FIRE FIGHTER SAFETY AND DEPLOYMENT STUDY

Report on
EMS Field Experiments

Lori Moore-Merrell
Rob Santos
Doug Wissoker
Ron Benedict
Nicole Taylor
Randy Goldstein
Greg Mears
Jane Brice
Jason D. Averill
Kathy Notarianni

NIST National Institute of Standards and Technology U.S. Department of Commerce
International Association of Fire Chiefs
IAFF AFL-CIO CLC
WPI
CFAI RISK
URBAN INSTITUTE
UNC SCHOOL OF MEDICINE
EMSpic PERFORMANCE IMPROVEMENT CENTER

September 2010

Report on EMS Field Experiments

Lori Moore-Merrell
Rob Santos
Doug Wissoker
Ron Benedict
Nicole Taylor
Randy Goldstein
Jane Brice
Greg Mears
Jason D. Averill
Kathy Notarianni

FIRE FIGHTER SAFETY AND DEPLOYMENT STUDY

Certain commercial entities, equipment, or materials may be identified in this document in order to describe an experimental procedure or concept adequately. Such identification is not intended to imply recommendation or endorsement by the partner organizations, nor is it intended to imply that the entities, materials, or equipment are necessarily the best available for the purpose.

Produced with the Cooperation of
Montgomery County, Maryland
Fire and Rescue, Department
Chief Richard Bowers

Produced with the Cooperation of
Fairfax County, Virginia
Fire and Rescue Department
Chief Ronald Mastin

Funding provided through DHS/FEMA Grant Program Directorate for FY 2008
Assistance to Firefighters Grant Program – Fire Prevention and Safety Grants
(EMW-2008-FP-01603)

NIST
National Institute of
Standards and Technology
U.S. Department of Commerce

IAFC
International Fire Chiefs Association
Org. 1873

IAFF
AFL-CIO CLC

WPI
Worcester Polytechnic Institute 1865

CFAI RISK

URBAN INSTITUTE

UNC
SCHOOL OF MEDICINE

EMSpic
PERFORMANCE IMPROVEMENT CENTER

Table of Contents

Abstract

The fire service has become the first line medical responder for all types of medical emergencies in the majority of the United States. Fire departments typically deliver first-on-scene, out-of-hospital care services, regardless of whether or not they provide transport. The design of fire department-based Emergency Medical Services (EMS) systems varies across communities. Some departments deploy only Basic Life Support (BLS) units and personnel, some deploy a mix of BLS and Advanced Life Support (ALS) units and personnel, and a few departments operate solely at an ALS level. Additionally, the number of total personnel dispatched on an EMS call also differs. This number is dependent on factors such as the type of system resources, the nature of the EMS incident, and the number of simultaneous and concurrent incidents.

For the first time, this study investigates the effects of varying crew configurations for first responders, the apparatus assignment of ALS personnel, and the number of ALS personnel on scene on the task completion times for ALS level incidents. This study is also unique because of the array of stakeholders and the caliber of technical experts involved. Throughout the experiments, all industry standards and safety protocols were followed and robust research methods were used. The results and conclusions will directly inform the NFPA 1710[1] and NFPA 1720 Technical Committees, who are responsible for developing industry operational and deployment standards.

This report presents the results of more than 102 field experiments designed to quantify the effects of various fire department-based EMS deployment configurations for three different scenarios—-1) patient access and removal from the incident scene, 2) a victim of systemic trauma due to a long distance fall and 3) a patient with chest pain leading to a cardiac arrest. In addition to systematically controlling for arrival times of units, first responder crew size was varied to consider two-, three-, and four-person staffing. ALS personnel configuration for both the first responder unit and ambulance transport unit were also varied for purposes of the experiments. In each deployment, personnel performed a series of defined tasks consistent with the scenario being evaluated. Report results quantify the effectiveness of crew size, ALS configuration, and the number of ALS personnel on the start, duration, and completion time of all tasks delineated in the three scenarios. Conclusions are drawn from statistically significant results.

Executive Summary

Increasing demands on the fire service, including the rising number of EMS responses, point to the need for scientifically-based studies on the effect of first responder crew size, Advanced Life Support configuration, and the number of Advanced Life Support (ALS) personnel on scene on the safety of responders, as well as the operational efficiency and effectiveness of fire departments responding to emergency medical incidents. To address this need, a research partnership of the Commission on Fire Accreditation International (CFAI), International Association of Fire Chiefs (IAFC), International Association of Fire Fighters (IAFF), National Institute of Standards and Technology (NIST), and Worcester Polytechnic Institute (WPI) was formed to conduct a multiphase study of firefighter safety and the deployment of resources. A portion of that study, as reported here, includes an assessment of time-to-tasks for EMS incidents.

Beginning in FY 2005, funding was provided through the Department of Homeland Security (DHS)/ Federal Emergency Management Agency (FEMA) Grant Program Directorate for Assistance to Firefighters Grant Program-Fire Prevention and Safety Grants. In addition to the EMS field experiments described in this report, the multiple phases of the overall research effort include development of a conceptual model for community risk assessment and deployment of resources, implementation of a generalizable department incident survey, and delivery of a software tool to quantify the effects of deployment decisions on resultant firefighter and civilian injuries and on property losses.

The first phase of the project was an extensive survey of more than 400 career and combination (both career and volunteer) fire departments in the United States with the objective of optimizing a fire service leader's capability to deploy resources to prevent or mitigate adverse events that occur in risk- and hazard-filled environments. The results of this survey are not documented in this report, which is limited to the EMS experimental phase. The survey results will constitute significant input into the development of a future software tool to quantify the effects of community risks and associated deployment decisions on resultant firefighter and civilian illnesses and injuries.

The National Fire Protection Association estimates that 10,380 EMS workers were exposed to infectious diseases in 2008 (Karter, 2009). Another study noted that almost 10 % of Emergency Medical Technicians (EMTs) and Paramedics miss work at any given time due to job-related illness or injury (Studnek et al, 2007). Another study noted that injury rates for EMS workers are higher than rates reported by the Department of Labor (DOL) for any other industry in 2000 (Maguire et al, 2005) and another study noted that EMS providers have a high risk for occupational injury, with approximately 25 % of workers reporting at least one work-related injury in the previous six months. Many of these injuries were the result of falls or lifting patients (Heick, 2009). Funding and additional research are critical to further defining the high risks to firefighters during EMS responses and developing interventions to mitigate this serious problem.

In order to address the primary research questions using realistic scenarios, the research was divided into three distinct, yet interconnected parts.

- Part 1 — Time-to-task experiments related to gaining access to a patient and removing the patient from the incident scene.
- Part 2 — Time-to-task experiments related to the care of a victim with multi-system trauma.
- Part 3 — Time-to-task experiments related to the care of a victim with chest pain and witnessed cardiac arrest.

These parts included the most basic elements of an overall EMS response, which are — access the patient, conduct patient assessment, deliver on scene patient care, package the patient, and remove the patient from the scene to a transport-capable vehicle.

Scope

The EMS portion of the Firefighter Safety and Deployment of Resources Study was designed solely to assess the personnel number and configuration aspect of an EMS incident for responder safety, effectiveness, and efficiency. This study does not address the efficacy of any patient care intervention. This study does however quantify first responder crew size, i.e., the number and placement of ALS trained personnel resources on the time-to-task measures for EMS interventions. Upon recommendation of technical experts, the investigators selected trauma and cardiac scenarios to be used in the experiments as these events are resource intensive and will likely reveal relevant differences in regard to the research questions. The applicability of the conclusions from this report to a large-scale hazardous or multiple-casualty event has not been assessed and should not be extrapolated from this report.

EMS protocols pertaining to the treatment and transport of patients vary by departments. For the purpose of this study, apparatus arrival times and on scene tasks were standardized by technical experts. Individual performance times were recorded for each task. Response data from more than 300 United States Fire Departments show that when dispatched simultaneously, a first responder arrives prior to an ambulance in approximately 80 % of EMS responses, (IAFC/IAFF, 2005). Therefore, arrival times of the first responder engine and the ambulance were staggered. Additionally, in real-world situations, as in this study, many of the tasks can be performed simultaneously based on the number and training level of responding personnel. Attempts to generalize the results from these experiments to individual departments must take into account response and patient care protocols and equipment that may vary from those used in the experiments.

Primary Findings

The objective of the experiments was to determine how first responder crew size, ALS provider placement, and the number of ALS providers is associated with the effectiveness of EMS providers. EMS crew effectiveness was measured by task intervention times in three scenarios including patient access and removal, trauma, and cardiac arrest. The results were evaluated from the perspective of firefighter and paramedic safety and scene efficiency rather than as a series of distinct tasks. More than 100 full-scale EMS experiments were conducted for this study.

Hundreds of firefighters and paramedics are injured annually on EMS responses. Most injuries occur during tasks that require *lifting or abnormal movement* by rescuers. Such tasks include lifting heavy objects (including human bodies both conscious and unconscious), manipulating injured body parts and carrying heavy equipment. Several tasks included in the experiments fall into this category, including splinting extremities, spinal immobilization (back boarding) and patient packaging. Similar to the lifting or heavy workload tasks, larger crews were able to complete the labor intensive tasks using multiple crew members on a single task to assure safe procedures were used reducing the likelihood of injury or exposure.

A number of tasks are also *labor intensive*. These tasks can be completed more efficiently when handled by multiple responders. Several tasks in the experiments are in this category. These include checking vital signs, splinting extremities, intubation with spinal restriction, establishing I.V. access, spinal immobilization, and patient packaging. During the experiments larger crews completed these tasks more efficiently by distributing the work load among more people thereby reducing the likelihood of injury.

Finally, there are opportunities on an EMS scene to reduce scene time by completing tasks simultaneously rather than sequentially thus increasing operational efficiency. For the experiments, crews were required to complete all tasks in each scenario regardless of their crew size or configuration. Therefore, patterns in task start times and overall scene times reveal operational efficiencies. When enough hands are available at the scene to complete tasks simultaneously, this leads to overall time reductions relative to smaller crews that are forced to complete tasks sequentially.

Patient Access and Removal

With regard to accessing the patient, crews with three or four first responders reached the patient around half a minute faster than smaller crews with two first responders. With regard to completing patient removal, larger first responder crews in conjunction with a two-person ambulance were more time efficient. The removal tasks require heavy lifting and are labor intensive. The tasks also involve descending stairs while carrying a patient, carrying all equipment down stairs, and getting patient and equipment out multiple doors, onto a stretcher and into an ambulance.

The patient removal results show substantial differences associated with crew size. Crews with three- or four-person first responders complete removal between 1.2 – 1.5 minutes faster than smaller crews with two first responders. All crews with first responders complete removal substantially faster (by 2.6 - 4.1 minutes) than the ambulance-only crew.

These results suggest that time efficiency in access and removal can be achieved by deploying three- or four-person crews on the first responding engine (relative to a first responder crew of two). To the extent that each second counts in an EMS response, these staffing features deserve consideration. Though these results establish a technical basis for the effectiveness of first responder crews and specific ALS crew configurations, other factors contributing to policy decisions are not addressed.

Trauma

Overall, field experiments reveal that four-person first responder crews completed a trauma response faster than smaller crews. Towards the latter part of the task response sequence, four-person crews start tasks significantly sooner than smaller crews of two or three persons.

Additionally, crews with one ALS provider on the engine and one on the ambulance completed all tasks faster and started later tasks sooner than crews with two ALS providers on the ambulance. This suggests that getting ALS personnel to the site sooner matters.

A review of the patterns of significant results for task start times reinforced these findings and suggests that (in general) small non-significant reductions in task timings accrue through the task sequence to produce significantly shorter start times for the last third of the trauma tasks.

Finally, when assessing crews for their ability to increase on-scene operational efficiency by completing tasks simultaneously, crews with an ALS provider on the engine and one ALS provider on the ambulance completed all required tasks 2.3 minutes (2 minutes 15 seconds) faster than crews with a BLS engine and two ALS providers on the ambulance. Additionally, first responders with four-person first responder crews completed all required tasks 1.7 minutes (1 minute 45 seconds) faster than three-person crews and 3.4 minutes (3 minutes and 25 seconds) faster than two-person crews.

Cardiac

The overall results for cardiac echo those of trauma. Regardless of ALS configuration, crews responding with four first responders completed all cardiac tasks (from at-patient to packaging) more quickly than smaller first responder crew sizes. Moreover, in the critical period following cardiac arrest, crews responding with four first responders also completed all tasks more quickly than smaller crew sizes. As noted in the trauma scenario, crew size matters in the cardiac response.

Considering ALS placement, crews responding with one ALS provider on both the engine and ambulance completed all scene tasks (from at-patient to packaging) more quickly than a crew with a BLS engine and two ALS providers on the ambulance. This suggests that ALS placement can make a difference in response efficiency. One curious finding was that crews responding with a BLS engine and an ambulance with two ALS providers completed the tasks that follow cardiac arrest 50 seconds *sooner* than crews with an ALS provider on both the engine and ambulance. As noted, this counter-intuitive difference in the results may be attributable to the delay of the patient arrest time based on the arrival of the 12-Lead ECG monitor with the two-person ALS Ambulance crew. The 12-Lead ECG task *end time* was the arrest *start time*. In this scenario, there were instantaneously two ALS providers present at the arrest rather than the one ALS provider placing the 12-Lead ECG device in the ALS engine /ALS Ambulance crew.

A review of the patterns of significant findings across task start times showed mixed results. An ALS on an engine showed an advantage (sooner task starting times) over an ALS on an ambulance for a few tasks located earlier in the cardiac response sequence (specifically, ALS Vitals 12-Lead through IV access). A first responder with four-person crew also showed shorter start times for a few early tasks in the cardiac response sequence (initial airway, breathing and circulation (ABCs), and the ALS Vitals 12-Lead and expose chest sequence). More importantly, a sequential time advantage appears for the last three tasks of the sequence (analyze shock #2 through package patient).

Finally, when assessing crews for their ability to increase on-scene operational efficiency by completing tasks simultaneously, crews with an ALS provider on the engine and one ALS provider on the ambulance completed all required tasks 45 seconds faster than crews with a BLS engine and two ALS providers on the ambulance. Regardless of ALS configuration, crews responding with four first responders completed all cardiac tasks from the 'at patient time' to completion of packaging 70 seconds faster than first responder crews with three persons, and 2 minutes and 40 seconds faster than first responder crews with two persons. Additionally, *after the patient arrested*, an assessment of time to complete remaining tasks revealed that first responders with four-person crews completed all required tasks 50 seconds faster than three-person crews and 1.4 minutes (1 minute 25 seconds) faster than two-person crews.

Summary

While resource deployment is addressed in the context of three basic scenarios, it is recognized that public policy decisions regarding the cost-benefit of specific deployment decisions are a function of many factors including geography, resource availability, community expectations as well as population demographics that drive EMS call volume. While this report contributes significant knowledge to community and fire service leaders in regard to effective resource deployment for local EMS systems, other factors contributing to policy decisions are not addressed. The results, however, do establish a technical basis for the effectiveness of first responder crews and ALS configuration with at least one ALS level provider on first responder crews. The results also provide valid measures of total crew size efficiency in completing on-scene tasks some of which involve heavy lifting and tasks that require multiple responders to complete.

These experimental findings suggest that ALS provider placement and crew size can have an impact on some task start times in trauma and cardiac scenarios, especially in the latter tasks leading to patient packaging. To the extent that creating time efficiency is important for patient outcomes, including an ALS trained provider on an engine and using engine crew sizes of four are worth considering. The same holds for responder safety – for access and removal and other tasks in the response sequence, the availability of additional hands can serve to reduce the risks of lifting injuries or injuries that result from fatigue (e.g., avoid having small crews repeatedly having to ascend and descend stairs).

Background

In recent years, the provision of emergency medical services has progressed from an amenity to a citizen-required service. Today more than 90 % of career and combination fire departments deliver emergency medical care services, making fire departments the largest group of providers of prehospital EMS in North America. Fire department operations are geared to rapid response, whether it is for EMS, resuce, or fire suppression. In many jurisdictions, EMS responses equate to over 75 % of a fire departments call volume. EMS deployment decisions are therefore a critical driving factor for any department considering both short and long term resource deployment decisions.

The National Fire Protection Association estimates that 10,380 EMS workers were exposed to infectious diseases in 2008 (Karter, 2009). Another study noted that almost 10 % of EMTs and Paramedics miss work at any given time due to job-related illness or injury (Studnek et al, 2007). Another study noted that injury rates for EMS workers are higher than rates reported by the Department of Labor (DOL) for any other industry in 2000 (Maguire et al, 2005) and another study noted that EMS providers have a high risk for occupational injury, with approximately 25 % of workers reporting at least one work-related injury in the previous 6 months. Many of these injuries were the result of falls or lifting patients (Heick, 2009). Funding and additional research are critical to further quantifying the high risks to firefighters during EMS responses and developing interventions to mitigate this serious problem.

Much discussion and past research has focused on ambulance transport services, largely ignoring the impact of critical interventions that can be provided prior to ambulance transport unit arrival. Ambulances are important for the transport of patients needing more definitive medical care (Pratt, 2007). However, based on the number and the geographic distribution of apparatus stationed for "all hazards" response, a more rapid response is typically provided by fire department baseline units carrying medical supplies and EMS trained personnel (IAFC/IAFF, 2005). As fire departments continue to enhance their roles in EMS, it becomes important to examine how different deployment configurations and initiation of specific medical interventions may change the long-term outcome for the patient. Consequently, community planners and decision-makers need tools to optimally align resources with their service commitment for adequate emergency medical care for citizens.

Problem

Despite the role played by the fire service in the provision of emergency medical services, there are no scientifically based tools available to community and fire service leaders to assess the effects of EMS crew size and deployment on firefighter safety. More and more individuals, including the indigent, the working uninsured, and the underinsured, rely on prehospital medical care, which continuously increases the need for EMS resources in fire departments. The continued lack of comprehensive community health services and comprehensive health care reform means addressing this issue is a critical step in the evolution of the fire service and public safety.

Presently, community and fire service leaders have a qualitative understanding of the effect of certain resource allocations. For example, an increase in the number of fire houses, medically equipped apparatus, and EMS trained personnel would lead to a decrease in the time citizens spend waiting for EMS resources to arrive. Consequently a decrease in the number of fire houses, medically equipped apparatus, and EMS trained personnel would likely lead to an increase in the time before critical medical interventions can be provided. However, decision-makers lack a sound basis for quantifying the overall impact of enhanced emergency medical resources and the number of EMS-trained personnel on the timely provision of life-saving procedures.

Studies on adequate deployment of resources are needed to enable fire departments, cities, counties, and fire districts to design an acceptable level of resource deployment based upon community risks and service provision commitment. These studies will assist with strategic planning and municipal and state budget processes. Additionally, as resource studies refine data collection methods and measures, both subsequent research and improvements to resource deployment models will have a sound scientific basis.

Literature Review

Within the past four decades, the range and structure of services provided by firefighters have broadened and changed dynamically as an ever-increasing amount of department resources are used to respond to emergency medical calls. Expanded activities and increased expectations bring advantages, as well as challenges for both communities and fire departments in terms of providing optimal protection during emergency situations, while quantitatively assessing objective systems performance.

Studies documenting engine and ladder response times and crew performance in diverse live and simulated fire hazard environments, show a relationship between apparatus staffing levels and a range of important performance variables and outcome measurements such as response time, time-to-task completion, fire growth status at the time of attack, and occupant toxicity levels (Averill et al, 2010). Recent analyses of EMS crew staffing configuration have suggested that both the number of personnel dispatched per unit and the level of emergency medical certification of that crew may influence similar standards of measurement in the realm of medical response by multi-role firefighters. (Brown et al, 1996)

The rapid evolution of emergency service delivery and the growth of fire-based EMS systems correspond with an increase in literature that has detailed both the need for careful outcomes evaluation and continued innovation in terms of establishing performance variables that accurately assess the effectiveness of prehospital care provided by emergency medical technicians (EMTs). Investigators from government, professional organizations, and academia have described the progress made in the field of prehospital care and the challenges that EMT's and multi-role firefighters face in an expanding body of literature (Moore, 2002).

Publications to date have continually reached towards ascertaining the performance measures, operational protocols, and dispatch configurations that optimize outcomes across diverse communities. Many of the currently established EMS benchmarks and obstacles identified in recent literature hold particular importance for multi-role firefighters. Far-reaching studies of EMS response have demonstrated how response time, scene time, transport time, crew size, equipment, and the level of crew staffing and certification levels have influenced patient survival (Cummins et al, 1991). While studies have continued to demonstrate the impact of these factors with increasingly sophisticated methods, the need to improve understanding of EMS delivery persists. Existing standards of care need to be reevaluated so current systems can adjust and progress in response to ongoing research findings.

Historically, total response time has been measured from the time a responding unit leaves a fire station until the time the unit arrives at the incident. However, anecdotal evidence suggests that total response time should include the time to locate and access the patient (time to patient side). Previous studies have shown a substantial time difference between the time the first responder arrives on-scene and the time of patient access. One study noted that the patient access time interval represented 24 % of the total EMS response time interval among calls originating less than three floors above or three floors below ground and 32 % of those located three or more stories above ground. (Morrison et al, 2005)

Early literature on out-of-hospital cardiac arrest (OHCA) sought to uncover the effects of patient characteristics and location of initial collapse on survival to hospital discharge, with researchers then beginning to quantify the importance of response time. A paper by researchers from the EMS Division of King County, Washington and University of Washington Departments of Medicine and Biostatistics found significantly higher survival rates for patients who arrested outside the home, noting that of those 781 patients, most were more frequently younger, male, and more likely to be witnessed at the time of collapse and had received bystander cardiopulmonary resuscitation (CPR). (Litwin et al, 1987)

A growing number of defibrillation effectiveness studies began to demonstrate that response time, EMT training and practice, and population density influenced the effectiveness of this type of EMS delivery. (Olson, 1989; Kellerman, 1992; Hallstrom, 2004; DeMaio, 2005) For an urban environment exceeding three million, at least one study noted that over a period of one year, survival rates were lower in urban environments than those reported for smaller cities, but reaffirmed that the single factor most likely contributing to poor overall survival was a relatively long interval between collapse and defibrillation. In their conclusions, the authors recommended the use of standardized terms and methodology and stressed that "detailed analysis of each component of the emergency medical services systems will aid in making improvements to maximize survival of out-of-hospital cardiac arrest." (Becker, 1991)

Researchers studying patient outcomes following traumatic brain injury (TBI) were employing the specific anatomic, physiologic, and age characteristics of patients to formulate methods that would evaluate the effectiveness of trauma care. The "Trauma and Injury Severity Scores" (TRISS) method was one such system that generated scores for patients based upon systolic blood pressure, capillary refill, respiratory rate, and respiratory expansion. These scores provided a means of accurate analysis for EMS performance for cases of TBI, just as situational characteristics for OHCA, such as location of collapse, collapsing rhythm, and time to initial call were being used to gauge the effectiveness of emergency medical interventions for patients in distinct crisis scenarios. For instance, the correlation between age and predicted mortality for patients with comparable Trauma and Injury Severity Scores in an early study of the TRISS method suggested that a significantly narrower margin of effectiveness exists for seriously injured patients age 55 years or older. (Boyd, 1987)

Fire departments have long grappled with the most appropriate dispatch and notification configurations for EMS systems in different communities. Analyses have focused on comparisons of "one-tier" versus "two-tier" notification systems. "One-tier" systems require ALS units to respond to and transport all calls. In

[2] "Multi-role" is a term given to firefighters cross-trained in a number of related emergency services fields, such as EMS, hazardous materials response, and technical rescue.

a "two-tier" system, ALS units are allowed to delegate varying degrees of responsibility for response and transport to BLS units. Two studies appearing in the *Annals of Emergency Medicine* in the same year examined the response capacity and performance measures for a broad sample of urban EMS systems with regard to dispatching protocols and notification systems. (Sweeney, 1998; Chu, 1998) Reviewing previously published studies on 39 emergency medical services programs from 29 different locations from 1967 to 1988, researchers focusing specifically on cardiac arrest and resuscitation outcomes noted survival rates to be higher for two-tiered systems where both a paramedic and either an EMT or EMT-D were dispatched to calls, as compared to survival rates for one-tier systems where dispatches were exclusive for an EMT, EMT-D, or paramedic. This analysis also showed rates of survival to hospital discharge to be slightly higher for patients with a collapse rhythm of ventricular fibrillation, which suggested that the earlier CPR initiation possible in two-tier configurations was a primary means to the higher survival rates in these systems (Eisenberg et al., 1990).

