specifically, this meta-analysis provides average response times broken down by rural, suburban, and urban EMS systems. However, differences between systems as well as the inherent differences in care delivery in urban and rural environments made local averages difficult to extract and national averages difficult to interpret. A particular weakness of our analysis was our limited ability to distinguish between urban and suburban populations. Despite this however, our breakdown between urban, suburban, and rural prehospital times remains the first of its kind on a national level and can serve to motivate future studies in better distinguishing between these three areas.

Another limitation to our study is the absence of uniformity in the reporting of prehospital care time intervals. Most of the articles used in this analysis reported transport time as just one part of a larger analysis. As a result, there was variation in the data reported across the sources included here. Uniform triage criteria do not exist nationally so we allowed the prehospital systems themselves to define what constitutes a trauma patient. In addition, strict definitions of prehospital time intervals and conformity to existing definitions could not be controlled as inconsistencies exist within the literature reviewed for this analysis. These data inconsistencies made comparing, compiling, and stratifying the quality of the articles challenging. Although we were able to successfully wade through and synthesize different definitions and reporting of prehospital care intervals, future studies reporting prehospital care time intervals should follow the model initially outlined more than 10 years ago[51,78] that we used here, or the model recently endorsed by the National Fire Protection Association.[79]

As with all meta-analyses, our study also potentially suffers from publication bias. That is, studies that may have value to our analysis may not have been published because they may have been seen as having low-impact, or negative findings. For instance, EMS systems with unusually long transport times may have been less likely to publish their findings. Our study thus represents only analyses that were performed and then published. This may mean that our numbers are, if anything, underestimates of true prehospital time intervals.

CONCLUSIONS

Standardized prehospital time intervals are used in the evaluation and research programs of many trauma systems.[81] These systems often function on the belief that ever-reduced prehospital care intervals lead to improved patient outcomes. However, until this study, no empirical, generalizable standards have been reported that give trauma and EMS systems the ability to compare their prehospital care intervals to averages nationally or in comparable geographic areas (urban, suburban, and rural). The nationally representative prehospital intervals provided here will help guide clinical decision-makers in better allocating trauma system resources. The intervals provided reflect average prehospital transport times for trauma patients over the last 30 years. In addition, the results reported here emphasize a need for a standardized method of gathering prehospital time intervals, both as a means to more accurately compare trauma systems as well as to facilitate more precise research on trauma outcomes. Our findings may also help in identifying trauma triage rules that are more sensitive to prehospital time constraints as well as the corresponding locations of trauma centers and ambulances that provide faster access to trauma centers for injured patients.

Prehospital time intervals are used by elected officials and the public as markers for the quality of prehospital care. Rapid availability of prehospital and trauma center care are among the most important predictors in overall public satisfaction with municipal emergency services.[82–85] Public expectations of the speed at which emergency personnel should respond are high and citizen tolerance for response time delay has become limited.[86] Prehospital time interval policies based on a perceived benefit to trauma patients, without prescribed guidelines, may lead to unrealistic expectations. The national averages we present here will help public officials set reasonable prehospital time intervals for their jurisdictions and, hopefully, prevent the stresses incurred when striving for indefinitely faster and perhaps impossible standards.

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