In an article that plotted responses to an EMS system configuration survey against Code 3 ("lights and sirens") response times to emergency calls, investigators identified three different types of "two-tier" configurations. In the first two-tier system, ALS units responded to all calls but once on-scene could turn a patient over to a BLS unit for transport. In the second two-tier model, ALS units did not respond to all calls and BLS units could be sent for noncritical calls. In the final two-tier configuration, a non-transport ALS unit was dispatched with a transporting BLS unit with ALS personnel joining BLS personnel for transport on all ALS calls. After reviewing survey responses from EMS systems in 25 mid-sized cities with populations of 400,000 to 900,000, researchers suggested that a two-tier response system that permitted dispatch of BLS units for noncritical calls would allow a given number of ALS units to serve a much larger population while still maintaining rapid Code 3 response times (Braun et al, 1990).

The emergence of the "chain of survival" concept in the prehospital treatment of cardiac arrest merged the effectiveness of specific EMS interventions for individual patient characteristics and the level of qualification of staffing on emergency apparatus as standards of measurement within a system-wide scheme of performance evaluation. In a statement explaining the chain of survival and detailing its components, researchers argued that time to recognition of OHCA, EMS system activation, initiation of CPR, defibrillation, intubation, and intravenous administration of medications were successive, distinct factors that directly influenced outcomes of sudden cardiac arrest and should therefore be used inclusively as measurements of overall performance for EMS systems. The authors presented a thorough review of past literature and noted that while a small number of urban EMS systems approached the then-current practical limit for survivability from sudden cardiac arrest, most EMS systems in the U.S. and other countries had defects in their chain, as demonstrated by a near universal preponderance of poor resuscitation rates. This paper was notable for describing the research supporting each "link" in the chain or performance measurement of EMS system effectiveness and recommending specific actions to improve each area, thereby strengthening the chain of survival. Moreover, researchers suggested that communities implementing two-tier, double response systems might show optimal improvements in survival rates, as reports on EMT-D systems showed small response times but restricted intervention methods while ALS-only systems recorded longer response times with more advanced treatment options (Cummins et al, 1991).

Time-to-task measurements that have more recently been formulated into the "chain of survival" model for sudden cardiac arrest have been widely accepted as measurements of fire crews' performance. The continuous patient care and vigilant monitoring of vitals advocated in most EMS models are duties that multi-role firefighters are distinctly well-equipped to perform, especially in emergency situations requiring both fire suppression and emergency medical response. Critical thinking, strategic teamwork, and ongoing, immediate priority assessments during emergency situations are all skills taught and regularly instilled by training and routine evaluation for multi-role firefighters.

In light of the existing literature, there remain unanswered questions about the relationship between resource deployment levels, in terms of first responder crew size and EMS training levels, and the associated task performance during EMS incidents. For the first time, this study investigates the effects of varying crew configurations for first responders, the apparatus assignment of ALS personnel, and the number of ALS personnel on scene on the task completion for ALS level incidents. This study is also unique because of the array of stakeholders and technical advisors involved. All industry standards and safety protocols were followed, and robust research methods were used. The results and conclusions will directly inform the NFPA 1710 Technical Committee, who is responsible for developing industry standards associated with the deployment of fire suppression operations, emergency medical operations, and special operations to the public by career fire departments.

Purpose and Scope of the Study

This project systematically studies deployment of fire department-based EMS resources and the subsequent effect on the ability to provide an efficient and effective response. It will enable fire departments and city/county managers to make sound decisions regarding optimal resource allocation to meet service commitments using the results of scientifically based research. Specifically, the EMS field experiments provide quantitative data on the effects on varying crew size configurations, ALS personnel placement, and the number of ALS personnel available on ALS level incidents.

The first phase of the multiphase project was an extensive survey of more than 400 career and combination fire departments in the United States with the objective of optimizing a fire service leader's capability to deploy resources to prevent or mitigate adverse events that occur in risk- and hazard-filled environments. The results of this survey are not documented in this report, which is limited to the experimental phase of the project, but they will constitute significant input into future applications of the data presented in this document.

In order to address the primary research questions using realistic scenarios, the research was divided into three distinct, yet interconnected parts.

- Part 1- Time-to-task experiments related to gaining access to a patient and removing the patient from the incident scene.
- Part 2- Time-to-task experiments related to the care of a victim with multi-system trauma.
- Part 3- Time-to-task experiments related to the care of a victim with chest pain and witnessed cardiac arrest.

These parts included the most basic elements of an overall EMS response and included time for personnel to access the patient, conduct patient assessment, deliver on-scene patient care, package the patient, and remove the patient from the scene to a transport-capable vehicle.

The EMS portion of the Firefighter Safety and Deployment of Resources Study was designed to assess the labor aspect of an EMS incident necessary to ensure safe, effective, and efficient operations. While studies have shown a relationship between response time and efficiency of patient care intervention, this project has no direct measures. This study does however quantify the effects of first responder crew size and ALS trained personnel resources on time-to-task for EMS interventions. The applicability of the conclusions from this report to a large-scale hazardous or multiple-casualty event has not been assessed and should not be extrapolated from this report.

EMS protocols pertaining to the treatment and transport of patients vary by departments. For the purpose of this study, tasks were standardized by technical experts and individual times were recorded for each task. In real-world situations, as in this study, many of these can be performed simultaneously based on the number and training level of responding personnel. Attempts to generalize the results from these experiments to individual departments must take into account protocols and equipment that vary from those used in the experiments.

A Brief Overview of the EMS Response

Considering the setting and the circumstances of emergency medical care delivery, the prehospital 9-1-1 emergency care patient should be considered a distinct type of patient in the continuum of health care. These patients not only have medical needs, but they may also need simultaneous physical rescue, protection from the elements and the creation of a safe physical environment, as well as management of non-medical surrounding sociologic concerns (Pratt et al., 2007). Interdependent and coordinated activities of all personnel are required to meet the priority objectives.

NFPA 1710: *Standard on Fire Department Operations, Emergency Medical Operations, and Special Operations to the public by Career Fire Departments* specifies that the number of on-duty EMS providers must be sufficient relative to the level of EMS provided by the fire department, and be based on the minimum levels needed to provide patient care and member safety.[3] NFPA Standard 1710 also recommends that personnel deployed to ALS emergency responses include a minimum of two members trained at the emergency medical technician-basic level and two members trained at the emergency medical technician-paramedic level, arriving at the scene within the established time frame of two hundred and forty seconds (four minutes) or less for BLS units and four hundred and eighty seconds (eight minutes) or less for ALS units provided that a first-responder with Automated External Defibrillator (AED) or BLS unit arrived in two hundred forty seconds (four minutes) or less travel time, or at the minimum levels established by the authority having jurisdiction.[4]

During each EMS experiment, a first responder unit and an ambulance transport unit was dispatched to the scene. Crew size for the first responder unit and ALS configuration for both the first responder unit and ambulance transport unit were varied for purposes of the experiments. There were three specific scenarios to which personnel responded.

- Patient access and removal from incident site
- Systemic trauma/fall victim
- Chest pain/cardiac arrest

Important time intervals typically not measured by EMS systems are "time to patient access" and the "time to patient removal" intervals. These intervals include the time it takes personnel with equipment to locate and access the patient and the time it takes personnel to remove the patient and equipment from the incident scene to the ambulance for transport. These intervals are critically important to calculating overall scene time, particularly in scenarios where the patient is not immediately accessible (high-rise buildings, commercial complexes, schools, etc.).

The Star of Life

The elements comprising an EMS incident are symbolized by the Star of Life.[5] The six branches of the star are symbols of the six main tasks executed by rescuers throughout an emergency medical event.

Figure 1: The Star of Life

The six branches of the star include the elements listed below.

- Detection: Citizens must first recognize that an emergency exists and know how to contact the emergency response system in their community. This can be done using several different methods such as dialing 9-1-1, dialing a seven digit local emergency number, using amateur radios, or call boxes.

- Reporting: Upon accessing a call center, callers are asked for specific information so that the proper resources can be sent. In an ideal system, certified Emergency Medical Dispatchers (EMDs) ask a pre-defined set of questions. In this phase, dispatchers also become a link between the scene and the responding units and can provide additional information as it becomes available.

- Response: This branch identifies the response of emergency crews to the scene. The response may include an engine with firefighters trained as EMT's followed by an ambulance carrying additional firefighter/EMT's or it may be a fire engine first responder crew followed by an ambulance carrying single role EMS personnel.

- On scene care: Definitive care is provided on the scene by the emergency response personnel. Standing orders and radio or cellular contact with an emergency physician has broadened the range of on scene care that can be provided by EMS responders. A long algorithm of procedures and drugs may be used before the patient is removed from the scene.

- Care in Transit: Emergency personnel transport the patient to the closest appropriate medical care facility for definitive care. During transport, patient care/treatment is continued.

- Transfer to Definitive care: Emergency crews transfer the patient to the appropriate specialized care facility. Transfer includes providing a detailed written report of the patient assessment and care provided on-scene and in-transit.

[3] NFPA 1710, Section 5.3.3.2.1: On duty EMS units shall be staffed with the minimum personnel necessary for emergency medical care relative to the level of EMS provided by the fire department.

[4] NFPA 1710, Section 5.3.3.3.4: Personnel deployed to ALS emergency responses shall include a minimum of two members trained at the emergency medical technician-paramedic level and two members trained at the emergency medical technician-basic level arriving on scene within the established travel time.

[5] Designed by Leo R. Schwartz, Chief of the EMS Branch, National Highway Traffic Safety Administration (NHTSA) in 1977.

EMS Response to Time Critical Events

In a statement explaining the chain of survival and detailing its components, researchers argued that time to recognition of OHCA, EMS system activation, initiation of CPR, defibrillation, intubation, and intravenous administration of medications were successive, distinct factors that directly influenced outcomes of sudden cardiac arrest and should therefore be used inclusively as measurements of overall performance for EMS systems. This paper was notable for describing the research supporting each “link” in the chain or performance measurement of EMS system effectiveness and recommending specific actions to improve each area, thereby strengthening the chain of survival (Cummins et al., 1991).

A typical EMS event, regardless of the nature of the incident, follows a basic script. The first arriving unit performs a scene size-up and initial life safety assessment. The crew then gathers the appropriate equipment from the unit based upon patient injury, illness and location, and accesses and treats the patient.

In an analysis of data from more than 300 U.S. Fire Departments, first responder units arrived prior to ambulances in approximately 80 % of responses (IAFC/IAFF 2005). This response capability is likely attributed to the strategic locations of fire stations housing the engines and the fact that engines are often more densely located than ambulance transport units. In some cases, as is the case with motor vehicles accidents with entrapment and some structural collapse incidents, initial responding personnel may need to perform patient treatment and stabilization while performing patient rescue. For these types of incidents, it is necessary to have additional personnel on scene to assist with patient care and removal from the incident scene.

However, even without these major impediments, additional crew members assist with patient care and movement. In the experiments, crew members were used to assist with patient treatment, packaging, removing the patient from the incident location to the ambulance transport unit, repositioning the ambulance transport unit, and other tasks that streamlined the on-scene activity.

The Relation of Time-to-Task Completion and Risk

Delayed response, combined with inadequate personnel resources exacerbates the likelihood of negative patient outcomes. While rapid response is critical to patient survival, the personnel who respond must also be highly competent in patient assessment and stabilizing treatment delivery.

Figure 2 illustrates a hypothetical sequence of events for response to a cardiac arrest (heart attack). A rapid response to an EMS incident is effective only if the personnel arriving on the scene can initiate appropriate emergency medical interventions. This requires adequate numbers of personnel, as well as appropriate equipment and prior training. Early advanced cardiac life support (ACLS) provided by paramedics at the scene is another critical link in the management of cardiac arrest. According to industry standards EMS systems should have sufficient staffing to provide a minimum of two rescuers trained in ACLS to respond to the emergency. However, because of the difficulties in treating cardiac arrest in the field, additional responders should be present (AHA, 2005).

The delivery of prehospital care is complex requiring both interpersonal and clinical skills. Firefighter/Paramedics must be able to communicate with patients, bystanders, on scene safety personnel, and hospital personnel. A lack of cooperation in any of these interactions could have a detrimental effect on the patient.

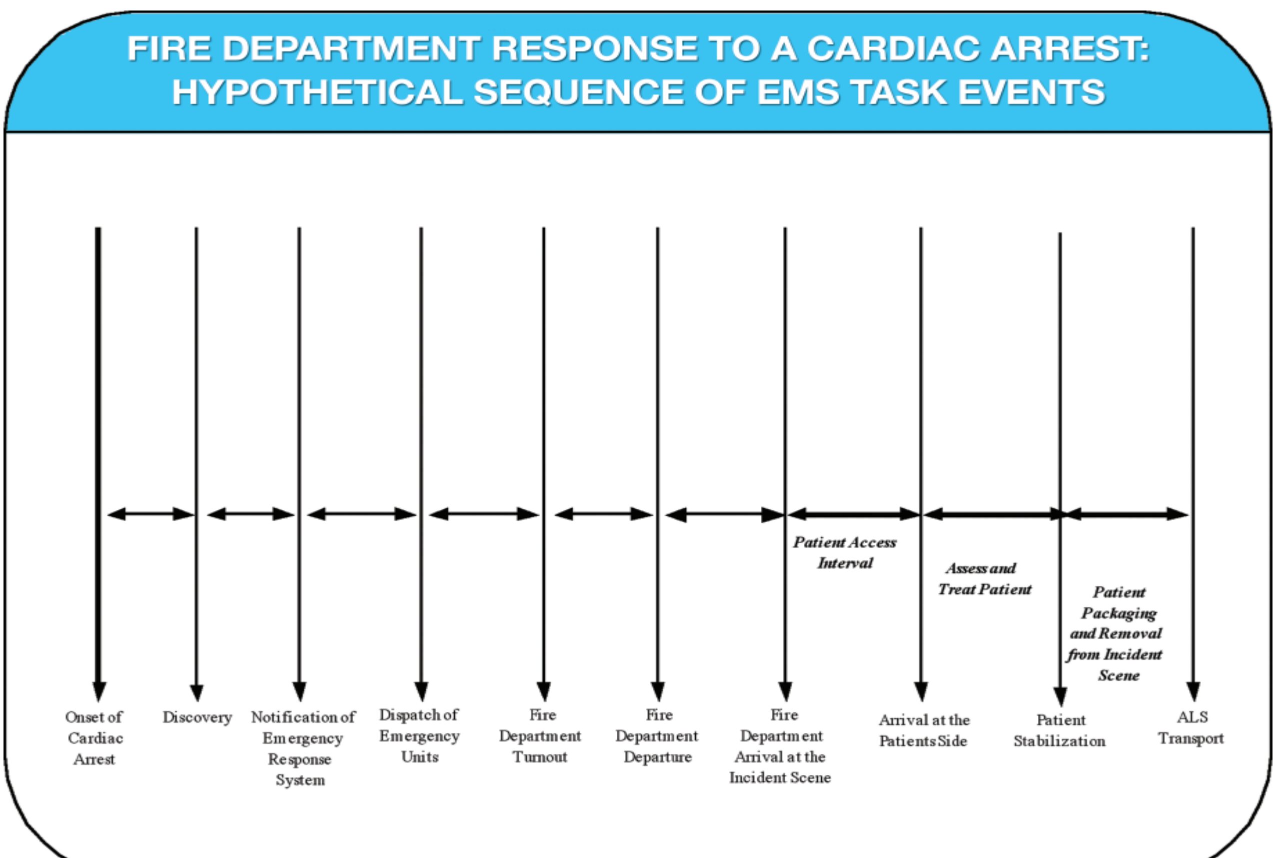

Figure 2: Hypothetical Timeline of a Fire Department Response to an EMS Incident

Standards of Response Cover

Developing a standard of response cover (SORC) related to service commitments to the community is a complex task. A SORC includes the policies and procedures that determine the distribution, concentration, and reliability of fixed and mobile resources for response to emergency medical incidents (CFAI, 2009). Fire departments that provide EMS must evaluate existing (or proposed) resources against identified risk levels in the community and against the tasks necessary to provide safe, efficient and effective emergency medical services. EMS risks that must be considered include population demographics such as socioeconomic status, age, ethnicity and health insurance status, as well as population density, community type (urban, suburban, or rural), access to healthcare, and traffic patterns and congestion. In addition to community risks, leaders must also evaluate geographic distribution and depth or concentration of resources deployed based on time parameters established by community expectation, state or local statute or industry standards.

Recognition and reporting of an emergency medical incident begins a chain of events that occur before firefighters arrive at the scene. These events include call receipt and processing, dispatch of resources, donning protective gear, and travel to the scene. NFPA 1710 defines the overall time from dispatch to the scene arrival as total response time. The standard divides total response time into a number of discrete segments, shown in Figure 2.

Arrival of emergency crews on scene is then followed by a sequence of tasks. Depending on the availability of resources available, tasks may be completed simultaneously or sequentially. Knowing the time it takes to accomplish each task with an allotted number of personnel and equipment can be useful in planning resource deployment. Ideally crews should arrive and intervene in sufficient time to prevent patient brain death, excessive blood loss, and minimize pain and suffering with the goal and expectation of transporting and delivering a viable patient to an appropriate medical facility.

Decision-making regarding staffing levels and geographic distribution of resources must also consider times when there are simultaneous events requiring multiple resource deployment into multiple areas of the jurisdiction. There should be sufficient redundancy or overlap in the system to allow for simultaneous incidents and high volume of near-simultaneous responses without compromising the safety of the patient, the public, or firefighters.

Policy makers have long lacked studies that quantify changes in EMS scene performance based on crew sizes and configuration. These experiments were designed to observe the impact of first responder crew size and ALS configuration on the time it takes to execute essential EMS tasks. It is expected that the results of this study will be used to inform the threshold performance objectives to the NFPA 1710 and 1720 Technical Committees.

Experiment Planning and Methodology

The EMS field experiments consisted of three distinct parts:

- Part 1- Time-to-task experiments related to gaining access to a patient and removing the patient from the incident scene.
- Part 2- Time-to-task experiments related to the care of a victim with multi-system trauma.
- Part 3- Time-to-task experiments related to the care of a victim with chest pain and witnessed cardiac arrest.

Following is a detailed description of the overall methods used throughout the experiments. Specific information pertaining to each part is presented separately.

The following research questions guided the experimental design of the EMS field experiments documented in this report:

- 1. What is the effect of first responder crew size on EMS task times?
- 2. What is the effect of ALS personnel placement on EMS task times?
- 3. What is the effect of the number of ALS trained personnel on EMS task times?

Department Participation

The experiments were conducted in Montgomery County, MD at the Montgomery County Public Safety Training Academy and in Fairfax County, VA at the EMS Simulation Center. Experiments took place during the months of April and May 2009. All experiments took place in daylight between 0800 hours and 1500 hours.

Montgomery County (MD) and Fairfax County (VA) firefighters and paramedics participated in the field experiments. Each day, both departments committed one ALS engine, one ALS ambulance and the associated crews. Firefighters and paramedics were identified and oriented to the experiments. Participants varied with regard to age and experience. The allocation of resources made it possible to conduct back-to-back experiments by rotating firefighters between field work and rehabilitation areas.

Crew Orientation

Daily orientations were conducted. Orientations included a description of the overall study objectives, as well as the actual experiments in which they would be involved. Crews were also oriented to the site layouts and specific scenarios to be conducted.

Cue Cards

Task procedures were standardized for each experiment/scenario. Technical experts worked with the study investigators to break down crew tasks based on crew size. Task flow charts were then created and customized for the various crew sizes. The carefully designed task flow ensured that the same overall workload was maintained in each experiment, but was redistributed based on the number of personnel available for work.

All tasks were included in each scenario and cue cards were developed for each individual participant in each scenario. For example, a four-person first responder crew would have a cue card for each person on the crew including the driver, officer, and two firefighter/EMTs or paramedics. Cards were color coded by crew size to ensure proper use in each scenario.

Tasks

Tasks were completed specific to each scenario (patient access and removal from incident scene, trauma, and cardiac). Meticulous procedures gathered data to measure key areas of focus such as individual start times, task completion times, and overall scenario performance times. Each task in each scenario was assigned a standardized start and end marker, such as retrieving the key from the Knox Box[6] or patient secured with straps to stretcher/cot. All tasks, with the events for measuring start and stop times, are shown in Table 3 through Table 5.

[6] A Knox Box, known officially as the KNOX-BOX Rapid Entry System is a small, wall-mounted safe that holds building keys for firefighters and EMTs to retrieve in emergencies. Local fire companies can hold master keys to all such boxes in their response area, so that they can quickly enter a building without having to force entry or find individual keys held in deposit at the station.

On-Scene EMS Tasks

The on-scene tasks focused on the activities firefighters perform after they arrive on the scene of an emergency medical incident. A number of nationally recognized EMS experts were consulted during the development of the on scene EMS tasks in order to ensure a broad applicability and appropriateness of task distribution.[7] The experiments compared crew performance and workload for typical medical response scenarios using two-, three-, and four-person first responder crews, along with a two-person ambulance crew. In total, 102 experiments were conducted to assess the time it took various crew configurations to complete the overall tasks in Parts 1, 2, and 3. In addition to first responder crew sizes, the experiments assessed the time necessary to access the patient, conduct a patient assessment, deliver on scene patient care, package the patient, and remove the patient from the incident scene to the ambulance. Two scenarios were selected as the basis of Parts 2 and 3. The scenarios included a patient with systemic trauma and a patient with chest pains leading to cardiac arrest.

The experiments also assessed the placement and number of responding ALS-trained personnel. There were 15 crew configurations considered during the experiments. These included the first responder crew being varied from two-, three-, and four-person crews. Additionally, the first responder crew configuration was varied to include either an all BLS crew or a combination crew containing one firefighter trained at the ALS level. The ambulance crew was held constant at two-persons. However, the ambulance crew configuration was varied to include two BLS crew members, one BLS and one ALS crew member, or two ALS crew members. Table 1 shows the crew configurations used throughout the experiments.

During the experiment crews dispatched to various scenarios included a first responder crew and ambulance transport unit or a single ambulance transport unit. For those experiments where both an engine company and an ambulance were dispatched, a three-minute stagger time was imposed for each of those trials. The three minute stagger time was determined from an analysis of deployment data from more than 300 fire departments responding to a survey of fire department operations conducted by the IAFC and the IAFF (2005). Each experiment containing a specific crew configuration was conducted in triplicate and completed in a randomized order (determined by randomization software) before a test configuration was repeated.

First Responder Engine Company	Ambulance Transport Unit	ALS Personnel On-Scene	Total Personnel On-Scene
N/A	2 BLS	0	2
N/A	2 ALS	2	2
N/A	1 BLS/1 ALS	1	2
2 BLS	2 ALS	2	4
3 BLS	2 ALS	2	5
4 BLS	2 ALS	2	6
1 BLS/1 ALS	1 BLS/1 ALS	2	4
2 BLS/1 ALS	1 BLS/1 ALS	2	5
3 BLS/1 ALS	1 BLS/1 ALS	2	6
2 BLS	1 BLS/1 ALS	1	4
3 BLS	1 BLS/1 ALS	1	5
4 BLS	1 BLS/1 ALS	1	6
1 BLS/1 ALS	2 BLS	1	4
2 BLS/1 ALS	2 BLS	1	5
3 BLS/1 ALS	2 BLS	1	6

Table 1: Crew Configurations for Time-to-Task Experiments

Radio Communication

Interoperability of radio equipment used by both participating departments made it possible to use regular duty radios for communication during the experiments. Company officers were instructed to use radios as they would in an actual incident. Montgomery County Fire and Rescue Communications recorded all radio interaction as a means of data backup. Once all data quality control measures were complete, the records were then overwritten as a routine procedure.

Task Timers

Ten observers/timers, trained in the use of identical standard stop watches with split-time feature, recorded time-to-task data for each field experiment. To assure understanding on the observed tasks, firefighters were used as timers, each assigned to specific tasks to observe and record the start and end times.

To enhance accuracy and consistency during recording times, the data recording sheets used several different colors for the tasks (see Appendix A). Each timer was assigned tasks that were coded in the same color as the recording sheet. All timers wore high-visibility safety gear on the incident scene.

Video records

In addition to the timers, video documentation provided a backup for timed tasks and for quality control. Cameras were used to record EMS scene activity from varied vantage points. Observer/timer data were compared to video records as part of the quality control process.

Crew Assignment

Crews from each department that regularly operated together were assigned to work as either a first responder crew or ambulance transport crew in each scenario. Both Fairfax County and Montgomery County crews participated in the experiment.

Crews assigned to each responding company position in one scenario were assigned to another responding company position in subsequent scenarios, with the objective of minimizing learning from one experiment to another. For example, crews in the role of first responder in the morning scenario might be assigned to the ambulance transport crew in the afternoon, thus eliminating learning the exact repetition of a task as a factor in time to completion. Additionally, participating crews from both Montgomery County and Fairfax County were from three different shifts, further reducing opportunities for participant repetition in any one position.

Props

Crews were assigned specific equipment lists to bring for this scenario. All equipment used was actual working equipment from the units assigned to the scenario. Specific items included in all scenarios were an airway bag, medical bag, oxygen cylinder, ECG monitor defibrillator, cot, and clipboard. Items specific to a particular scenario will be listed in that section of the report, including manikins and a live individual acting as a patient.

[7] Technical experts included Greg Mears, Michael McAdams, and Philip Pommerening. More information about the experts is presented in the Acknowledgements later in this report.

Safety Protocols

Participant safety was a primary concern in conducting the experiments. All participants and experiments complied with guidelines and recommendations as outlined in NFPA 450: *Guide for Emergency Medical Services and Systems*, NFPA 1500: *Standard on Fire Department Occupational Safety and Health Program*, and NFPA 1999: *Standard on Protective Clothing for Emergency Medical Operations.*

Figure 3: Safety Officer

A safety officer from the Montgomery County Fire and Rescue Department was assigned to oversee all experiments.

The safety officer ensured all protocols concerning participant safety, under both real and experimental conditions were followed. This included wearing the correct personal protective equipment, vehicle maneuvering, and overall scene safety. The safety officer participated in all orientation activities and daily briefings. The safety officer had full authority to terminate any operation if any safety violation was observed. Radio communication was always available.

A closely related concern to firefighter safety and readiness to repeat experiments with equivalent performance was adequate rehabilitation. Each "team" of participants had ample time between experiments to rest and rehydrate.

Response Time Assumptions

Response time assumptions were made based on time objectives set forth in NFPA 1710. Time stagger allocations were set by project technical advisors in order to assess the impact of arriving unit time separation on task start and completion times, as well as overall scene time. Table 2 shows the values assigned to the various segments in overall response time.

Event Occurrence = time zero
60 seconds for recognition and call to 9-1-1
90 seconds for call processing and dispatch
60 seconds for responder turnout
Travel time = first responder engine = 420 seconds post event
Ambulance = 600 seconds post event

Table 2: Response Time Assumptions

Figure 4: Ascending Stairs to Access Patient

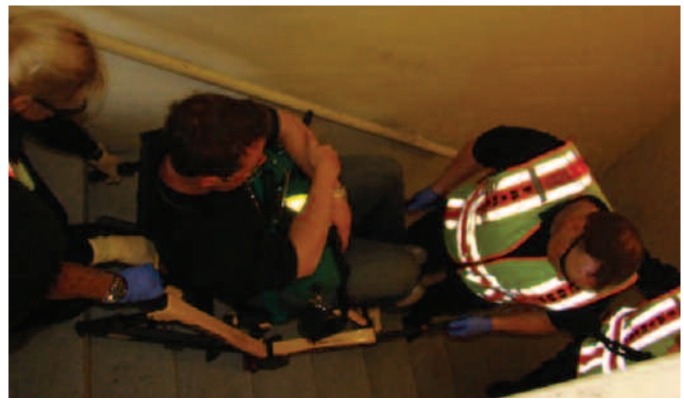

Figure 5: Carrying Patient Using Stair Chair

Figure 6: Trauma Patient Assessment

Figure 7: Trauma Patient Spinal Immobilization

Figure 8: Trauma Patient Packaging

Figure 9: Loading Patient on to Stretcher for Transport

Figure 10: Cardiac Patient Assessment

Figure 11: Cardiac Patient Intubation

Figure 12: Cardiac Patient I.V. & Medication Admin.

Figure 13: Moving Patient for Transport

Part 1: Patient Access and Removal from Incident Scene

Historically, total response time has been measured from the time a responding unit leaves a fire station until the time the unit arrives at the incident location. However, some studies suggest that total response time should include the additional time to locate and access the patient. Previous studies have shown a substantial time difference between the time the first responder arrives on scene and the time of patient access. One study noted that the patient access time interval represented 24 % of the total EMS response time interval among calls originating less than three floors above or three floors below ground and 32 % of those located three or more stories above ground (Morrison et al., 2005).

This study quantifies the time interval from arrival at the incident address until the crew begins the patient assessment, known as "at patient arrival time." The experiment assumed the patient was on the 3rd floor of a garden style apartment complex with stair access. This is representative of a typical structure to which firefighters respond in many residential neighborhoods. Patient assessment and treatment were not performed during the patient access and removal experiment. The primary purpose of this part of the experiment was to ascertain patient access and removal times. This part of the experiment was conducted separately from the patient care scenarios in an effort to establish distinctive timelines for patient access and removal separate from the patient care scenarios where on scene time can vary widely based on patient illness or injury.

Incident Scene

Garden Apartment Complex Scenario:

Firefighters from Fairfax County (VA) and Montgomery County (MD) simulated an initial EMS response for a patient with difficulty breathing in a garden style apartment building, represented by Simulation Lab #1 on the grounds of the Montgomery County Safety Training Academy in Rockville, MD. Simulation Lab #1 is a seven-story building, consisting of concrete scissor stairwells leading to the top floor of the building. The front of the building was equipped with a Knox Box, which firefighters accessed before entering the building. This task was typical of security access at any apartment complex.

Apparatus and crews were staged approximately 500 ft (150 m) from the Montgomery County Simulation Lab #1. Apparatus responded to the incident location, personnel dismounted and assembled equipment. Equipment included a defibrillator, airway bag, oxygen, and drug bag. Additionally, ambulance crews were required to bring the stair chair for patient packaging and removal. A crew member obtained an access key from the Knox Box and gained entry. Once crews entered the building they proceeded with the equipment to locate the patient on the third floor stairwell landing.

Patient assessment and treatment were not performed in this part of the experiments. In each experiment, the patient was packaged onto a stair chair, and then the patient and equipment were carried down three flights of stairs and out of the building. The patient was then transferred to a stretcher and loaded into the ambulance for transport.

Tasks

Tasks for the garden apartment scenario for patient access and removal are delineated in Table 3.

Tasks	Measurement Parameters
1. Arrive on Scene	START- Engine stopped at building - Ambulance stopped at building - Wheels stopped/brake engaged
2. Assemble Equipment	START- Personnel off engine - Personnel off ambulance STOP- Equipment in hand moving toward patient
3. Conduct size-up/Scene safety	START- Officer off engine - Officer off ambulance STOP- Officer begins scene report
4. Enter door/building Knox Box or access code	START- Touch door STOP- Door open
5. Ascend stairs (three stories)	START- Personnel with foot on first stair STOP- Crew assembled at top of stairs
6. Package patient	START- Load onto stair chair with monitor, straps in place STOP- Moving patient out towards exit
7. Descend stairs	START- Personnel with foot on first stair STOP- Crew and patient at bottom of stairs
8. Exit door/building	START- Personnel exits building with patient on stair chair
9.Transfer patient to cot/stretcher	START- Begin transfer of patient onto cot/ stretcher with monitor, straps in place STOP- Patient secure on cot/stretcher
10. Turn ambulance for loading	START- Firefighter in ambulance driver seat STOP- Ambulance positioned for patient loading
11. Load Ambulance	START- Patient secure on cot/stretcher STOP- Patient loaded and ambulance doors

Table 3: Time-to-Task Measures for Garden Apartment Scenario/Patient Access and Removal

Part 2: Trauma Patient

The trauma scenario involved time-to-task experiments focusing on a labor intensive traumatic scenario. In the experiment, a patient had fallen from a 25 ft (7.5 m) ladder at a construction site. This part of the experiment quantified the time intervals for different crew sizes and configurations responding to this event.

Incident Scene

The gymnasium at the Montgomery County (MD) Public Safety Training Academy was used for the trauma experiments. A classroom at the facility was also used for crew orientation and staging. Prior to the start of the experiments, participants were provided with the scenario background. Specifically, the call originated from a construction site that was only accessible by foot.

When cued, crews entered the gym and walked approximately 40 ft (12 m), carrying an airway bag (including suction), oxygen, spinal mobilization equipment, a trauma bag, and a radio and clip board. The "patient" was a 150 lb (68 kg) training manikin "voiced" when prompted by one of the timers. The patient could answer basic questions until the point in the sequence where the patient lost consciousness. During the scenario, when it became clear that the patient needed to be transported, a backboard was brought into the scene by the ambulance crew. After packaging the patient onto a backboard, the patient and equipment were carried out of the construction site to a waiting stretcher approximately 40 ft (12 m) away.

Tasks

The on-scene tasks focused on the activities firefighters regularly perform after they arrive on the scene of a patient with a traumatic injury. The experiments compared time-to-task performance based on varying crew sizes and ALS configurations.

Forty-five trauma experiments were conducted to assess the time it took various crew sizes and ALS configurations to complete the assigned tasks. Time between arrival of the first responding unit and ambulance transport unit was held constant at three minutes.

The following narrative describes the general sequence of activities in Part 2 of the experiments.

The first responding unit arrived, conducted a size-up and initial life safety assessment of the area, and gathered the appropriate equipment. The crew, with equipment, then proceeded into the construction site and located the patient. The patient was lying supine on the ground. The responders introduced themselves, obtained patient consent to examine and treat, and immediately initiated cervical spinal immobilization precautions and the patient interview. Other crew members then followed Airway, Breathing, and Circulation (A, B, C's) protocols. During the patient assessment, it was revealed the patient had a head laceration and an angulated fracture of the tibia/fibula (closed) on the right leg. Patient information was recorded on a standardized form created for the experiments and can be seen in Appendix B.

During the scenario, when the backboard straps were secure, the patient went into respiratory arrest. Crews then rechecked vital signs which revealed the patient had stopped breathing. The crew immediately began respiratory arrest protocol including administering a patent patient airway using an endotracheal tube. Intubation was performed using strict spinal immobilization restriction. With the airway established, the patient was then ventilated using a bag-valve-mask and patient packaging was completed. Crews then carried the patient and all equipment out of the construction site to the waiting stretcher.

Tasks	Measurement Parameters
1.At patient	START- Personnel at patient side One point in time
2. Spinal motion restriction	START- Personnel touches patient to position for immobilization STOP- Patient supine and personnel holding neck tension, patient immobilized
3. A, B, C's	START- At patient STOP- Personnel notes A, B, C's intact
4. Patient interview	START- Ask three questions 1) What happened? 2) Where are you hurting? 3) What is your name STOP- Questions answered 1) Don't know 2) Head and right leg 3) Joe
5. Body sweep- find laceration on head and angulated fracture of tibia/fibula (closed) on <u>Right</u> leg	START- Personnel starts patient survey/sweep- touches patient and explains "Sir, I am going to check you for injuries" STOP- Personnel locates/identifies head laceration and leg fracture. Head-to-toe sweep complete. Starts on right, goes down, the back up left side to shoulder
6. Oxygen (O^2) administration- face mask	START- Accessing O^2 administration equipment STOP- Mask on patient and O^2 on high flow
7. Check vitals	START- Accessing equipment for any vitals check Blood pressure (BP) cuff, stethoscope, cardiac monitor, or pulse oximiter STOP- All vitals checked and reported
8. Expose patient as indicated	START- Touch patient clothing for removal STOP- Patient chest and legs exposed
9. Control bleeding	START- Personnel accesses equipment (bandages) STOP- Head wound bandaged (gauze and tape)
10. Splint leg	START- Personnel accesses equipment (splint) or touch foot to check pulse STOP- Leg splinted- pulse check when splint in place
11. Back board	START- Personnel accesses equipment (board, collar, straps) STOP- Patient secured on back board- all straps in place
Movement causes labored breathing = Agonal Respiration >> Patient Vomits >> Patient Unconscious	
12. Airway- Endotracheal (ET) intubation with spinal motion restriction (completed on ground due to distance from transport unit)	START- Paramedic (and assisting personnel) touches airway bag (including laryngeal scope, ET tube, syringe, and stethoscope) STOP- ET tube in place, cuff inflated, lung sounds checked, and tube secured
13. Bag Valve Mask (BVM)	START- Paramedic touches BVM STOP- BVM- first squeeze
14. Package patient/move for transport	START- Pick up back board to move to cot/stretcher STOP- Ambulance door closed

Table 4: Time-to-Task Measures for Trauma Scenerio

Fourteen tasks were completed in the trauma experiments. Meticulous procedures gathered data to measure key areas of focus, such as individual task start times, task completion times, and overall scenario performance times. Each task was assigned a standardized start and end marker, such as accessing oxygen equipment (start) until the mask was on the patient and oxygen was flowing (stop). The 14 tasks can be seen in Table 4.

Part 3: Cardiac Patient

The cardiac scenario involved time-to-task experiments focusing on a labor-intensive medical event, i.e., a patient that experiences a myocardial infarction leading to cardiac arrest. This part of the experiment quantified the time intervals for different crew sizes and ALS configurations responding to the event.

Incident Scene

The cardiac experiments were conducted in a laboratory at the Fairfax County Fire and Rescue Department EMS Simulation Center. The Simulation Center houses classrooms, laboratories, and offices for training of EMT's and paramedics. Assorted furniture was staged in the laboratory to duplicate a "home" setting. When cued, crews entered the room and proceeded approximately 10 ft (3 m) to the patient. The patient was represented by SimMan® by Laerdal. SimMan® is an adult-sized manikin that can produce vital signs including, a pulse, heartbeat, lung sounds, blood pressure and other signs noted in real humans. SimMan® also had vocal capabilities such as speaking or crying (Laerdal, 2010). SimMan® was operated remotely from a control booth adjacent to the laboratory.

Prior to the start of the experiments, participants were provided with the scenario background. Specifically, the call originated from a private residence and the caller complained of chest pain. Responders entered the room carrying an airway bag, oxygen, drug bag, and defibrillator. The defibrillator was either an AED and/or a 12-Lead ECG model defibrillator dependent upon the arrival of ALS trained personnel. During the scenario, the patient went into cardiac arrest on cue and crews reacted by changing their path of patient care for chest pain to a more time-critical path of treatment for a pulseless, apneic patient. When crews had completed on-scene patient care tasks, the patient was packaged onto a backboard and stretcher. The patient and all equipment were removed from the room to conclude the experiment.

Tasks

As noted previously, the on-scene tasks focused on the activities firefighters perform after they arrive on the scene of a patient with a cardiac emergency. The experiments compared crew performance for a typical cardiac scenario using a combination of varying crew sizes and configurations.

Forty-five cardiac experiments were conducted to assess the time it took various crew sizes and configurations to complete the assigned tasks. Time between arrival of the first responding unit and ambulance transport unit was held constant at three minutes.

The following narrative describes the general sequence of activities in Part 3 of the experiments.

> The first responding unit arrived, conducted a size-up and initial life safety assessment of the building and gathered the appropriate equipment. The crew, with equipment, then proceeded to the front door of the patient residence, knocked, and entered. After confirming the scene was safe, patient assessment was begun.
>
> The responders introduced themselves, obtained the patient's consent to examine and treat and then proceeded to conduct the patient interview. The patient interview was standardized to include SAMPLE and OPQRST protocols. Patient information was recorded on a standardized form created for the experiments and can be seen in Appendix C.
>
> During the scenario, on cue, the patient went into cardiac arrest. Upon patient arrest, the crew rechecked the patient's vital signs which revealed the patient had stopped breathing and had no pulse.
>
> The crew then followed protocol and moved the patient to the floor where they could immediately begin CPR and prepare to administer defibrillation. Study protocol then followed Advanced Cardiac Life Support guidelines for patient care (AHA, 2005).

Twenty-two tasks were completed in the cardiac experiments. Meticulous procedures gathered data to measure key areas of focus, such as individual task start times, task completion times, and overall scenario performance times. Each task was assigned a standardized start and end marker, such as accessing oxygen tank equipment (start) until the mask was on patient and oxygen was flowing (stop). The 22 tasks can be seen in Table 5.

Table 5: Time-to-Task Measures for Cardiac Scenerio

Tasks	Measurement Parameters
1. Identify and enter door/ patient quarters	START- Enter door STOP- One point in time
2. At patient	START- Personnel at patient side STOP - One point in time
3. A, B, C's	START- At patient's side STOP- Personnel notes A, B, C's intact
4. Patient interview	START- Ask patient history questions, "SAMPLE", and "OPQRST" pain survey STOP- Questions asked and answered
5. O^2 administration	START- Accessing O^2 administration equipment "Let's put patient on four liters O^2" STOP- Cannula on patient and O^2 flowing
6. Check vitals (pulse, respiratory rate, BP, pulse oximetry)	START- Accessing equipment for vitals check (BP cuff, stethoscope, cardiac monitor, or pulse oximeter) STOP- All vitals checked and reported BLS = Pulse, respiratory rate, BP, and pulse oximetry ALS = cardiac monitor, 12-lead in place
7. ALS vitals- Electrocardiogram (ECG) 12-lead	START- Touch patient shirt for removal STOP- 12-lead monitor in place
8. Expose patient	START- Touch patient shirt for removal STOP- Chest exposed
PATIENT ARREST	START - Timer cued when task complete STOP - Witnessed arrest
9. Position Patient	START- Touch patient to move to floor STOP- Patient supine on floor
10. A, B, C's	START- Personnel touches patient STOP- Airway, breathing, and pulse checked and reported "No pulse, no breathing"
11. Apply defibrillator pads	START- Access defibrillation equipment (pads) STOP- Pads in place (4)- push analyze button
12. Defibrillate- shock #1 Shock works = NO	START- Push button to charge machine STOP- Shock delivered
13. A, B, C's	START- Personnel touches patient STOP- Airway, breathing and pulse checked and reported "No pulse, no breathing"
14. CPR- bag valve	START- Lead personnel says "start CPR" STOP- CPR begun- including chest compressions and bag valve mask
15. Airway intubation- ET	START- Paramedic (and assisting personnel) accesses equipment including laryngeal scope, ET tube, syringe, and tape STOP- ET tube in place, cuff inflated, and lung sounds checked and tube secured
16. Intravenous (IV) access	START- Paramedic (and assisting personnel) accesses equipment including catheter, bag, tubing, tourniquet, and tape STOP- IV in place, taped, and fluid running
17. Meds- 1 Epinephrine (Epi)	START- Paramedic (and assisting personnel) accesses equipment- "let's push 1 Epi" STOP- Epi pushed in IV line- "Epi in"
18. AED auto countdown "Analyze patient"	START- push button to analyze >>>>>>>>>>>>>
19. Defibrillate- shock #2 Shock works = YES	START- Push button to charge machine STOP- Shock delivered
20. Check vitals (Pulse, Respiratory rate, BP, pulse oximetry) Patient unconscious	START- Accessing equipment for vitals check (BP cuff, stethoscope, cardiac monitor, or pulse oximeter) STOP- All vitals checked and reported (pulse, respiratory rate, BP, pulse oximetry)
21. Meds (1 lidocaine bolus)	START- Paramedic (and assisting personnel) accesses equipment "Let's push 1 bolus lidocaine" STOP- Lidocaine pushed in IV line "Lidocaine in"
22. Package patient	START- Access equipment- (board, spider straps) STOP- Stretcher personnel, and equipment out door

Analysis of Experimental Results

This section describes the analytic approaches used to address the research objectives of the study. The statistical methods used to analyze the EMS time-to-task observations are presented. Then the time-to-task results are reported for EMS responses in three scenarios:

- access and removal of patient;
- a trauma event; and
- a cardiac event.

Time-to-Task Analysis

Time-to-task data were compiled into a database and assessed for outliers and missing entries. As is common in a repeated experiment with many pieces of data to be entered, occasionally data elements were not collected. Missing data occurred in less than 1 % of timing observations. Such instances were reviewed via video and/or radio tapes. Missing data attributable to timer error were replaced by the time observed in the video. Where video and/or radio documentation proved inadequate, missing data were imputed with the mean of the observed corresponding task times from the other two experiments. The extremely low occurrence of missing data and associated imputation should have a negligible impact on the statistical findings in the analyses.

Data Queries

The statistical methods used to analyze the time-to-task data were driven by the principal goals of this research project —- to assess the effect of crew size, ALS placement on the responding crews, and the number of ALS trained personnel in the crew configuration on time-to-task for critical steps in each EMS scenario. The research goal motivated the development of four specific research questions (see Figure 14) that in turn pointed to specific statistical analyses to generate inference and insight.

TIME-TO-TASK RESEARCH QUESTIONS

For Response Access & Removal:

1. What are the effects of first responder crew size regardless of ALS placement with respect to:

   a. reaching a patient?
   b. removing a patient after packaging?

For Cardiac and Trauma Scenarios (task timings measured between *arrival at patient* to the *completion of patient packaging*):

1. What is the effect of crew size on EMS task times?

2. What is the effect of ALS personnel placement on EMS task times?

3. What is the effect of the number of ALS trained personnel on EMS task times?

Figure 14: Research Questions for Time-to-Task Experiments

Statistical Methods

The analysis of the time-to-task data involved a sequence of ordinary least squares regression models. The models relate the *experimental outcomes* (i.e., various measures of time — start time, completion time, or duration of the task) to *key dimensions* for each scenario as follows:

For Access and Removal:

- first responder crew size (regardless of ALS placement), and
- ambulance-only versus ambulance with first responder engine with varying crew sizes.

For Trauma and Cardiac scenarios:

- presence of an engine at the scene,
- crew size on the first responder engine, and
- placement and number of ALS personnel (on the engine, on the ambulance, or both).

To account for these dimensions in the analyses, indicator variables representing each key dimension were employed. For example, for the trauma and cardiac scenarios there were indicators for the number of first responders on the engine, three indicators of the assignment of ALS personnel to the ambulance or engine, and indicators for the "no engine" scenarios.

Using these indicators, sets of regression equations were developed for the analysis of each scenario. Indicators corresponding to the three scenarios and multiple dimensions listed above were included. For example, when an engine was sent, the number of first responders (two, three, or four) assigned to the engine were varied, as well as the placement of ALS personnel (one ALS on the engine only; one on the ambulance only; two on the ambulance; and one ALS each on the ambulance and engine). When no engine was sent, zero, one, or two ALS personnel were placed on the ambulance.

The regression equations took the form:

$$y_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \ldots + \beta_k x_{ik} + \varepsilon_i$$

Where the x_k represented the test conditions such as presence of an engine or placement of ALS personnel, and the dependent variable y represents the observed outcome (e.g., task duration).

The model coefficients from the completed regressions provided direct estimates of the change in time associated with the number of first responders (e.g., four versus two, three versus two), as well as the change in time associated with alternative assignments of ALS personnel. These estimates are generally the same as those obtained by comparing the difference in means across groups. However, for a small number of outcomes, the estimates differ from those obtained using difference in means by appropriately accounting for data that are missing in particular scenarios.

Table 6 to Table 8 present the list of time-related outcomes that were used to explore effects on outcomes for patient access/removal, as well as for cardiac and trauma scenarios, respectively. Not all tasks were subjected to testing for this report. Only substantively critical milestones in the task sequence were considered. For instance, the *assembly of equipment* and *conduct* *of size*-up were **not** assessed for the Access and Removal scenario. Instead, the elapsed time from arrival on scene to reaching the patient (as denoted by completing the ascent of stairs) was determined to be of primary importance. Similarly, the elapsed time between packaging patient and the completion of loading the ambulance was assessed rather than individual timings of any task in the sequence between these two major milestones. Similar judicious choices of critical milestones were made in the assessments of trauma and cardiac, and these are depicted in the outcome measures tables.

Although several of the analytic questions of interest can be obtained directly from the model, others require a linear combination of the coefficients. The statistical software (Stata) calculates both the desired combination of coefficients and the measure of statistical significance via t-test.

ACCESS & REMOVAL -- Outcome Measures			
	Task:	*Elapsed Time Arrival to Completion*	*Elapsed Time Package Patient to End of Loading*
1	**Arrive on Scene**		
2	Assemble Equipment		
3	Conduct Size Up - Scene Safety		
4	Enter Door - Building - 'Knox box'		
5	**Ascend - Stairs (2 stories—ground floor to third floor)**	x	
6	**Package Patient - stair chair**		
7	Descend Stairs (2 stories – third floor to ground) with Patient		
8	Exit Door - Building		
9	Transfer Patient to Cot/stretcher		
10	Turn Ambulance for Loading		
11	**Load Ambulance / Seat Belt**		x

Table 6: Outcome Measures for Access and Removal Scenario by Task

	Task:	TRAUMA -- Outcome Measures *Elapsed Time Until Start*	*Task Duration*	*Elapsed Time to Completion*
1	At Patient - Engine			
2	At Patient - Ambulance			
3	Spinal Motion Restriction	X		
4	ABC's	X	X	
5	Patient Interview	X		
6	Body Sweep	X	X	
7	O² Administration	X		
8	Check Vitals	X	X	
9	Expose Patient	X		
10	Wound Bandaged	X		
11	Splint Leg	X	X	
12	Back Board	X	X	
13	Airway - Intubation ET	X	X	
14	Bag Valve Mask	X		
15	Package Patient /Equipment	X		X

Table 7: Outcome Measures for Trauma Scenario by Task

	Task:	CARDIAC -- Outcome Measures *Elapsed Time Until Start*	*Task Duration*	*Elapsed Time to Completion (from arrest)*
1	At Patient			
2	ABCs	X	X	
3	Patient Interview	X		
4	O² Administration	X		
5	Check Vitals	X	X	
6	ALS Vitals 12-Lead	X		
7	Expose Chest	X		
8	Patient Arrest			
9	Position Patient			
10	ABC's *(from Arrest time)*	X		
11	Defibrillator pads *(from Arrest time)*	X		
12	Analyze / Shock #1	X		
13	ABC's after Shock #1 *(from Arrest time)*	X		
14	CPR			
15	Airway Intubation *(from Arrest time)*		X	
16	IV Access	X	X	
17	Meds (Epinephrine) *(from Arrest time)*	X		
18	Analyze / Shock #2 *(from Arrest time)*	X		
19	ROSC			
20	Meds (Lidocaine) *(from Arrest time)*	X		
21	Package Patient/Equip *(from Arrest time)*	X		X

Table 8: Outcome Measures for Cardiac Scenario by Task

The objective of the experiments was to determine the relative effects of first responder crew size, ALS provider placement and the number of ALS providers on the effectiveness of the EMS crews relative to key milestones among the task intervention times for each of the three scenarios. The experimental results are discussed below.

Of the various EMS tasks measured during the experiments, those described in the remainder of this section were determined to have significant differences based on the crew configurations studied. Their differential outcomes based on variation of first responder crew size, ALS crew configuration, and the number of ALS level providers on scene, are statistically significant at the 95 % confidence level or better. Times reported in seconds are rounded to the nearest five seconds. As a final technical note, we did not adjust significance levels to take into account the large number of tests being conducted. The observed number of significant results far exceeds what would be expected simply by chance.

Measurement Uncertainty

The measurement of tasks using stopwatch timing has unique components of uncertainly that must be evaluated in order to determine the fidelity of the data. All timers were equipped with the same model of digital stopwatch with a resolution of 0.01s and an uncertainty of $\pm$ 3s per 24 hr. The uncertainty of the timing mechanism in the stopwatches is small enough over the duration of an experiment that it can be neglected.

There are three components of uncertainty when using people to time the EMS tasks. First, timers may have a bias depending on whether they record the time in anticipation of, or in reaction to an event. Second, multiple timers were used to record all tasks. Third, the mode of the stimulus to which the timer is reacting—audible or visual.

Milestone events in the EMS experiments were recorded both audibly and visually. A test series described in the *NIST Recommended Practice Guide for Stopwatch and Timer Calibrations* noted that reaction times for the two modes of stimulus to be approximately the same, so this component can be neglected. Based on the assumptions made in the Residential Fireground Experiments (Averill et al., 2010), bias estimated for timer reaction time was determined to be 230 ms as a worst case scenario.

Considering the above, the total estimated combined standard uncertainty is $\pm$ 3.23 s. The magnitude of uncertainty associated with these measurements has no impact on the statistical inferences presented in this report.

How to Interpret the Time-to-Task Graphs

Figure 15 presents a sample of a time-to-task results graph. Each crew size/configuration has a bar graphic showing the start time and completion time for the task. Visually, bars start from the left and extend horizontally across the graph based on time expended by various EMS crew configurations. The length of the bar graphic is a visualization of the duration of the task. Longer bars indicate longer duration times. Actual time data are also shown on each bar.

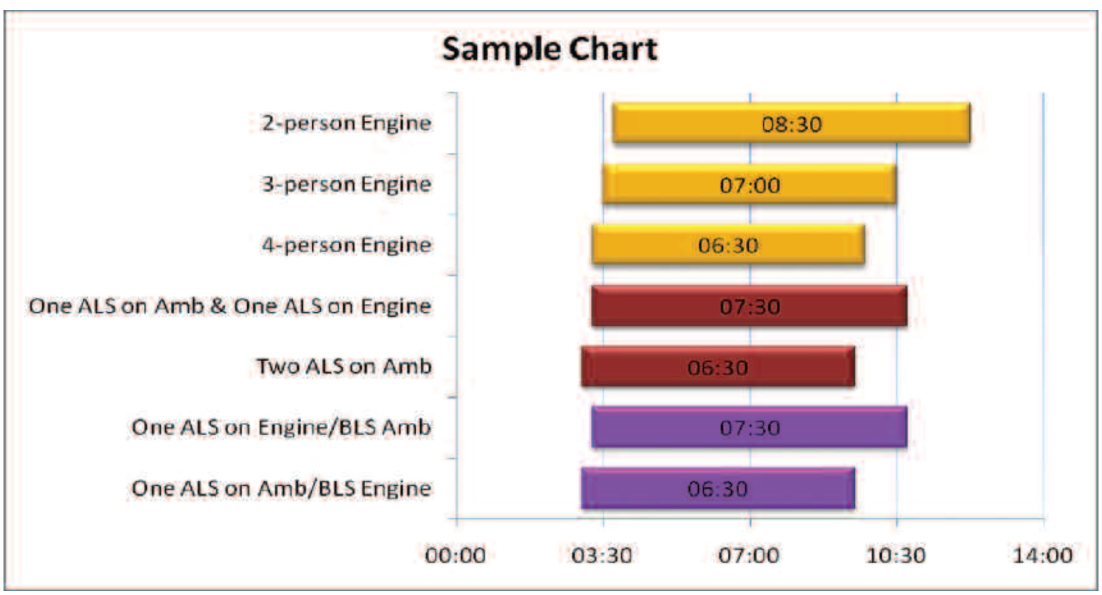

Figure 15: Sample Time-to-Task Graph

Time-to-Task Graphs

Part 1- Patient Access and Removal

Overall Scene Time (Time to complete all EMS tasks for Patient Access and Removal)

Access

The crews can differ in the time required to reach the patient (*access*) and in the time needed for patient *removal*. To address these tasks, sets of simulations were conducted by varying crew size on the first responding engine. Ambulance crews were held constant at two persons. As noted previously, the arrival times were staggered between the engine and the ambulance. When an ambulance was sent without a first responder engine, for measurement consistency, it was assumed to arrive at the scene *at the same time* as would an engine (i.e., there is no systematic, built-in delay).

The results for *patient access* show that two-person first responder crews take longer to reach a patient than configurations with larger crew sizes. Two-person crews finished the patient access tasks approximately *half a minute* later than larger first responder crews. Moreover, the ambulance crew alone finished with a time between that of the two-person and the larger first responder crews. The *ambulance alone* result is likely attributed to the removal of the staggered arrival time when first responder crews were not sent. (See Appendix E for the timings by staffing configuration, difference of means and associated t-tests.)

Patient Removal

The patient removal results show substantial differences associated with crew size. Crews with two-person first responder crews completed patient removal between (1.2 – 1.5) minutes slower than larger crews, depending on crew size. This is largely the result of work load in carrying equipment, supplies and the patient with fewer crew members. All crews with first responders completed removal substantially faster (by 2.6 min. - 4.1 min.) relative to the ambulance-only crew. Again, this is largely the result of the difficulty of carrying and loading the patient, as well as the equipment and supplies with only a two-person crew, given that one person must remain with the patient at all times. (See Appendix E)

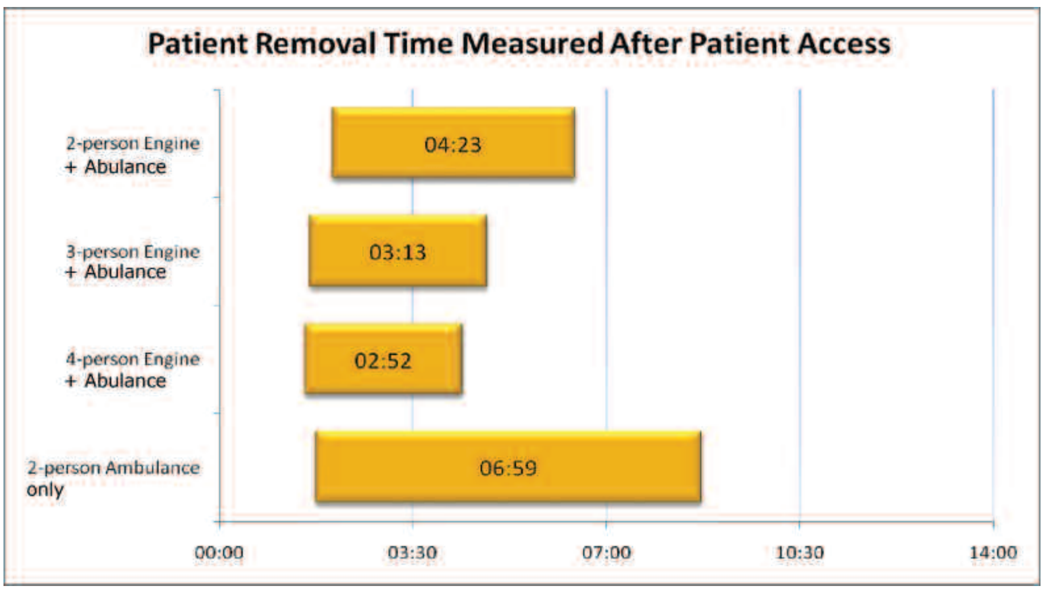

Figure 16: Patient Removal Time

Part 2- Multi-System Trauma

Overall Scene Time (Time to complete all EMS tasks for Trauma Patient)

As previously noted, for the trauma scenario part of the experiments, there was an assumed three minute stagger in arrival between the first responder crew and the ambulance crew.

Crews responding with one ALS provider on the engine and on the ambulance completed all trauma tasks 2.3 minutes (2 minutes and 16 seconds) faster than crews with a BLS engine and an ALS ambulance with two ALS level providers.

Crews responding with four-person first responder crews, regardless of ALS configuration, completed all trauma tasks 1.7 minutes (1 minute and 50 seconds) faster than first responder crews with three persons, and 3.4 minutes (3 minutes and 25 seconds) faster than first responder crews with two persons. This suggests that for trauma scenarios, the more hands available, the easier it is to implement the full portfolio of tasks to be completed.

The statistical tests that correspond to these findings appear in Appendix F. Appendix H shows the original regression coefficient estimates upon which the tests in Appendix F were constructed.

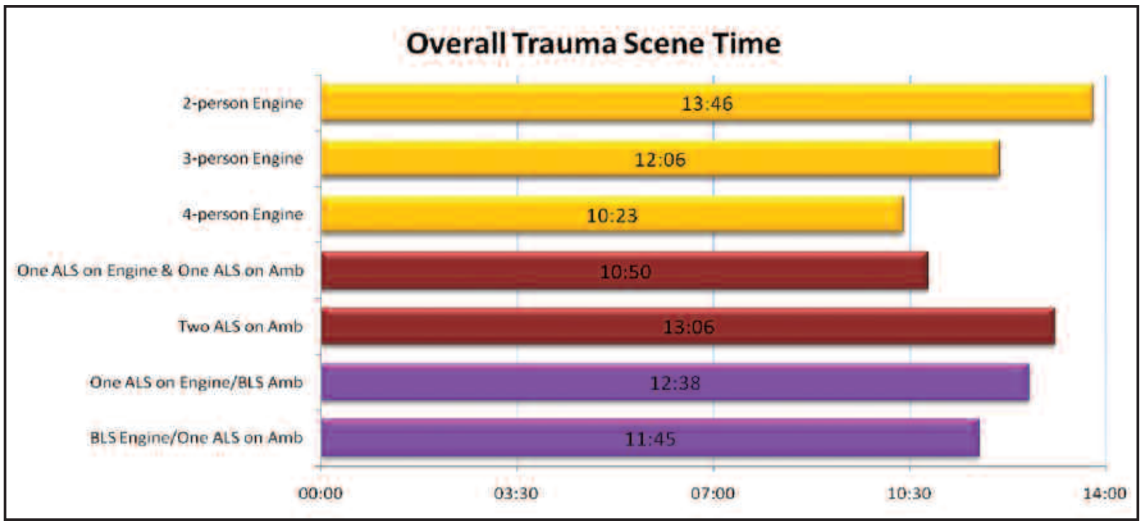

Figure 17: Overall Trauma Scene Time

Individual Task Times

Oxygen Administration

First responders with four-person crews were able to begin oxygen administration to the patient nearly a full minute (55 seconds) sooner than the three-person crew.

Vital Sign Assessment

First responders with four-person crews were able to begin checking the patient's vital signs nearly one minute (55 seconds) sooner than a two-person crew. They also completed the check about 80 seconds faster than the two-person crew. First responders with four-person crews were able to begin checking the patient's vital signs 30 seconds sooner than a three-person crew. To the extent that checking vitals is a critical task in a trauma response sequence, the reduction of half a minute to a minute of time could be seen as an important improvement.

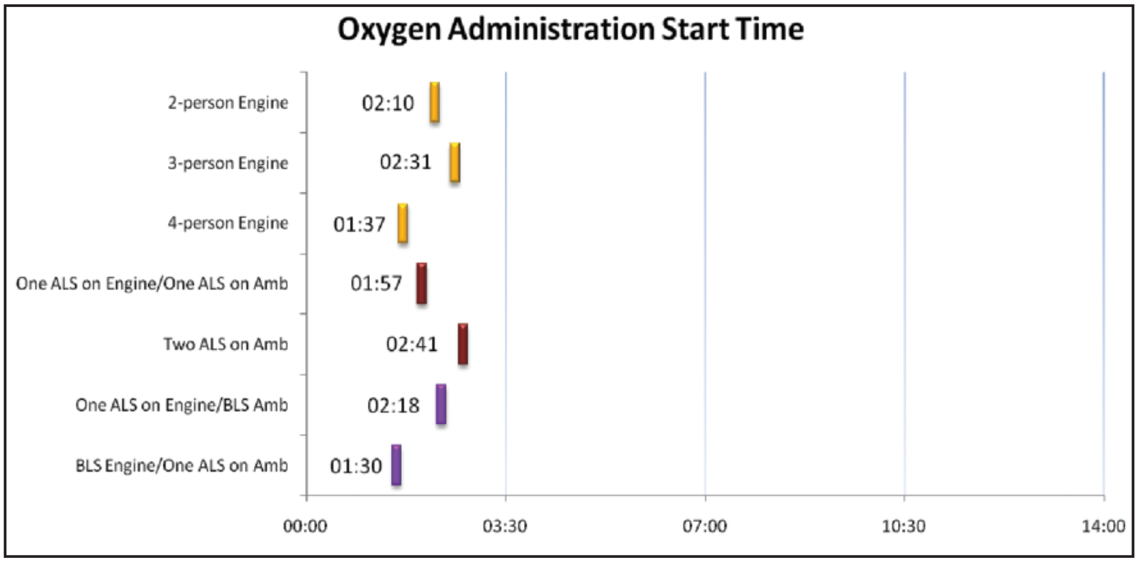

Figure 18: Oxygen Administration Start Time

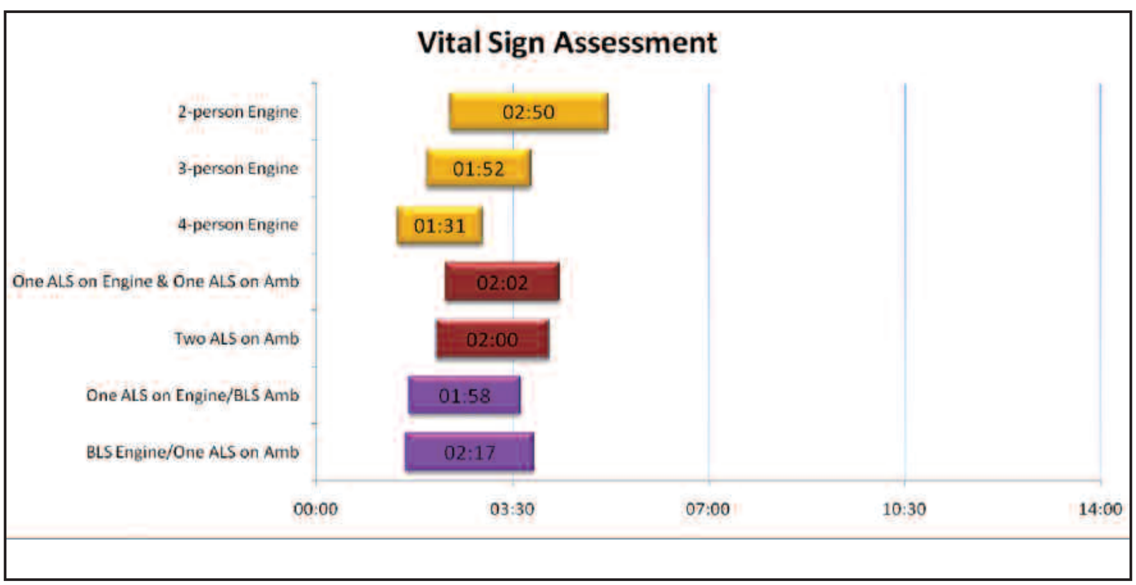

Figure 19: Vital Sign Assessment Start and Duration

Wound Bandaging

First responders with three-person crews were able to begin bandaging the patient's wounds a minute and 40 seconds sooner than first responders with two-person crews. The value of a four-person crew witnessed in the earlier tasks (e.g., checking vitals) did not manifest for this task.

Splint Leg

First responders with four-person crews were able to begin splinting the patient's leg approximately a minute faster than either the two- or three-person crews. A small advantage of a four-person crew re-emerges at this next step (i.e., following bandaging) in the response task sequence.

Crew configurations with one ALS provider on the first responding engine and one on the ambulance were able to begin splinting the patient's leg 40 seconds sooner than crews with two ALS providers on the ambulance.

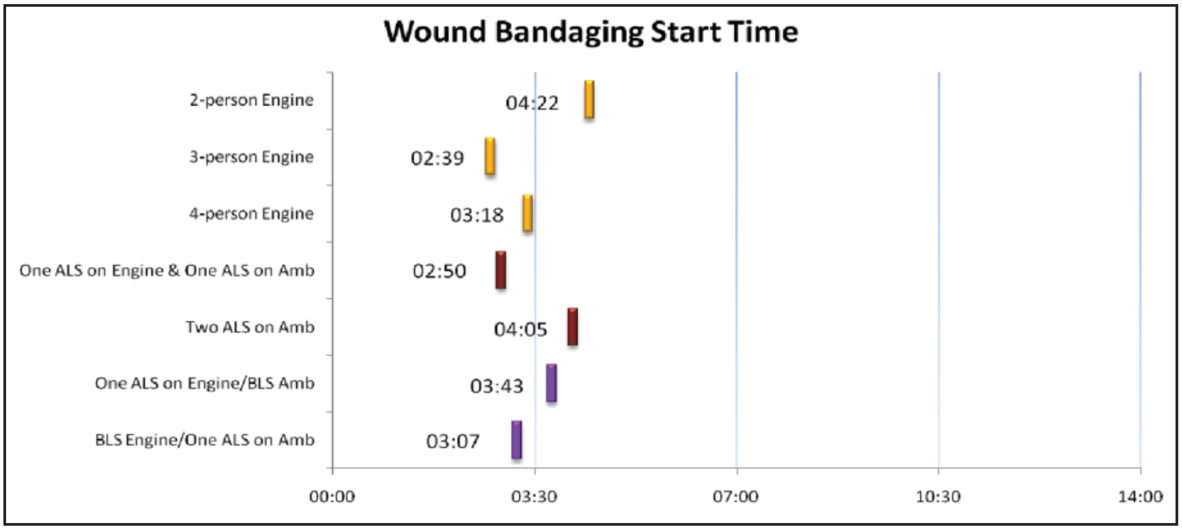

Figure 20: Wound Bandaging Start Time

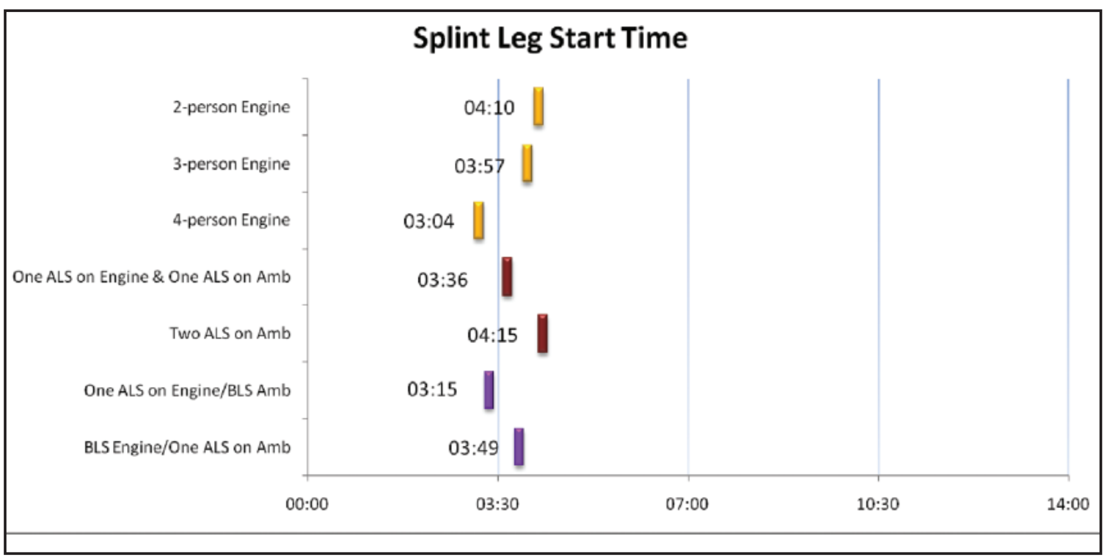

Figure 21: Splint Leg Start Time

Spinal Immobilization/ Back board

First responders with four-person crews were able to conduct spinal immobilization/back-boarding of the patient two minutes faster than either two- or three-person crews. No differences were observed based on placement or number of the ALS personnel.

Airway — Endotracheal Intubation

First responders with four-person crews were able to begin securing the patient's airway using endotracheal intubation two and one-half minutes (2 minutes and 35 seconds) sooner than the two-person crews and two minutes sooner than the three-person crews.

Crew configurations with one ALS provider on the first responding engine and one on the ambulance were able to begin securing the airway using endotracheal intubation one minute and 25 seconds sooner than crews with two ALS providers on the ambulance.

Additional personnel marginally speed up the intubation procedure. A second ALS person and having more than two persons on the engine each reduce the time of the intubation by half a minute.

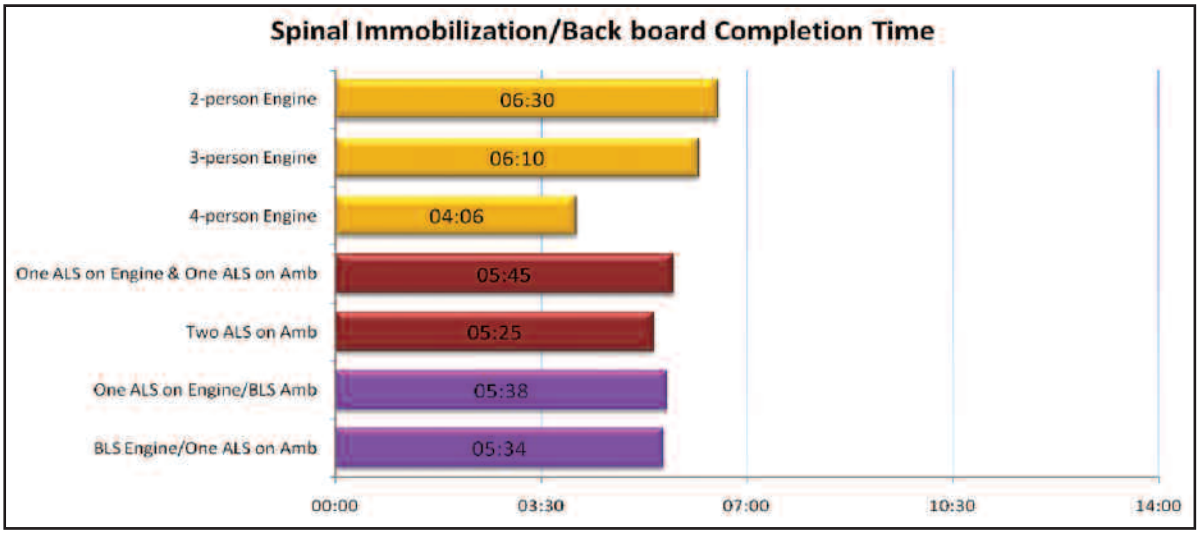

Figure 22: Spinal Immobilization Time Airway – Endotracheal Intubation

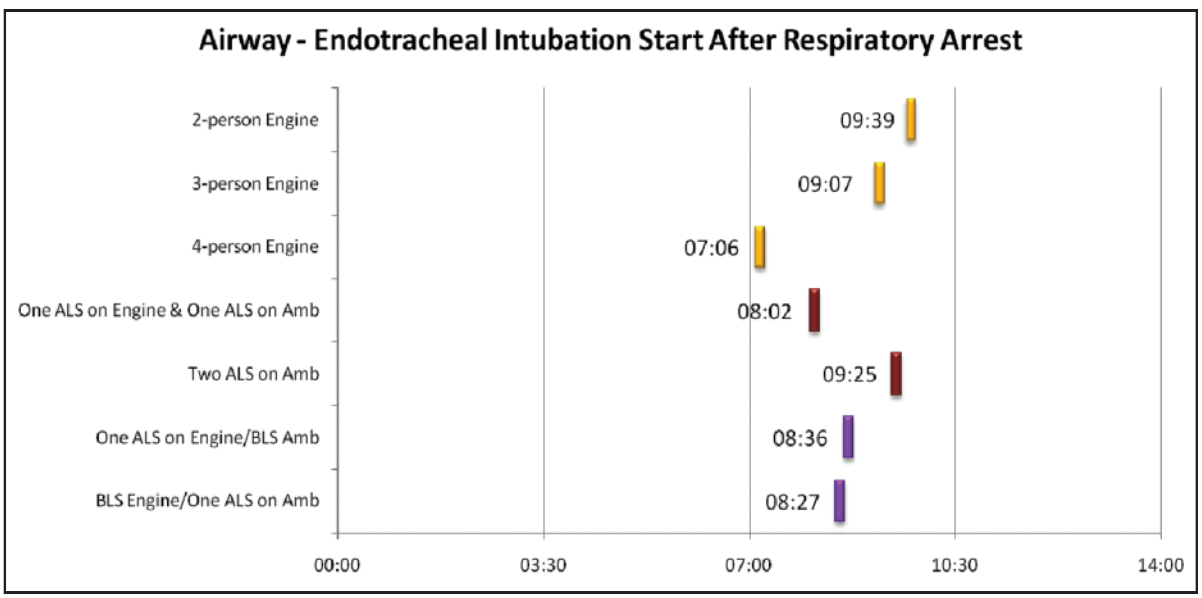

Figure 23: Airway – Intubation Start Time

Bag Valve Mask

First responders with four-person crews were able to begin bag valve mask ventilation after intubation two minutes and 35 seconds sooner than the two–person crews and nearly two minutes (110 seconds) sooner than the three-person crews.

Crew configurations with one ALS provider on the first responding engine and one on the ambulance were able to begin bag valve mask ventilation after intubation one and one-half minutes (one minute and 29 seconds) sooner than crews with two ALS providers on the ambulance.

Patient Packaging

Additional first responders reduce the times until the start and completion of packaging. First responders with four-person crews were able to begin patient packaging 3.1 minutes (three minutes and 5 seconds) sooner and complete all packaging activities moving toward transport nearly 3.4 minutes (three minutes and 25 seconds) sooner than the two-person crews. In addition, the four-person crews were able to begin patient packaging 1.6 minutes (one minute 35 seconds) sooner and complete all packaging activities moving toward transport 1.7 minutes (one minute 40 seconds) sooner than the three–person crews.

Crew configurations with one ALS provider on the first responding engine and one on the ambulance were able to begin patient packaging 2.1 minutes (two minutes and 5 seconds) sooner and complete all packaging activities moving toward transport 2.3 minutes (two minutes and 15 seconds) sooner than crews with both ALS personnel arriving on the ambulance. No differences were associated with placement of a single ALS

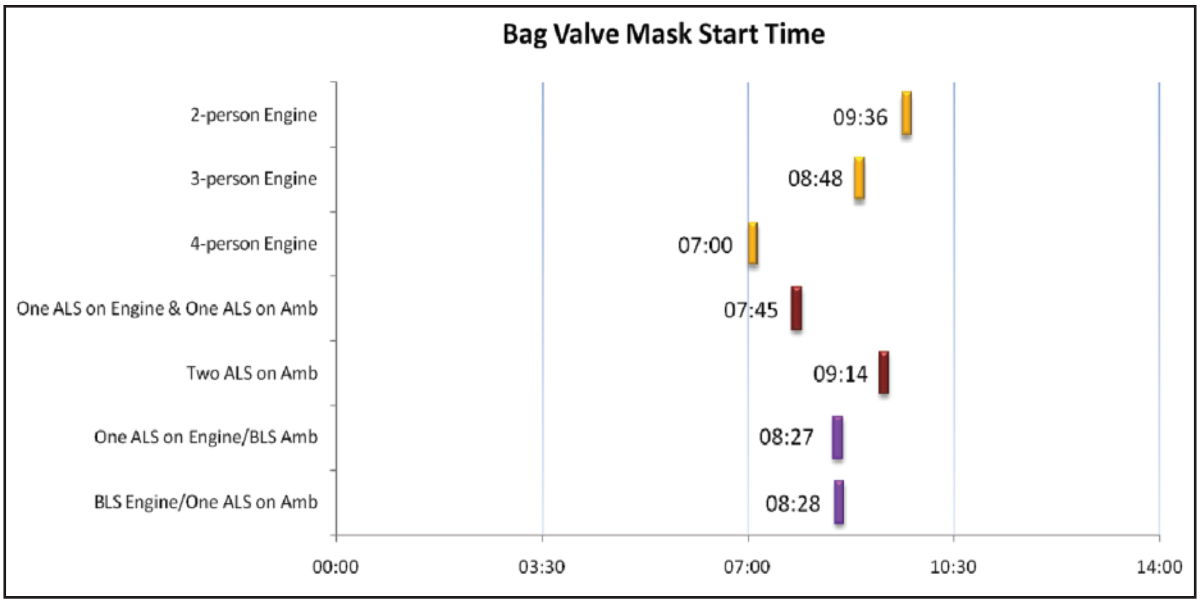

Figure 24: Bag Valve Mask Start Time

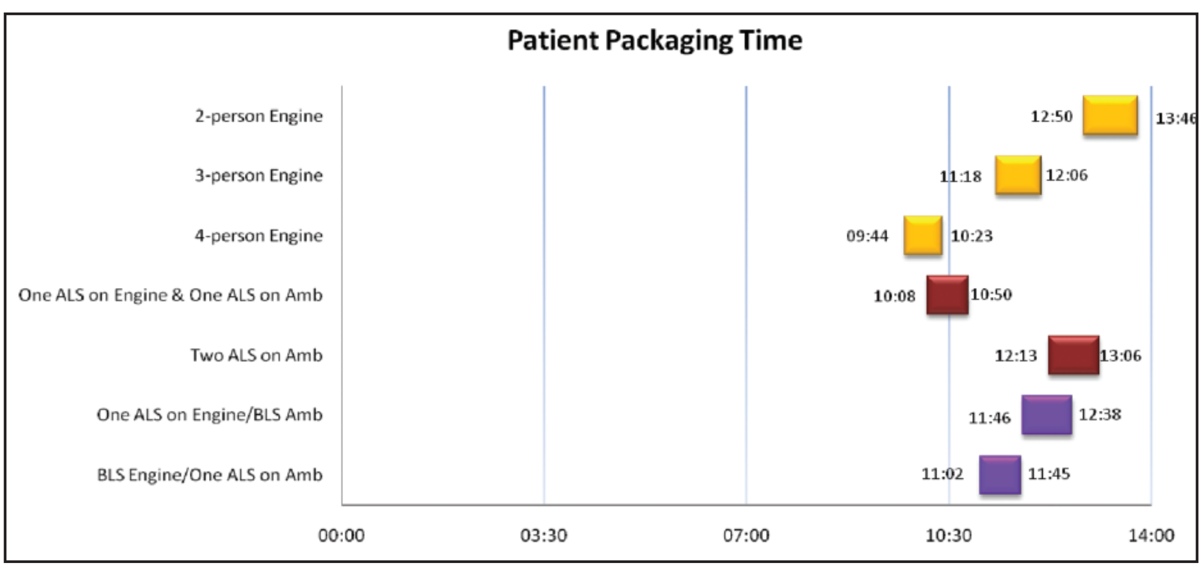

Figure 25: Patient Packaging Start and End Times

provider or with the availability of a second ALS provider.

Patterns in the Trauma Scenario

The preceding presentation focuses on the specific tasks that comprise the overall trauma response sequence. Examination of the collection of findings across tasks, reveals patterns that provide insight into how crew configurations affect trauma response. To examine this, the occurrences of significant differences of elapsed time to start by task were tabulated. Table 9 presents the task sequence and statistically significant differences when comparing ALS placement (Columns A and B) and contrasting crew sizes (Columns C – E) for the outcome "elapsed time to the start of a task." Column A shows a clear advantage to placing one ALS on the engine (with one on an ambulance that arrives three minutes later) versus two ALS on a later arriving ambulance. The time advantage manifests in the last third of the task sequence, beginning with splinting the leg. One explanation for this would be that that having an ALS on the engine creates small increments of time that cumulate and finally manifest (at a statistically significant level) beginning with splinting the leg and carrying forward to all subsequent tasks. Another factor may be that certain tasks may be performed concurrently rather than sequentially when enough hands are available at the scene and this leads to overall time reductions relative to smaller crews that are forced to complete some set of tasks sequentially.

No clear pattern emerges for starting time significant differences when contrasting the addition of a second ALS person (Column B). The same appears to be true for comparing the crew sizes of three versus two (see Column C).

On the other hand, distinct patterns are seen in Columns D and E of Table 9 which depict the comparison of four versus two and four versus three crew sizes, respectively. Although there is some evidence of real time savings (as far as elapsed time to start a task) for the middle third of tasks in the sequence (for example between O^2 administration and splint leg), a consistent pattern favoring a crew size of four is seen beginning with airway intubation and continuing through patient packaging.

Taken as a whole, Table 9 suggests that while a crew size of four may not consistently produce time savings in the start of tasks initially in the trauma task sequence, there are clear advantages as work progresses, beginning with airway intubation through patient packaging. The same can be seen (beginning earlier with leg splinting) when comparing the start times for one ALS on the engine and one on the ambulance versus two ALS on the ambulance. No such pattern emerges for the single ALS provider regardless of placement on the engine versus the ambulance.

Trauma Scenario Coefficient Direction and Significant Differences for Elapsed Time to Start* by Task and Staff Configuration**

	A	B	C	D	E
TRAUMA Task Sequence:	**PLACEMENT: 1 ALS on Amb and 1 ALS on Engine vs 2 on Ambulance**	**PLACEMENT: 2 ALS vs 1 ALS**	**CREW SIZE: 3 vs. 2**	**CREW SIZE: 4 vs. 2**	**CREW SIZE: 4 vs. 3**
Spinal Motion Restriction					
ABCs			S +		
Patient Interview		S +			
Body sweep					
O2 administration					S -
Check Vitals		S +		S -	S -
Expose patient					
Wound Bandaged					
Splint Leg	S -			S -	S -
Back Board	S -				
Airway - intubation	S -			S -	S -
Bag Valve Mask	S -			S -	S -
Package Patient / move for transport	S -		S -	S -	S -

* An 'S' cell entry denotes a statistically significant difference at the 0.05 level for Elapsed Time to Start under the test shown in the Column heading. Also, a '+' indicates a positive coefficient value (longer time) ; a '−' denotes a negative coefficient value (shorter time).
** The contrast of one ALS on Engine vs one ALS on Ambulance showed no statistically significant differences for start time and therefore is not presented in this table.

Table 9: Trauma Scenario Coefficient Direction and Significant Differences

Part 3- Chest Pain and Witnessed Cardiac Arrest

Overall Scene Time

Crews responding with four first responders, regardless of ALS configuration, completed all cardiac tasks from the "at patient time" 70 seconds faster than first responder crews with three persons, and two minutes and 40 seconds faster than first responder crews with two persons.

Additionally, crews responding with one ALS provider on both the engine and ambulance completed all scene tasks from the "at patient time" 45 seconds sooner than crews with two ALS providers on the ambulance and a BLS engine.

Crews responding with an ALS Engine and a BLS Ambulance completed tasks from "at patient time" two minutes 36 second sooner than crews with a BLS Engine and one ALS provider on the Ambulance.

These results echo the trauma findings.

Due to the nature of the cardiac scenario, where crews began the experiment with a chest pain patient who then went into cardiac arrest (no pulse and no respirations), it was necessary to assess some tasks relative to the time the patient arrested. The arrest was cued from the end time for the 12-Lead ECG task.

Crews responding with four first responders, regardless of ALS configuration, completed cardiac tasks following the patient going into cardiac arrest 85 seconds faster than first responder crews with two persons.

Crews responding with a BLS engine and an ambulance with two ALS level providers completed all cardiac tasks following the patient arrest 50 seconds sooner than crews with an ALS provider on both the engine and ambulance. This counter-intuitive difference in the results may be attributable to the delay of the patient arrest time based on the arrival of the 12-Lead ECG monitor with the two-person ALS Ambulance crew. The 12-Lead ECG task *end time* was the arrest *start time*. In this scenario, there were instantaneously two ALS providers present at the arrest rather than the one ALS provider placing the 12-Lead ECG device in the ALS engine /ALS Ambulance crew.

The statistical tests that correspond to these findings appear in Appendix G. Appendix H shows the original regression coefficient estimates upon which the tests in Appendix G were constructed.

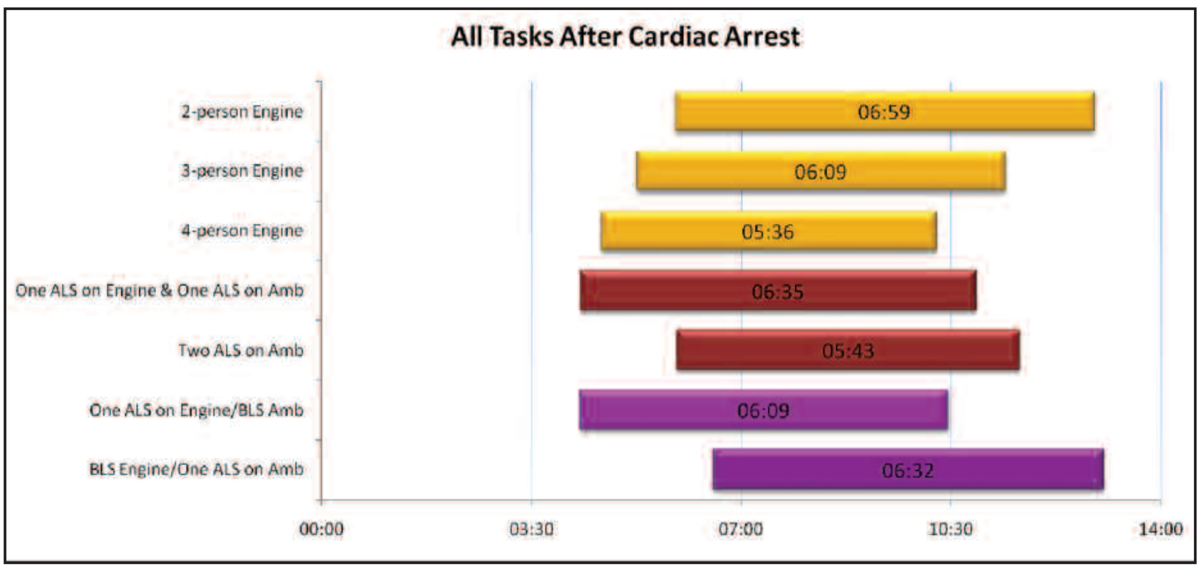

Figure 27: Total Cardiac Completion Time

Individual Task Times

12-Lead ECG Monitor

Crew configurations with one ALS provider on the first responding engine and one ALS level provider on the ambulance were able to apply the 12-lead ECG device two minutes and 20 seconds sooner than crews with both ALS providers on the ambulance.

Similarly, crew configurations with one ALS provider on the first responding engine and no medic on the ambulance also were able to apply the 12-lead ECG device two minutes and 20 seconds sooner than crews with no ALS on the first responding engine and a single ALS level provider on the ambulance.

These results may be influenced by the fact that this task can only be administered by ALS level providers. When ALS personnel are only on the ambulance, the task cannot begin until three minutes after the start of the experiment – the ambulance arrival time built into the experiments. Nonetheless, this finding is noteworthy given that national data show that ambulances typically arrive later than first responder crews.

Only a small difference in the time to begin applying the ECG device was associated with having a second ALS provider on the scene. This is not surprising, as ECG application typically requires a single ALS trained provider. Other ALS tasks later in the sequence show greater significance for having two ALS personnel on scene.

IV Access

Crew configurations with one ALS provider on the first responding engine and no medic on the ambulance were able to start the procedure for IV access two minutes and 30 seconds sooner than crews with no ALS on the first responding engine and a single ALS level provider on the ambulance. No reductions in the time to IV access were associated with a second ALS on scene. Although likely a by-product of the three-minute ambulance stagger, this finding is noteworthy because of the typical lag (behind first responders) in the arrival of an ambulance.

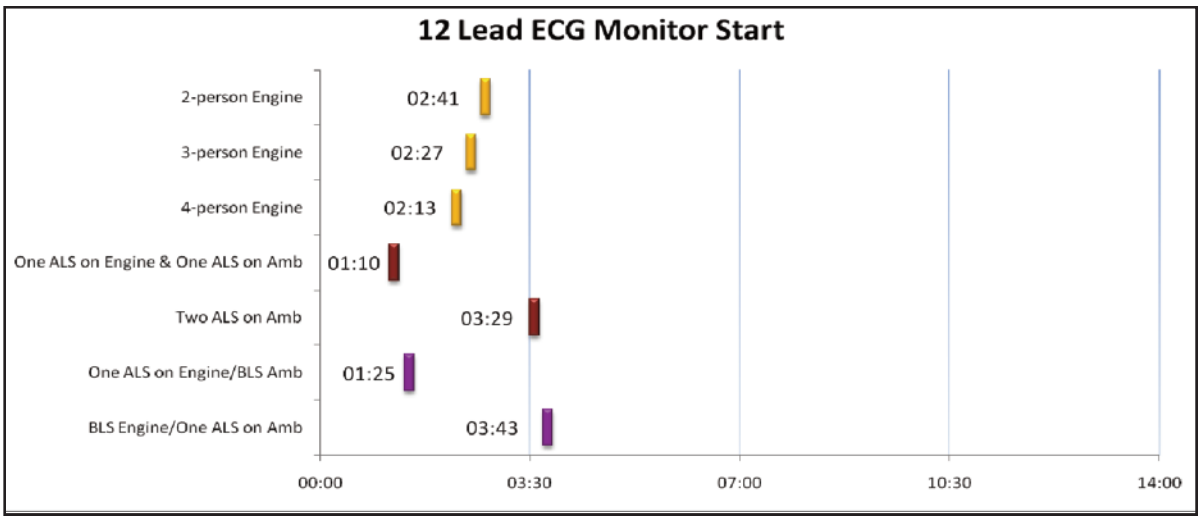

Figure 28: 12-Lead ECG Start Time

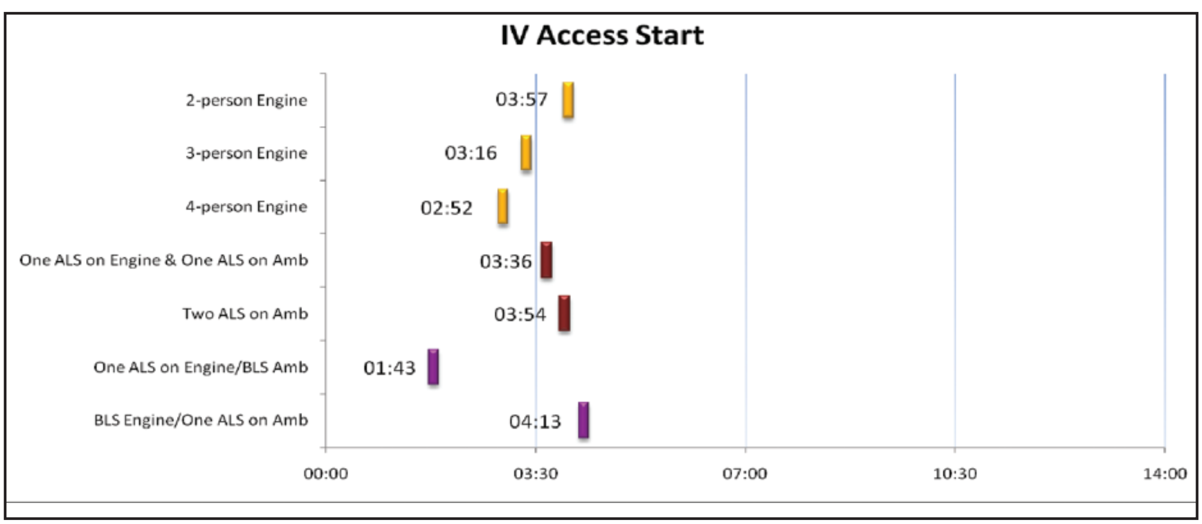

Figure 29: IV Access Start Time

Airway- Endotracheal Intubation

Crew configurations with two ALS level providers were able to begin to secure the patient's airway using endotracheal intubation over a minute (65 seconds) sooner than crew configurations with one ALS provider.

Patient Packaging

Measured from the time of arrest, first responders with four-person crews were able to begin patient packaging one minute sooner and complete all packaging activities moving toward transport one minute and 25 seconds sooner than the two-person crews.

First responders with three-person crews were able to complete all patient packaging activities moving toward transport 50 seconds sooner than the two-person crews, while four-person crews were able to complete all patient packaging activities moving toward transport 85 seconds sooner than the two-person crews.

Crew configurations with two ALS personnel arriving on the ambulance were able to complete all packaging activities, post arrest and move toward transport 50 seconds sooner than crews with one ALS provider on the first responding engine and one on the ambulance.

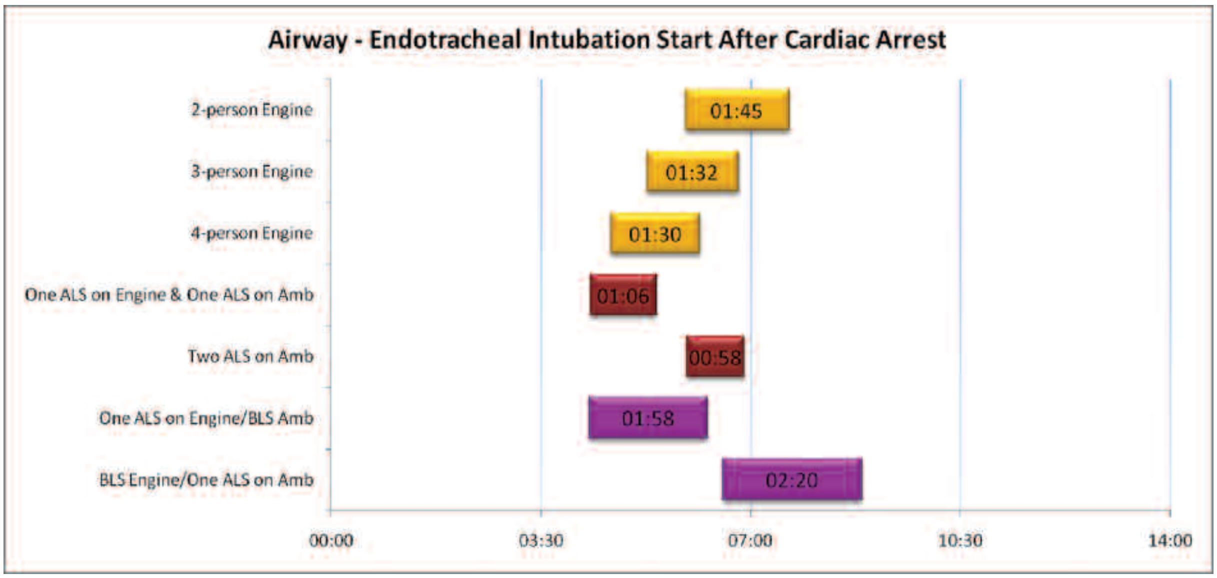

Figure 30: Airway- Intubation After Patient Arrest

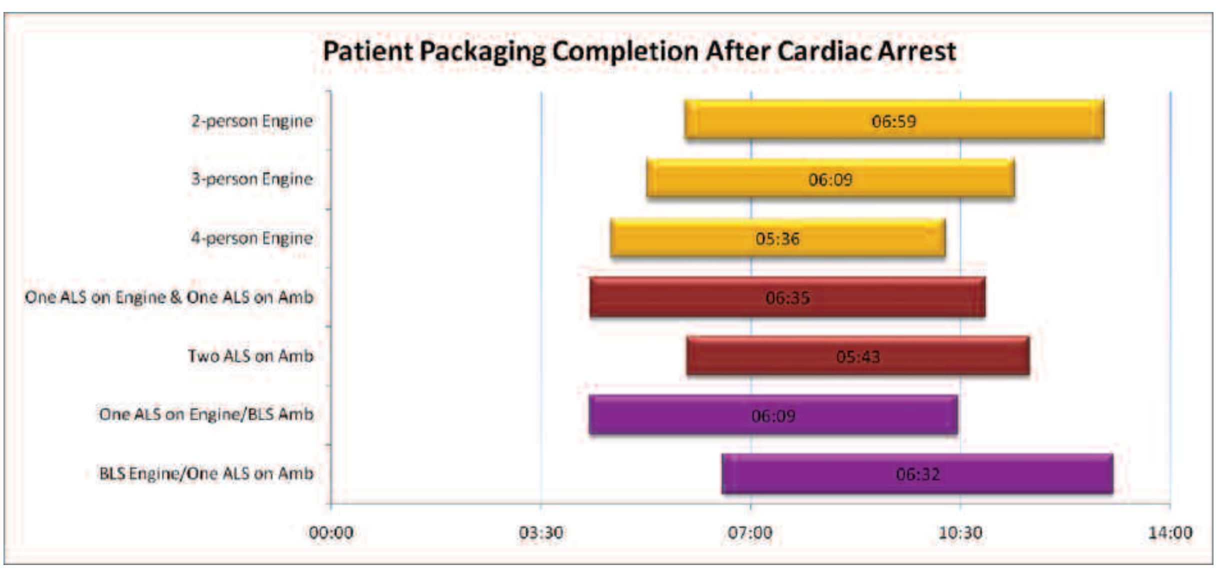

Figure 31: Patient Packaging Completion After Patient Arrest

Patterns in the Cardiac Scenario

As with the trauma analysis, the preceding presentation of findings focused on specific tasks that comprise an EMS cardiac response. The significant differences of elapsed task start times were tabulated by task and appear as Table 10. The table presents the task sequence and statistically significant differences when comparing ALS placement (Columns A – C) and contrasting crew sizes (Columns D – F) for the outcome "elapsed time to the start of a task."

The results appear mixed. Column A shows that an ALS provider on an engine has advantages over an ALS provider on an ambulance for start times in earlier tasks – ALS Vitals 12-Lead through IV access. No other ALS provider placement advantages appear for the remainder of the response sequence.

Columns B and C show sporadic task-specific advantages for start times in a few tasks. For example, when comparing crews with one ALS provider on the engine and one ALS provider on the ambulance versus two ALS providers on ambulance, and when comparing crew configurations with two ALS providers (regardless of placement) to crews with one ALS provider. A Similar sporadic advantage appears when comparing first responder crew sizes of three versus a crew size two.

A pattern similar to that observed with trauma appears when comparing the start times for a first responder crew of four versus a first responder crew of two. The advantage of the four-person crew appears in a few early tasks with at least two tasks being completed sequentially, including the initial ABC's being completed with the vital sign check, and the 12-Lead ECG being completed with exposing the patient's chest task. However, comparing these first responder crew sizes, a greater sequential time advantage is revealed for the last three tasks (analyze shock #2 through package patient), as shown in the last three rows of Column E.

Cardiac Scenario Coefficient Direction and Significant Differences for Elapsed Time to Start* by Task and Staff Configuration**

CARDIAC Tasks:	A PLACEMENT: 1 ALS on Engine vs 1 ALS on Ambulance	B PLACEMENT: 1 ALS on Amb and 1 ALS on Engine vs 2 on Ambulance	C PLACEMENT: 2 ALS vs 1 ALS	D CREW SIZE: 3 vs. 2	E CREW SIZE: 4 vs. 2
ABCs				S -	S -
Patient Interview					
O2 administration					
Check Vitals					
ALS Vitals 12-Lead	S -	S -			S -
Expose Chest	S -	S -			S -
IV Access	S -				
Position Patient (from arrest)			S -		
ABCs (from arrest)					
Defib pads (from arrest)					
Analyze / Shock #1 (from arrest)					
ABCs – After Shock #1 (from arrest)					
CPR – CPR (from arrest)					
Airway Intubation (from arrest)			S -		
Meds (Epi) (from arrest)		S +			
Analyze / Shock #2 (from arrest)				S -	S -
Medis (Lidocaine) (from arrest)			S -		S -
Package Patient/Equip (from arrest)					S -

Table 10: Cardiac Scenario Coefficient Direction and Significant Differences

Conclusions

The objective of the experiments was to determine how first responder crew size, ALS provider placement, and the number of ALS providers is associated with the effectiveness of EMS providers. EMS crew effectiveness was measured by task intervention times in three scenarios including patient access and removal, trauma, and cardiac arrest. The results were evaluated from the perspective of firefighter and paramedic safety and scene efficiency rather than as a series of distinct tasks. More than 100 full-scale EMS experiments were conducted for this study.

As noted in the literature review, hundreds of firefighters and paramedics are injured annually on EMS responses. Most injuries occur during tasks that require *lifting or abnormal movement* by rescuers. Such tasks include lifting heavy objects (including human bodies both conscious and unconscious), manipulating injured body parts and carrying heavy equipment. Several tasks included in the experiments fall into this category, including splinting extremities, spinal immobilization (back boarding) and patient packaging. During the experiments larger crews completed these tasks more efficiently by distributing the workload among more people thereby reducing the likelihood of injury.

A number of tasks are also *labor intensive*. These tasks can be completed more efficiently when handled by multiple responders. Several tasks in the experiments are in this category. These include checking vital signs, splinting extremities, intubation with spinal restriction, establishing IV access spinal immobilization, and patient packaging. Similar to the lifting or heavy work load task, larger crews were able to complete labor intensive tasks using multiple crew members on a single task to assure safe procedures were used reducing the likelihood of injury or exposure.

Finally, there are opportunities on an EMS scene to reduce scene time by completing tasks simultaneously rather than concurrently thus increasing operational efficiency. Since crews were required to complete all tasks in each scenario regardless of their crew size or configuration, overall scene times reveal operational efficiencies.

Each of these perspectives is discussed below for the patient access/removal scenario, as well as both the trauma and the cardiac scenarios.

Patient Access and Removal

With regard to accessing the patient, crews with three or four first responders reached the patient around half a minute faster than smaller crews with two first responders. With regard to completing patient removal, larger first responder crews in conjunction with a two-person ambulance were more time efficient. The removal tasks require heavy lifting and are labor intensive. The tasks also involve descending stairs while carrying a patient, carrying all equipment down stairs, and getting patient and equipment out multiple doors, onto a stretcher and into an ambulance.

The patient removal results show substantial differences associated with crew size. Crews with three- or four-person first responders complete removal between (1.2 – 1.5) minutes faster than smaller crews with two first responders. All crews with first responders complete removal substantially faster (by 2.6 min. - 4.1 min.) than the ambulance-only crew.

These results suggest that time efficiency in access and removal can be achieved by deploying three-or four-person crews on the first responding engine (relative to a first responder crew of two). To the extent that each second counts in an EMS response, these staffing features deserve consideration. Though these results establish a technical basis for the effectiveness of first responder crews and specific ALS crew configurations, other factors contributing to policy decisions are not addressed.

Trauma

Overall, field experiments reveal that four-person first responder crews completed a trauma response faster than smaller crews. Towards the latter part of the task response sequence, four-person crews start tasks significantly sooner than smaller crews.

Additionally, crews with one ALS provider on the engine and one on the ambulance completed all tasks faster and started later tasks sooner than crews with two ALS providers on the ambulance. This suggests that getting ALS personnel to the site sooner matters.

A review of the patterns of significant results for task start times reinforced these findings and suggests that (in general) small non-significant reductions in task timings accrue through the task sequence to produce significantly shorter start times for the last third of the trauma tasks.

Finally, when assessing crews for their ability to increase on-scene operational efficiency by completing tasks simultaneously, crews with an ALS provider on the engine and one ALS provider on the ambulance completed all required tasks 2.3 minutes (2 minutes 15 seconds) faster than crews with a BLS engine and two ALS providers on the ambulance. Additionally, first responders with four-person first responder crews completed all required tasks 1.7 minutes (1 minute 45 seconds) faster than three-person crews and 3.4 minutes (3 minutes and 25 seconds) faster than two-person crews.

Cardiac

The overall results for cardiac echo those of trauma. Regardless of ALS configuration, crews responding with four first responders completed all cardiac tasks (from at-patient to packaging) more quickly than smaller first responder crew sizes. Moreover, in the critical period following cardiac arrest, crews responding with four first responders also completed all tasks more quickly than smaller crew sizes. As noted in the trauma scenario, crew size matters in the cardiac response.

Considering ALS placement, crews responding with one ALS provider on both the engine and ambulance completed all scene tasks (from at-patient to packaging) more quickly than a crew with a BLS engine and two ALS providers on the ambulance. This suggests that ALS placement can make a difference in response efficiency. One curious finding was that crews responding with a BLS engine and an ambulance with two ALS providers completed the tasks that follow cardiac arrest 50 seconds *sooner* than crews with an ALS provider on both the engine and ambulance. As noted, this counter-intuitive difference in the results may be attributable to the delay of the patient arrest time based on the arrival of the 12-Lead ECG monitor with the two-person ALS Ambulance crew. The 12 -Lead ECG task *end time* was the arrest *start time*. In this scenario, there were instantaneously two ALS providers present at the arrest rather than the one ALS provider placing the 12-Lead ECG device in the ALS engine /ALS Ambulance crew.

A review of the patterns of significant results across task start times showed mixed results. An ALS on an engine showed an advantage (sooner task starting times) over an ALS on an ambulance for a few tasks located earlier in the cardiac response sequence (specifically, ALS Vitals 12-Lead through IV access). A crew size of four also showed shorter start times for a few early tasks in the cardiac response sequence (initial ABC's, and the ALS Vitals 12-Lead and expose chest sequence). More importantly, a sequential time advantage appears for the last three tasks of the sequence (analyze shock #2 through package patient).

Finally, when assessing crews for their ability to increase on-scene operational efficiency by completing tasks simultaneously, crews with an ALS provider on the engine and one ALS provider on the ambulance completed all required tasks 45 seconds faster than crews with a BLS engine and two ALS providers on the ambulance. Regardless of ALS configuration, crews responding with four first responders completed all cardiac tasks from the "at patient time" to completion of packaging 70 seconds faster than first responder crews with three persons, and two minutes and 40 seconds faster than first responder crews with two persons. Additionally, *after the patient arrested*, an assessment of time to complete remaining tasks revealed that first responders with four-person crews completed all required tasks 50 seconds faster than three-person crews and 1.4 minutes (1 minute 25 seconds) faster than two-person crews.

Summary

While resource deployment is addressed in the context of three basic scenarios, it is recognized that public policy decisions regarding the cost-benefit of specific deployment decisions are a function of many factors including geography, resource availability, community expectations as well as population demographics that drive EMS call volume. While this report contributes significant knowledge to community and fire service leaders in regard to effective resource deployment for local EMS systems, other factors contributing to policy decisions are not addressed. The results however do establish a technical basis for the effectiveness of first responder crews and ALS configuration with at least one ALS level provider on first responder crews. The results also provide valid measures of total crew size efficiency in completing on-scene tasks some of which involve heavy lifting and tasks that require multiple responders to complete.

These experimental findings suggest that ALS provider placement and crew size can have an impact on some task start times in trauma and cardiac scenarios, especially in the latter tasks leading to patient packaging. To the extent that creating time efficiency is important for patient outcomes, including an ALS trained provider on an engine and using engine crew sizes of four are worth considering. The same holds for responder safety – for access and removal and other tasks in the response sequence, the availability of additional hands can serve to reduce the risks of lifting injuries or injuries that result from fatigue (e.g., avoid having small crews repeatedly having to ascend and descend stairs). Cost considerations for EMS response and crew configurations were not considered in this study.

Study Limitations

The scope of this study is limited to understanding the relative influence of deployment variables on labor-intensive emergency medical incidents, specifically multi-system trauma and cardiac arrest events. It should be noted that the applicability of the conclusions from this report to a large scale hazardous or multiple-casualty event have not been assessed and should not be extrapolated from this report.

The crews involved in this study typically operate using three- to four-person engine crews, and two-person ambulance crews. However, other departments across the United States vary in crew sizes, some using two- to five-person first responder engine crews and three-person ambulance crews.

Every attempt was made to ensure the highest possible degree of realism in the experiments including the use of multiple crews from multiple shifts in the participant departments. However, as the trauma and cardiac experiments were repeated a minimum of 45 times, for crews involved in more than one experiment, a learning curve on the part of the participants may have been established.

All experiments were conducted indoors, during daylight hours. Treating patients outside among varying weather conditions or at night, when visibility is lower, could pose additional obstacles. Additionally, the actual effect of ALS interventions on patient outcome is beyond the scope of this study. Patient outcomes were not quantified or estimated.

The design of the experiments limited the patient care scenarios to a systemic trauma event and a medical cardiac event. Other patient illnesses and injuries including diabetes, seizures, gunshot wounds, stabbings, and motor vehicle accidents were not considered.

EMS protocols pertaining to the treatment and transport of patients vary by departments. For the purpose of this study, tasks were standardized by technical experts and individual times were recorded for each task. In real-world situations, as in this study, many of these can be performed simultaneously based on the number and training level of responding personnel. Attempts to generalize the results from these experiments to individual departments must take into account protocols and equipment that vary from those used in the experiments.

Finally, data from U.S. fire departments were used to set response and arrival time assumptions. For departments with different deployment capability for both first responder crews and ambulances, the results may vary.

Future Research

In order to realize a significant reduction in firefighter and paramedic line-of-duty injury, fire service leaders must focus directly on resource allocation and the deployment of resources, a known contributing factor to LOD injury. Future research should use similar methods to evaluate firefighter/paramedic deployment to other medical emergencies as well as combination scenes where both fire suppression and EMS resources are needed. Additionally, resource deployment to multiple-casualty disasters or terrorism events should be studied to provide insight into levels of risks specific to individual communities and to recommend resource deployment proportionate to such risk. Future studies should continue to investigate the effects of resource deployment on the safety of firefighters, paramedics and the civilian population to better inform public policy. Finally, the ability to relate response and task timing to patient outcomes and survival rates should be quantified.

Acknowledgements

A project of this magnitude extends well beyond the capabilities and expertise of the authors of this report. The following individuals were instrumental to the success of the EMS experiments.

- Technical Experts – Phil Pommerening, Captain II, Station 34A from Fairfax County Fire and Rescue Department, Michael McAdams, EMS Chief, Montgomery County Fire and Rescue Department, Dr. Greg Mears, Medical Director, University of North Carolina, Paul Neal, Safety Officer for Montgomery County Fire and Rescue Department, Lt. Tom Papoutsis, EMS Training, Fairfax County Fire and Rescue Department, and Adam Barowy, National Institute of Standard and Technology.

- Project Support — Montgomery County Fire and Rescue Department – Chief Richard Bowers AND Fairfax County Fire and Rescue Department – Chief Ronald Mastin for supporting this study over a period of years to an unprecedented degree.

- IAFF Staff/Data Entry/ Timer supervision – Nicole Taylor, Randy Goldstein, and Ron Benedict

- Timers – Cliff Berner, Lead, DeWayne Dutrow, Alyssa Vance, Nicole Taylor, Ron Benedict, Randy Goldstein, and Adam Barowy.

- The dedicated Fire and EMS Officers and Firefighters/Paramedics from Montgomery County Fire and Rescue and Fairfax County Fire and Rescue, who performed the difficult work of EMS response and patient care safely and effectively.

References

- American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiac Care (2005). Circulation, Vol. 112, No. 24 (Suppl), Pg 1-88.
- Averill, J.D., et al.; Moore-Merrell, L. ;Barowy, A.; Santos, R.; Peacock, R.; Notariann, K.; Wisooker, D. (2010), NIST Report on Residential Fireground Field Experiments. Natl. Inst. Stand. Technol, NIST Technical Note 1661.
- Becker, L.B.; Ostrander, M.P.; Barrett, J.; Kondon, G.T. (1991). Outcome of CPR in a Large Metropolitan Area- Where are the Survivors? Ann Emerg Med, Vol. 20, No. 4, Pg. 355.
- Boyd, C.R.; Tolson, M.A.; and Copes, W.S. (1987). Evaluating Trauma Care: The TRISS Method. J. Trauma, Vol. 27, No. 4, 370-378.
- Braun, O.; McCallion, R.; Fazackerley, J. (1990). Characteristics of Midsized Urban EMS Systems. Ann Emerg Med, Vol. 19, No. 5, Pg. 536.
- Brown, L. H.; Owens Jr., C. F.; March, J. A.; Archino, E. A. (1996). Does Ambulance Crew Size Affect On-Scene Time or Number of Prehospital Interventions? Prehosp Disast Med, Vol. 11, No. 3, Pg. 214.
- Commission on Fire Accreditation International (CFAI) Standards of Cover, Fifth Edition (2008) Chantilly, VA
- Chu, K.;Swor, R.; Jackson, R.; Domeier, R.; Sadler, E.; Basse, E.; Zaleznak, H.; Gitlin, J. (1998). Race and Survival after Out-of-Hospital Cardiac Arrest in a Suburban Community. Ann Emerg Med, Vol. 31, No. 4, Pg. 478.
- Cummins, R. O.; Ornato, J. P.; Thies, W. H.; Pepe, P. E. (1991). Improving Survival from Sudden Cardiac Arrest: The "Chain of Survival Concept." Circulation, Vol. 83, No. 5, Pg. 18-32.
- DeMaio, V.J.; Stiell, I.G.; Nesbitt, L.; Wells, G.A. (2005). Faster Advanced Life Support Response Intervals May Improve Cardiac Arrest Survival. Acad Emerg Med, Vol. 12, No. 5, Pg. 16.
- Eisenberg, M.S.; Horwood, B.T.; Cummins, R.O.; Reynolds-Haertle, R.; Hearne, T.R. (1990). Cardiac Arrest and Resuscitation: A Tale of 29 Cities. Ann Emerg Med, Vol. 19, No. 2, Pg. 179-186.
- Hallstrom, A.P.; Ornato, J.P.; Weisfeldt, M.; Travers, A.; Christenson, J.; McBurnie, M.A.; Zalenski, R.; Becker, L.B.; Schron, E.B.; Proschan, M. (2004). Public-Access Defibrillation and Survival after Out-of-Hospital Cardiac Arrest. N Engl J Med, Vol. 21, No. 7, Pg. 637.
- Heick, R.; Young, T.;Peek-Asa, C. (2009). Occupational Injuries Among Emergency Medical Service Providers in the United States. J Occup Med, Vol. 51, No. 8, Pg. 963-968.
- IAFC/IAFF Fire and EMS Operation Database: Analysis of Response Times (2005).
- Karter, M.J. Jr.; Molis, J.L. (2009). U.S. Firefighter Injuries-2008. NFPA Journal, November/December 2009.
- Kellerman, A.L.; Hackman, B.B.; Somes, G.; Kreth, T.K.; Nail, L.; Dobyns, P. (1992). Impact of First Responder Defibrillation in an Urban EMS System. Ann Emerg Med, Vol. 21, No. 14, Pg. 1708.
- Laerdal Medical Corporation. (n.d.) Retrieved from http://www.laerdal.com/doc/7320252/SimMan.html.
- Litwin, P. E.; Eisenberg, M. S.; Hallstrom, A. P.; Cummins, R. O. (1987). The Location of Collapse and its Effect on Survival from Cardiac Arrest. Ann Emerg Med, Vol. 16, No. 7, Pg. 787.
- Maguire, B.J.; Hunting, K.L., Guidotti, T.L.; Smith, G.S. (2005). Occupational Injuries Among Emergency Medical Services Personnel. Prehop Emerg Care, No. 4, Pg. 405-411.
- Moore, L.L. Quality Performance Measures for Fire Department-Based EMS Systems. UMI, Ann Arbor, Michigan (2002).
- Morrison, L.J.; Angelini, M.P.; Vermeulen, M.J.; Schwartz, B. (2005). Measuring the EMS Patient Access Time Interval and the Impact of Responding to High-rise Buildings. Prehosp Emerg Care, Vol. 9, No. 1, Pg. 14-18.
- National Fire Academy (1981). Fire Engines are Becoming Expensive Taxi Cabs: Inadequate Manning. United States Fire Administration, Emmitsburg, MD.
- NFPA (2009). 450: Standard for Emergency Medical Services and Systems. National Fire Protection Association, Quincy, MA.
- NFPA (2007). 1500: Standard on Fire Department Occupational Safety and Health Program. National Fire Protection Association, Quincy, MA.
- NFPA (2010). NFPA 1710: Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments. National Fire Protection Association, Quincy, MA.
- NFPA (2010). NFPA 1720: Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Volunteer Fire Departments. National Fire Protection Association, Quincy, MA.
- NFPA (2008) 1999: Standard on Protective Clothing for Emergency Medical Operations. National Fire Protection Association, Quincy, MA.
- Olson, D.W.; LaRochelle, J.; Fark, D.; et al. (1989). EMT-Defibrillation: The Wisconsin Experience. Ann Emerg Med, Vol. 18, No. 8, Pg. 806.

- Pratt, F.D.; Katz, S.; Pepe, P.E.; Persse, D. (2007). Prehospital 9-1-1 Emergency Medical Response: The Role of the United States Fire Service in Delivery and Coordination. White paper.

- Studnek, J.R.; Ferketich, A.; Crawford, J.M. (2007) On the Job Illness and Injury Resulting in Lost Work Time Among a National Cohort of Emergency Medical Services Professionals. Am J Indus Med, Vol. 50, No.12, Pg. 921-931.

- Sweeney, T.A.; Runge, J.W.; Gibbs: et al. (1998). EMT Defibrillation Does Not Increase Survival from Sudden Cardiac Death in a Two-Tiered Urban-Suburban EMS System. Ann Emerg Med, Vol. 31, No. 2, Pg. 234.

Glossary

12-Lead Electrocardiogram (ECG) — A representation of the heart's electrical activity recorded from 10 electrodes placed in standard positions on the body's surface.

Advanced Cardiac Life Support (ACLS) — A set of clinical interventions for the urgent treatment of cardiac arrest and other life threatening medical emergencies, as well as the knowledge and skills to use those interventions.

Advanced Life Support (ALS) — Emergency medical treatment beyond basic life support that provides for advanced airway management including intubation, advanced cardiac monitoring, defibrillation, establishment and maintenance of intravenous access, and drug therapy.

Ambulance Transport Unit — Provides transport for patients from the incident scene to a health care facility.

Automated External Defibrillator (AED) — A portable electronic device that automatically diagnoses potentially life-threatening cardiac arrhythmias of ventricular fibrillation, and is able to treat them through defibrillation, the application of electrical therapy which stops the arrhythmias, allowing the heart to reestablish an effective rhythm.

Basic Life Support (BLS) — A specific level of prehospital medical care provided by trained responders, focused on rapidly evaluating a patient's condition; maintaining a patient's airway, breathing, and circulation; controlling external bleeding; preventing shock; and preventing further injury or disability by immobilizing potential spinal or other bone fractures.

Cardiac Arrest — Sudden cessation of heartbeat and heart functions, resulting in the loss of effective circulation.

Cardiopulmonary Resuscitation (CPR) — Procedure designed to support and maintain breathing and circulation for a person who has stopped breathing (respiratory arrest) or whose heart has stopped (cardiac arrest).

Chain of Survival — The four components of EMS response to out-of-hospital cardiac arrest that are thought to effect the most optimal patient outcome. The four components include early recognition and EMS access, early CPR, rapid defibrillation, and advanced life support.

Combination Fire Department — Fire department consisting of both paid (career) and volunteer personnel.

Crew configurations — Specific ways of staffing or organizing members of the work force.

Definitive Medical Care — Medical treatment or services beyond emergency medical care, initiated upon inpatient admission to a hospital or health care facility.

Emergency Medical Services (EMS) — The treatment of patients using first aid, cardiopulmonary resuscitation, basic life support, advanced life support, and other medical procedures prior to arrival at a hospital or other health care facility.

EMS Protocols — Written medical instructions authorized by an EMS medical director to be used by personnel in the field without the necessity of on-line or real-time consultation with a physician or nurse.

Emergency Medical Technician (EMT) — A member of the emergency medical services team who provides out-of-hospital emergency care, trained to any level of emergency medical services.

Emergency Medical Technician- Basic (EMT-B) — A member of the emergency medical services team who provides out-of-hospital emergency care, trained in the delivery of Basic Life Support services.

Emergency Medical Technician- Defibrillator (EMT-D) — A member of the emergency medical services team with special training in the use of cardiac defibrillating equipment. (Defibrillation training is now part of Basic Emergency Medical training.)

Emergency Medical Technician- Paramedic (EMT-P) — A member of the emergency medical services team who provides out-of-hospital emergency care, trained in the delivery of Advanced Life Support services.

Endotrachael Tube (ET) — Flexible plastic catheter placed into the trachea to protect the airway and provide a means of mechanical ventilation.

First Responder — Functional provision of initial assessment (i.e., airway, breathing, and circulatory systems) and basic first-aid intervention, including CPR and automatic external defibrillator capability.

First Responder Unit — The first arriving unit at an emergency medical incident, whether it be a fire suppression vehicle or ambulance.

Intervention — Act designed to alter or hinder an action or development.

Intravenous (IV) — An injection administered into a vein.

Intubation — Insertion of a tube through the mouth or nose and into a patient's lungs to help them breathe.

Knox Box Rapid Entry System — Small, wall-mounted safe that holds building keys for firefighters and EMTs to retrieve in emergencies.

Mayocardial Infarction — Heart attack.

Measurement uncertainty — Parameter, associated with the result of a measurement that characterizes the dispersion of the values that could reasonably be attributed to the measure.

National Fire Protection Association (NFPA) — A nonprofit organization, established in 1896, with the mission to reduce the worldwide burden of fire and other hazards on the quality of life by providing and advocating consensus codes and standards, research, training and education.

NFPA 450— Guide for emergency medical services and systems.

NFPA 1500 — Standard on fire department occupational safety and health program.

NFPA 1710 — Standard for the organization and deployment of fire suppression operations, emergency medical operations, and special operations to the public by career fire departments.

NFPA 1720 — Standard for the organization and deployment of fire suppression operations, emergency medical operations, and special operations to the public by volunteer fire departments.

NFPA 1999 — Standard on protective clothing for emergency medical operations.

One-Tier EMS System — EMS system in which all units are advanced life support.

Operational Effectiveness — Capable of producing a particular desired effect in "real world" circumstances.

Operational Efficiency — The effect or results achieved in relation to the effort expended.

Ordinary Least Squares (OLS) — In statistics and econometrics, OLS or linear least squares is a method for estimating the unknown parameters in a linear regression model.

Out-of-hospital — Care for the sick or injured in settings other than hospitals or hospital-affiliated outpatient medical or surgical facilities, typically beginning with a call to 9-1-1.

Patient Packaging — Securing a patient to a mobile contrivance (e.g., stretcher or stair chair) for moving to the transport unit.

Pulse Oximeter — Medical device that measures the oxygen saturation of a patient's blood.

Regression analysis — Includes any techniques for modeling and analyzing several variables, when the focus is on the relationship between a dependent variable and one or more independent variables. More specifically, regression analysis helps us understand how the typical value of the dependent variable changes when any one of the independent variables is varied, while the other independent variables are held.

Standard of Response Cover (SORC) — Policies and procedures that determine distribution, concentration, and reliability of fixed and mobile resources for an emergency response system.

Standard t-test — Measures whether there is any statistical difference in the mean of two groups.

Statistical significance — A number that expresses the probability that the result of a given experiment or study could have occurred purely by chance. This number can be a margin of error or it can be a confidence level.

System resources — Personnel, vehicles, and equipment used in providing EMS.

Systemic trauma — Injury or shock affecting the body generally.

Transport — Conveyance of the sick or injured in an ambulance or emergency vehicle to a hospital setting.

Trauma and Injury Severity Scores (TRISS) — A system developed in the 1980's to improve the prediction of patient outcomes through the use of physiological and anatomical criteria.

Two-Tier EMS System — EMS system that uses first responder or BLS units that typically arrive and begin treatment prior to the arrival of a transport unit.

Acronyms

- **A, B, C's —** Airway, Breathing, and Circulation
- **ACLS —** Advanced Cardiac Life Support
- **AED —** Automated External Defibrillator
- **AHA —** American Heart Association
- **ALS —** Advanced Life Support
- **BLS —** Basic Life Support
- **CFAI —** Commission on Fire Accreditation International
- **CPR —** Cardiopulmonary resuscitation
- **DHS —** Department of Homeland Security
- **DOL —** Department of Labor
- **ECG —** Electrocardiogram
- **EMS —** Emergency Medical Services
- **EMT —** Emergency Medical Technician
- **EMT-B —** Emergency Medical Technician- Basic
- **EMT-D —** Emergency Medical Technician- Defibrillator
- **EMT-P —** Emergency Medical Technician- Paramedic
- **FEMA —** Federal Emergency Management Agency
- **IAFC —** International Association of Fire Chiefs
- **IAFF —** International Association of Fire Fighters
- **LOD —** Line-of-Duty
- **NFPA —** National Fire Protection Association
- **NIST —** National Institute of Standards and Technology
- **OHCA —** Out-of-hospital cardiac arrest
- **OPQRST —** Onset, Provokes, Quality, Radiates, Severity, Time
- **SAMPLE —** Signs and Symptoms, Allergies, Previous history, Medications, Last oral intake, Events leading up to
- **SORC —** Standard of Response Cover
- **TBI —** Traumatic brain injury
- **TRISS —** Trauma and Injury Severity Scores
- **WPI —** Worcester Polytechnic Institute

Appendix A: Time to Task Measures

Time-to-Task Data Collection Chart -EMS

(Overall Response- Patient Access and Removal)

Date ___________ Start Time____________ End Time (all tasks complete) ___________

Crew Used: ❑ Montgomery County ❑ Fairfax County

Timer Name____

Task	Start Time	Completion Time	Difference
Arrive on Scene			
Assemble Equipment			
Conduct Size-up – Scene Safety			
Enter Door- Building- 'Knox box'			
Ascend – Stairs (3 stories)			
Package Patient – stair chair			
Descent – Stairs (3 stories) with patient in stair chair			
Exit Door – Building			
Transfer Patient to cot/stretcher			
Turn Ambulance for Loading			
Load Ambulance/ Seat Belt			

Time-to-Task Data Collection Chart -EMS

(Trauma — BLS — ALS on scene)

Date ___________ Start Time____________ End Time (all tasks complete) ___________

Timer Name____

Task	Start Time	Completion Time	Difference
At Patient			
Spinal motion restriction			
A, B, C's			
Patient Interview			
Body sweep – find laceration on head and angulated fracture of tib/fib (closed) on Right leg			
O^2 Administration – face mask			
Check Vitals (Pulse, Resp., BP, Pulse Ox)			
Expose patient as indicated			
Control Bleeding			
Splint leg			
Back Board			
Movement causes labored breathing – Agonal Respiration ➔ Patient vomits (projectile)			
Airway – Intubation ET with spinal motion restriction – on ground due to distance from transport unit			
Bag Valve Mask			
Package patient / move for transport			

Time-to-Task Data Collection Chart -EMS

(Medical — Cardiac)

Date ___________ Start Time____________ End Time (all tasks complete) ___________

Timer Name____

Task	Start Time	Completion Time	Difference
At Patient			
A, B, C's			
Patient Interview			
O^2 Administration			
Check Vitals (Pulse, Resp., BP, pulse Ox)			
ALS Vitals - ECG 12-Lead			
Expose patient as indicated			
Patient Arrest >>>>>>>>			
Position patient			
ABC's			
Apply Defibrillator pads			
Defibrillate – Shock # 1 – Shock works = NO			
ABC's			
CPR – Bag Valve			
Airway Intubation - ET			
IV access			
Meds (1 Epi)	>>>>	>>>>>>>>>	>>>>>
AED Auto Countdown- "Analyze Patient"			
Defibrillate – Shock #2 – Shock works = **YES**			
Check Vitals – ROSC - unconscious			
Meds (1 Lidocaine Bolus)			
Package Patient			

Appendix B: Trauma Patient Assessment and Interview Form

Name:______________________________________ Age: ________ Male / Female

Chief Complaint: ____

Mechanism of Injury: ____

Primary Survey:

Airway status: open / occluded

Breathing: normal / labored-abnormal / none

Circulation: normal / shocky / none

Mental Status: alert / voice / pain / unresponsive

Body Sweep Findings? ____________________

Secondary / Focused Survey Findings:

Head	L Arm
Face	R Arm
Neck	Abdomen
Chest	L Leg
Back	R Leg

Vital Signs:

BP ______ Pulse: ______ Resp:______ PulseOx: ______

BP ______ Pulse: ______ Resp:______ PulseOx: ______

Treatment:

❑ oxygen ❑ C-spine ❑ Splinting ❑ Bandaging

Appendix C: Medical Patient Interview Form

Name:____ Age: ________ Male / Female

Chief Complaint: ____

Mechanism of Injury: ____

"SAMPLE" history	**"OPQRST" pain survey**
Signs & Symptoms	**Onset?** What were you doing?
Allergies	**Provokes?** What makes it better or worse?
Medications	**Quality?** "What does it feel like?
Previous Medical History	**Radiation?** "Does it go anywhere?"
Last Oral Intake	**Severity?** 1-10 scale
Events Leading Up to?	**Time?** When did it begin?

Vital Signs:

BP ______ Pulse: ______ Resp: _____ PulseOx: _____

Treatment:

❑ oxygen ❑ ECG ❑ 12-lead ❑ IV

❑ medications? ____

Appendix D: Medical Patient Assessment/Interview Form

"SAMPLE HISTORY"

Signs & Symptoms "What is bothering you this morning?	Pain under my breastbone.
Allergies "Are you allergic to any medications?"	None
Medications "Do you take any medications?"	Aspirin and Cardizem.
Previous History "Do you have any medical problems? Has this ever happened to you before?"	I was diagnosed with high blood pressure two years ago. No, I have never felt pain like this before.
Last Oral Intake "Have you been eating normally?"	Yes. Had a full breakfast this morning.
Events Leading Up to? "What happened prior to you developing this pain?"	Nothing, I was feeling fine before this.

PAIN SURVEY

PAIN SURVEY Onset? "What were you doing when pain began?"	I was sitting on the couch watching television.
Provokes? "Have you done anything that makes the pain better?"	No, it is a steady pain and I can't get in a comfortable position.
Radiates? "Do you feel the pain anywhere besides your chest?"	Yes, I feel it in my spine also.
Severity? "On a scale of 1 to 10, with ten worst pain you can imagine, how severe is your pain now?"	It is a 6.
Time? "When did your chest pain begin?"	About 30 minutes ago.

Average Timing in Seconds by Numbers of First Responders Regardless of ALS Placement				
Task:	**No First Responder**	**2-person First Responder Crews**	**3-Person First Responder Crews**	**4- Person First Responder Crews**
Arrive Scene				
Assemble equipment	29.7	46.7	26.7	22.7
Conduct scene size up	31.7	181.7	167.3	172.0
Enter building	19.7	13.3	15.7	7.3
Ascend stairs	22.0	30.0	20.3	23.3
Time between Arrival and ascent of stairs	***104.7***	***123.0***	***98.3***	***93.0***
Package patient	59.7	46.3	59.0	36.0
Descend stairs	87.0	69.7	78.7	91.0
Exit door	102.7	114.3	92.3	89.0
Transfer patient	55.0	54.0	42.0	31.7
Turn ambulance	56.3	84.3	87.0	60.3
Load ambulance	76.3	53.3	31.0	18.3
Time between packaging patient and completion of loading patient	***418.7***	***263.3***	***192.7***	***171.7***

Access and Removal Differences of Means and Associated T-Tests (Time in Minutes)						
Dependent Variable:	**Ambulance vs. 2 Crew**	**Ambulance vs. 3 Crew**	**Ambulance vs. 4 Crew**	**Value of 3 vs. 2 Crew**	**Value of 4 vs. 2 Crew**	**Value of 4 vs. 3 Crew**
ACCESS: Arrival end to ascend stairs	**-0.306**	**0.106**	**0.194**	**-0.411**	**-0.500**	**-0.089**
SE	0.167	0.167	0.167	0.167	0.167	0.167
p-value	0.105	0.546	0.279	0.039	0.017	0.610
REMOVAL: Package patient to end	**2.589**	**3.767**	**4.117**	**-1.178**	**-1.528**	**0.350**
SE	0.521	0.521	0.521	0.521	0.521	0.521
p-value	0.001	0.000	0.000	0.054	0.019	0.521

Appendix F: Statistical Analysis of Time to Task Data Patient Systemic Trauma Patient

Testing the Effects of ALS, Engine Placements, and Crew Size on Engine to Address Research Questions for the Trauma Analysis (Contrasts are in Minutes)						
TRAUMA Task:	**Q1: One ALS -- Engine vs. Ambulance**	**Q2: Two ALS: One Amb One Engine vs. Two on Ambulance**	**Q3: Value of 2nd ALS**	**Q4: Value of 3 vs. 2 Crew**	**Q5a: Value of 4 vs. 2 Crew**	**Q5b: Value of 4 vs. 3 Crew**
Spinal Motion Restriction – start	**-0.200**	**-0.106**	**0.064**	**-0.007**	**-0.092**	**-0.085**
SE	0.104	0.083	0.066	0.090	0.086	0.066
p-value	0.062	0.213	0.343	0.939	0.296	0.206
ABCs – start	**-0.026**	**-0.067**	**0.078**	**0.100**	**0.035**	**-0.065**
SE	0.041	0.065	0.039	0.046	0.051	0.044
p-value	0.536	0.313	0.052	0.037	0.503	0.149
ABCs – duration	**-0.130**	**-0.280**	**-0.234**	**-0.079**	**-0.157**	**-0.078**
SE	0.229	0.160	0.140	0.191	0.163	0.156
p-value	0.574	0.090	0.102	0.681	0.344	0.622
Patient Interview – start	**-0.017**	**-0.002**	**0.124**	**0.115**	**0.025**	**-0.090**
SE	0.056	0.104	0.059	0.070	0.068	0.078
p-value	0.767	0.986	0.043	0.111	0.715	0.257
Body sweep - – start	**-0.383**	**0.048**	**0.425**	**-0.247**	**-0.614**	**-0.367**
SE	0.274	0.509	0.289	0.425	0.376	0.233
p-value	0.170	0.925	0.151	0.564	0.112	0.125
Body sweep - duration	**-0.076**	**-0.248**	**-0.003**	**-0.093**	**-0.168**	**-0.075**
SE	0.245	0.365	0.220	0.317	0.280	0.197
p-value	0.759	0.501	0.990	0.771	0.552	0.706
O2 administration – start	**0.793**	**-0.724**	**0.414**	**0.347**	**-0.551**	**-0.899**
SE	0.404	0.543	0.338	0.457	0.377	0.404
p-value	0.058	0.191	0.229	0.453	0.153	0.033
Check Vitals – start	**0.065**	**0.165**	**0.596**	**-0.414**	**-0.932**	**-0.518**
SE	0.260	0.448	0.259	0.360	0.328	0.254
p-value	0.727	0.302	0.140	0.842	0.300	0.070
Wound Bandaged – start	**0.604**	**-1.239**	**0.045**	**-1.708**	**-1.064**	**0.644**
SE	0.618	0.714	0.472	0.548	0.607	0.578
p-value	0.335	0.092	0.924	0.004	0.089	0.273
Splint Leg – start	**-0.554**	**-0.650**	**0.385**	**-0.206**	**-1.099**	**-0.893**
SE	0.450	0.294	0.269	0.308	0.348	0.331
p-value	0.227	0.034	0.161	0.509	0.003	0.011
Splint Leg – duration	**0.830**	**-0.509**	**-0.277**	**-0.135**	**-0.340**	**-0.206**
SE	0.268	0.380	0.233	0.283	0.250	0.317
p-value	0.004	0.189	0.242	0.638	0.183	0.521
Back Board – start	**-0.250**	**-1.654**	**0.235**	**-0.293**	**-0.058**	**0.235**
SE	0.539	0.604	0.405	0.536	0.514	0.432
p-value	0.646	0.010	0.565	0.588	0.910	0.590
Back Board – duration	**0.063**	**0.330**	**-0.024**	**-0.340**	**-2.410**	**-2.069**
SE	0.426	0.535	0.342	0.427	0.484	0.330
p-value	0.883	0.542	0.944	0.431	0.000	0.000
Airway - intubation – start	**0.137**	**-1.389**	**0.194**	**-0.535**	**-2.558**	**-2.024**
SE	0.692	0.500	0.427	0.582	0.432	0.542
p-value	0.844	0.009	0.652	0.365	0.000	0.001
Airway - intubation – duration	**0.465**	**-0.437**	**-0.460**	**-0.775**	**-0.363**	**0.413**
SE	0.268	0.291	0.198	0.193	0.281	0.244
p-value	0.091	0.142	0.026	0.000	0.206	0.100
Bag Valve Mask – start	**-0.020**	**-1.487**	**0.031**	**-0.797**	**-2.603**	**-1.806**
SE	0.622	0.519	0.405	0.550	0.439	0.493
p-value	0.974	0.007	0.939	0.157	0.000	0.001
Package Patient / move fo r transport – start	**0.733**	**-2.089**	**-0.232**	**-1.525**	**-3.106**	**-1.581**
SE	0.763	0.692	0.515	0.641	0.589	0.660
p-value	0.343	0.005	0.656	0.023	0.000	0.022

Appendix G: Statistical Analysis of Time to Task Data Cardiac Arrest Patient

Testing the Effects of ALS , Engine Placements, and Crew Size on Engine to Address Research Questions for the Cardiac Analysis (Contrasts are in Minutes)						
CARDIAC Tasks:	Q1: One ALS -- Engine vs Ambulance	Q2: Two ALS: One Amb and One Engine vs Two on Ambulance	Q3: Value of 2nd ALS	Q4: Value of 3 vs. 2 Crew	Q5a: Value of 4 vs. 2 Crew	Q5b: Value of 4 vs. 3 Crew
ABCs—start	**-0.019**	**0.020**	**0.029**	**-0.057**	**-0.069**	**-0.013**
SE	0.022	0.026	0.017	0.023	0.021	0.019
p-value	0.395	0.446	0.101	0.020	0.002	0.505
ABCs-- duration	**-0.009**	**0.028**	**-0.004**	**0.022**	**-0.026**	**-0.049**
SE	0.040	0.026	0.024	0.029	0.033	0.026
p-value	0.820	0.290	0.878	0.445	0.427	0.072
Patient Interview - start	**0.000**	**0.031**	**0.016**	**-0.024**	**-0.024**	**0.000**
SE	0.006	0.031	0.016	0.024	0.024	0.006
p-value	1.000	0.323	0.331	0.323	0.323	1.000
O2 administration- start	**-0.120**	**-0.039**	**-0.106**	**-0.121**	**-0.169**	**-0.049**
SE	0.140	0.111	0.089	0.095	0.120	0.113
p-value	0.396	0.729	0.246	0.210	0.166	0.669
Check Vitals – start	**-0.100**	**-0.031**	**0.086**	**-0.268**	**-0.286**	**-0.018**
SE	0.146	0.157	0.107	0.142	0.151	0.095
p-value	0.499	0.843	0.428	0.067	0.067	0.850
Check Vitals – duration	**0.024**	**0.230**	**-0.008**	**0.031**	**-0.208**	**-0.239**
SE	0.322	0.211	0.193	0.256	0.214	0.236
p-value	0.941	0.285	0.966	0.906	0.338	0.319
ALS Vitals 12-Lead - start	**-2.309**	**-2.330**	**-0.240**	**-0.235**	**-0.471**	**-0.236**
SE	0.277	0.239	0.183	0.233	0.222	0.216
p-value	0.000	0.000	0.198	0.321	0.041	0.281
Expose Chest - start	**-1.665**	**-1.404**	**-0.094**	**-0.593**	**-0.985**	**-0.392**
SE	0.447	0.490	0.331	0.392	0.397	0.428
p-value	0.551	0.113	0.081	0.476	0.358	0.811
Position Patient – start (difference from Arrest time)	**0.039**	**-0.044**	**-0.042**	**0.028**	**0.000**	**-0.028**
SE	0.029	0.024	0.019	0.023	0.022	0.025
p-value	0.183	0.077	0.034	0.229	1.000	0.265
ABCs – Start (difference from arrest time)	**0.000**	**-0.033**	**0.067**	**-0.079**	**-0.131**	**-0.051**
SE	0.072	0.122	0.071	0.093	0.093	0.071
p-value	1.000	0.786	0.352	0.402	0.170	0.473
Defib pads – Start (difference from arrest time)	**0.006**	**-0.056**	**-0.055**	**-0.086**	**-0.156**	**-0.069**
SE	0.120	0.119	0.084	0.120	0.118	0.061
p-value	0.963	0.642	0.521	0.477	0.195	0.265
Analyze / Shock #1 – Start (difference from arrest time)	**-0.078**	**-0.069**	**-0.071**	**-0.133**	**-0.179**	**-0.046**
SE	0.158	0.157	0.112	0.157	0.149	0.095
p-value	0.626	0.666	0.527	0.402	0.238	0.633

Continued

Testing the Effects of ALS , Engine Placements, and Crew Size on Engine to Address Research Questions for the Cardiac Analysis (Contrasts are in Minutes)						
CARDIAC Tasks:	**Q1: One ALS -- Engine vs Ambulance**	**Q2: Two ALS: One Amb and One Engine vs Two on Ambulance**	**Q3: Value of 2nd ALS**	**Q4: Value of 3 vs. 2 Crew**	**Q5a: Value of 4 vs. 2 Crew**	**Q5b: Value of 4 vs. 3 Crew**
ABCs – Start – After Shock #1 (difference from arrest time)	**-0.098**	**0.026**	**-0.034**	**-0.178**	**-0.239**	**-0.061**
SE	0.153	0.214	0.132	0.187	0.182	0.098
p-value	0.526	0.904	0.796	0.349	0.198	0.539
CPR – CPR—Start (difference from arrest time)	**0.207**	**0.026**	**-0.057**	**-0.015**	**-0.021**	**-0.006**
SE	0.183	0.234	0.148	0.196	0.187	0.161
p-value	0.264	0.912	0.701	0.938	0.912	0.973
Airway Intubation- Start – (difference from arrest time)	**-0.359**	**0.128**	**-1.123**	**-0.207**	**-0.247**	**-0.040**
SE	0.438	0.254	0.253	0.321	0.256	0.347
p-value	0.418	0.618	0.000	0.524	0.340	0.908
Airway Intubation-- Duration	**0.081**	**-0.037**	**0.582**	**-0.172**	**-0.594**	**-0.422**
SE	0.346	0.315	0.234	0.319	0.301	0.232
p-value	0.681	0.097	0.009	0.135	0.021	0.328
Package Patient/Equip- Start (difference from arrest time)	**-0.606**	**0.991**	**-0.193**	**-0.733**	**-1.013**	**-0.279**
SE	0.551	0.583	0.401	0.538	0.450	0.480
p-value	0.279	0.098	0.634	0.182	0.031	0.565
Package Patient/Equip- Completion (difference from arrest time)	**-0.380**	**0.867**	**-0.190**	**-0.843**	**-1.394**	**-0.551**
SE	0.402	0.418	0.290	0.393	0.340	0.329
p-value	0.352	0.046	0.517	0.039	0.000	0.103

Regression Analysis Coefficients, Standard Errors and P-Values For Addressing Research Questions about Cardiac Time from Arrest (Coefficients are in Minutes) : Each Task Row Represents a Separate Regression

TRAUMA Tasks:	no engine	no engine & 2 ALS on ambulance	crew size 3 on engine	crew size 4 on engine	1 ALS on engine & 0 ALS on Ambulance	0 ALS on engine & 1 ALS on Ambulance	0 ALS on engine & 2 ALS on Ambulance	Constant
p-value	0.000	0.002	0.453	0.153	0.496	0.290	0.191	0.000
Check Vitals – start	**3.290**	**0.950**	**-0.414**	**-0.932**	**-0.646**	**-0.711**	**-0.165**	**2.754**
SE	0.501	0.611	0.360	0.328	0.384	0.419	0.448	0.474
p-value	0.000	0.130	0.259	0.008	0.102	0.099	0.715	0.000
Check Vitals – duration	**0.571**	**-0.572**	**-0.964**	**-1.311**	**-0.052**	**0.259**	**-0.028**	**2.784**
SE	1.458	1.434	0.601	0.546	0.524	0.574	0.687	0.658
p-value	0.698	0.692	0.118	0.022	0.922	0.654	0.968	0.000
Expose patient – start	**3.266**	**-0.317**	**0.067**	**-0.325**	**-0.187**	**-0.102**	**0.424**	**1.879**
SE	0.329	0.148	0.333	0.309	0.273	0.259	0.404	0.298
p-value	0.000	0.040	0.842	0.300	0.497	0.697	0.302	0.000
Wound Bandaged – start	**4.831**	**-1.533**	**-1.708**	**-1.064**	**0.876**	**0.272**	**1.239**	**3.763**
SE	2.074	2.549	0.548	0.607	0.764	0.667	0.714	0.677
p-value	0.026	0.551	0.004	0.089	0.260	0.686	0.092	0.000
Splint Leg – start	**4.250**	**-1.689**	**-0.206**	**-1.099**	**-0.337**	**0.217**	**0.650**	**4.027**
SE	1.142	1.128	0.308	0.348	0.441	0.278	0.294	0.271
p-value	0.001	0.144	0.509	0.003	0.450	0.442	0.034	0.000
Splint Leg – duration	**0.697**	**-0.700**	**-0.135**	**-0.340**	**0.946**	**0.117**	**0.509**	**2.281**
SE	0.650	1.018	0.283	0.250	0.266	0.226	0.380	0.192
p-value	0.291	0.496	0.638	0.183	0.001	0.609	0.189	0.000
Back Board – start	**4.438**	**-0.017**	**-0.293**	**-0.058**	**0.467**	**0.717**	**1.654**	**2.134**
SE	0.865	1.087	0.536	0.514	0.547	0.224	0.604	0.367
p-value	0.000	0.988	0.588	0.910	0.399	0.003	0.010	0.000
Back Board – duration	**4.283**	**-5.567**	**-0.340**	**-2.410**	**-0.109**	**-0.172**	**-0.330**	**6.661**
SE	1.165	1.465	0.427	0.484	0.419	0.438	0.535	0.506
p-value	0.001	0.001	0.431	0.000	0.796	0.697	0.542	0.000
Airway - intubation – start	**8.904**	**-5.561**	**-0.535**	**-2.558**	**0.569**	**0.432**	**1.389**	**9.057**
SE	1.753	1.755	0.582	0.432	0.696	0.417	0.500	0.493
p-value	0.000	0.003	0.365	0.000	0.420	0.308	0.009	0.000
Airway - intubation – duration	**0.293**	**0.772**	**-0.775**	**-0.363**	**0.911**	**0.446**	**0.437**	**2.296**
SE	0.481	0.706	0.193	0.281	0.229	0.305	0.291	0.250

Appendix H: All Regression Coefficients Continued

Regression Analysis Coefficients, Standard Errors and P-Values For Addressing Research Questions about Cardiac Time from Arrest (Coefficients are in Minutes) : Each Task Row Represents a Separate Regression

TRAUMA Tasks:	no engine	no engine & 2 ALS on ambulance	crew size 3 on engine	crew size 4 on engine	1 ALS on engine & 0 ALS on Ambulance	0 ALS on engine & 1 ALS on Ambulance	0 ALS on engine & 2 ALS on Ambulance	Constant
p-value	0.546	0.282	0.000	0.206	0.000	0.153	0.142	0.000
Bag Valve Mask – start	**8.867**	**-5.556**	**-0.797**	**-2.603**	**0.702**	**0.722**	**1.487**	**8.878**
SE	1.830	1.812	0.550	0.439	0.643	0.444	0.519	0.499
p-value	0.000	0.004	0.157	0.000	0.283	0.113	0.007	0.000
Package Patient / move for transport – start	**10.330**	**-5.544**	**-1.525**	**-3.106**	**1.643**	**0.909**	**2.089**	**11.670**
SE	2.542	2.644	0.641	0.589	0.738	0.546	0.692	0.611
p-value	0.000	0.044	0.023	0.000	0.033	0.105	0.005	0.000
Package Patient / move for transport – completion	**11.030**	**-5.039**	**-1.672**	**-3.390**	**1.806**	**0.915**	**2.267**	**12.520**
SE	2.612	2.760	0.657	0.597	0.773	0.565	0.704	0.617
p-value	0.000	0.077	0.016	0.000	0.025	0.115	0.003	0.000

Appendix H: All Regression Coefficients

Regression Analysis Coefficients, Standard Errors and P-Values For Addressing Research Questions about Cardiac Time from Arrest (Coefficients are in Minutes) : Each Task Row Represents a Separate Regression								
CARDIAC Tasks:	**no engine**	**no engine & 2 ALS on ambulance**	**crew size 3 on engine**	**crew size 4 on engine**	**1 ALS on engine & 0 ALS on Ambulance**	**0 ALS on engine & 1 ALS on Ambulance**	**0 ALS on engine & 2 ALS on Ambulance**	**Constant**
ABCs—start	**3.017**	**-0.017**	**-0.057**	**-0.069**	**-0.048**	**-0.030**	**-0.020**	**0.316**
SE	0.047	0.041	0.023	0.021	0.027	0.025	0.026	0.028
p-value	0.000	0.687	0.020	0.002	0.084	0.249	0.446	0.000
ABCs-- duration	**0.012**	**-0.044**	**0.022**	**-0.026**	**-0.015**	**-0.006**	**-0.028**	**0.172**
SE	0.046	0.051	0.029	0.033	0.041	0.033	0.026	0.035
p-value	0.805	0.391	0.445	0.427	0.722	0.869	0.290	0.000
Patient Interview - start	**2.953**	**0.000**	**-0.024**	**-0.024**	**-0.031**	**-0.031**	**-0.031**	**0.047**
SE	0.046	0.000	0.024	0.024	0.031	0.031	0.031	0.046
p-value	0.000	0.358	0.323	0.323	0.323	0.323	0.323	0.311
O2 administration- start	**3.207**	**0.044**	**-0.121**	**-0.169**	**0.065**	**0.185**	**0.039**	**0.815**
SE	0.283	0.452	0.095	0.120	0.132	0.123	0.111	0.094
p-value	0.000	0.922	0.210	0.166	0.625	0.141	0.729	0.000
Check Vitals – start	**2.728**	**-0.050**	**-0.268**	**-0.286**	**-0.120**	**-0.020**	**0.031**	**1.005**
SE	0.133	0.052	0.142	0.151	0.130	0.141	0.157	0.128
p-value	0.000	0.340	0.067	0.067	0.360	0.886	0.843	0.000
Check Vitals – duration	**0.335**	**-0.689**	**0.031**	**-0.208**	**-0.094**	**-0.119**	**-0.230**	**1.948**
SE	0.410	0.399	0.256	0.214	0.229	0.300	0.211	0.218
p-value	0.419	0.094	0.906	0.338	0.683	0.695	0.285	0.000
ALS Vitals 12-Lead - start	**2.789**	**0.678**	**-0.235**	**-0.471**	**0.250**	**2.559**	**2.330**	**1.394**
SE	0.437	0.472	0.233	0.222	0.346	0.240	0.239	0.255
p-value	0.000	0.160	0.321	0.041	0.474	0.000	0.000	0.000
Expose Chest - start	2.772	-0.433	-0.593	-0.985	-0.037	1.628	1.404	2.267
SE	0.583	0.479	0.392	0.397	0.496	0.501	0.490	0.470

Appendix H: All Regression Coefficients Continued

Regression Analysis Coefficients, Standard Errors and P-Values For Addressing Research Questions about Cardiac Time from Arrest (Coefficients are in Minutes) : Each Task Row Represents a Separate Regression

CARDIAC Tasks:	no engine	no engine & 2 ALS on ambulance	crew size 3 on engine	crew size 4 on engine	1 ALS on engine & 0 ALS on Ambulance	0 ALS on engine & 1 ALS on Ambulance	0 ALS on engine & 2 ALS on Ambulance	Constant
Airway Intubation-- Duration	**1.768**	**1.106**	**-0.696**	**-1.083**	**-1.889**	**0.619**	**0.298**	**4.199**
SE	0.958	1.398	0.563	0.570	0.783	0.761	0.809	0.893
p-value	0.074	0.434	0.225	0.066	0.021	0.422	0.715	0.000
IV Access – start	**0.382**	**-0.578**	**-0.194**	**-0.243**	**0.080**	**0.282**	**-0.361**	**1.785**
SE	0.462	0.410	0.270	0.261	0.253	0.351	0.222	0.260
p-value	0.414	0.168	0.476	0.358	0.755	0.428	0.113	0.000
IV Access – duration	**0.394**	**-0.261**	**0.028**	**0.000**	**0.083**	**0.044**	**0.044**	**0.072**
SE	0.259	0.272	0.023	0.022	0.032	0.021	0.024	0.021
p-value	0.138	0.343	0.229	1.000	0.015	0.040	0.077	0.002
Position Patient – start (difference from Arrest time)	**0.104**	**-0.383**	**-0.079**	**-0.131**	**-0.050**	**-0.050**	**0.033**	**0.307**
SE	0.364	0.336	0.093	0.093	0.113	0.108	0.122	0.141
p-value	0.776	0.261	0.402	0.170	0.660	0.645	0.786	0.036
ABCs – Start (difference from arrest time)	**0.345**	**-0.378**	**-0.086**	**-0.156**	**0.085**	**0.080**	**0.056**	**0.555**
SE	0.247	0.265	0.120	0.118	0.093	0.130	0.119	0.117
p-value	0.171	0.163	0.477	0.195	0.364	0.544	0.642	0.000
Defib pads – Start (difference from arrest time)	**0.242**	**-0.194**	**-0.133**	**-0.179**	**0.067**	**0.144**	**0.069**	**0.991**
SE	0.283	0.269	0.157	0.149	0.142	0.189	0.157	0.174
p-value	0.399	0.475	0.402	0.238	0.641	0.449	0.666	0.000
Analyze / Shock #1 – Start (difference from arrest time)	**0.089**	**-0.189**	**-0.178**	**-0.239**	**-0.028**	**0.070**	**-0.026**	**1.522**
SE	0.331	0.239	0.187	0.182	0.188	0.226	0.214	0.256
p-value	0.790	0.434	0.349	0.198	0.883	0.757	0.904	0.000
ABCs – Start – After Shock #1	**0.477**	**-0.356**	**-0.015**	**-0.021**	**0.148**	**-0.059**	**-0.026**	**0.779**
SE	0.459	0.460	0.196	0.187	0.191	0.182	0.234	0.186
p-value	0.306	0.445	0.938	0.912	0.444	0.746	0.912	0.000
CPR – CPR—Start (difference from arrest time)	**1.545**	**0.183**	**-0.207**	**-0.247**	**0.880**	**1.239**	**-0.128**	**1.244**

Regression Analysis Coefficients, Standard Errors and P-Values For Addressing Research Questions about Cardiac Time from Arrest (Coefficients are in Minutes) : Each Task Row Represents a Separate Regression

CARDIAC Tasks:	no engine	no engine & 2 ALS on ambulance	crew size 3 on engine	crew size 4 on engine	1 ALS on engine & 0 ALS on Ambulance	0 ALS on engine & 1 ALS on Ambulance	0 ALS on engine & 2 ALS on Ambulance	Constant
SE	0.588	1.163	0.321	0.256	0.313	0.374	0.254	0.236
p-value	0.013	0.876	0.524	0.340	0.008	0.002	0.618	0.000
Airway Intubation- Start and duration – (difference from arrest time)	**-0.244**	**-0.078**	**-0.172**	**-0.594**	**-0.522**	**-0.604**	**0.037**	**2.800**
SE	0.417	0.453	0.319	0.301	0.322	0.286	0.315	0.260
p-value	0.562	0.865	0.593	0.057	0.114	0.043	0.907	0.000
Meds (Epi)- Start (difference from arrest time)	**0.632**	**-0.542**	**-0.228**	**-0.508**	**-0.504**	**-0.394**	**-1.022**	**2.751**
SE	0.957	1.262	0.339	0.303	0.365	0.390	0.408	0.430
p-value	0.513	0.671	0.506	0.103	0.177	0.318	0.017	0.000
Analyze / Shock #2 -- Start time	**-0.070**	**-0.300**	**-0.442**	**-0.479**	**-0.009**	**-0.137**	**-0.133**	**4.003**
SE	0.394	0.237	0.216	0.208	0.245	0.255	0.250	0.315
p-value	0.860	0.214	0.049	0.027	0.970	0.594	0.597	0.000
Medis (Lidocaine) - Start (difference from arrest time)	**2.054**	**-2.278**	**-0.440**	**-0.721**	**0.293**	**0.424**	**-0.596**	**4.763**
SE	0.424	0.404	0.287	0.297	0.296	0.359	0.350	0.258
p-value	0.000	0.000	0.135	0.021	0.329	0.246	0.097	0.000
Package Patient/Equip- Start	**1.444**	**0.328**	**-0.733**	**-1.013**	**-0.606**	**0.000**	**-0.991**	**5.795**
SE	0.673	1.375	0.538	0.450	0.554	0.530	0.583	0.480
p-value	0.039	0.813	0.182	0.031	0.282	1.000	0.098	0.000
Package Patient/Equip- Completion	**2.173**	**-0.072**	**-0.843**	**-1.394**	**-0.433**	**-0.054**	**-0.867**	**7.327**
SE	0.610	1.248	0.393	0.340	0.365	0.458	0.418	0.402
p-value	0.001	0.954	0.039	0.000	0.244	0.907	0.046	0.000

NOTES: