OHIO EMS INJURY PREVENTION RESEARCH GRANT

2007-2008 RESEARCH PROJECT

FINAL PROJECT REPORT

(August 2009)

PROJECT NAME: The Effect of Delay in Transfer to Advanced Trauma Center Care on Trauma Patient Outcome in Ohio

Principal Investigator: Gary A. Smith, MD, DrPH

Telephone: (614)722-2400

Institution: Center for Injury Research and Policy, The Research Institute at Nationwide Children's Hospital, Columbus, Ohio

Introduction

This study conducted probabilistic linkage of two large statewide datasets for Ohio (Emergency Medical Services Incidence Reporting System [EMSIRS] and Ohio Trauma Registry [OTR]) and then analyzed the new combined database to determine the impact that delay in delivery of definitive trauma center care has on trauma patient outcomes in Ohio. Analytic models were constructed to account for the influence of potential confounding and interacting variables. This is the first study to use Ohio-specific data to evaluate this important issue, and study findings will provide useful information for improvement of trauma care in Ohio.

Table of Contents Page

Executive Summary

Background - The premise of the "Golden Hour" is that patients with serious trauma should reach definitive trauma care within the first hour of injury. When appropriate trauma care cannot be obtained in an initial treating hospital, trauma systems must ensure expeditious transfer to an appropriate trauma center.[1] Despite its importance, the scientific evaluation of many aspects of existing trauma systems, including system protocols and quality indicators, remains to be done.

Study Objective - This study evaluates the impact that delay in delivery of definitive trauma center care has on trauma patient outcomes in Ohio. Our *central hypothesis* is that the length of stay at a referring hospital emergency department prior to transfer to a higher level trauma center and the length of time from the traumatic event until arrival at an appropriate trauma center for definitive care affect the outcome of patients with moderate to severe acute injury. *Specific Aim 1 & 2:* Test the hypothesis that the length of stay at a referring hospital emergency department prior to transfer to a higher level trauma center affects survival and other outcomes (hospital length of stay, admission to Intensive Care Unit, Intensive Care Unit length of stay, admission to rehabilitation facility, required ventilation, and total ventilator days) of patients with moderate to severe acute injury. *Specific Aim 3 & 4:* Test the hypothesis that the length of time from the traumatic event until arrival at a medical center for definitive care affects survival and other outcomes (see above) of patients with moderate to severe acute injury.

Methodology - We conducted an investigation of this issue using probabilistically-linked statewide datasets (Emergency Medical Services Incidence Reporting System, and the Ohio Trauma Registry for the years 2005 through 2007). Our analyses evaluated the influence of two different time periods on trauma patient outcomes: (1) the interhospital transfer time for individuals who received initial care at one hospital and were subsequently transferred to another hospital for further care, and (2) the transport time between a call received at a dispatch center until the arrival of the patient at the definitive treating hospital.

Major Conclusions - The average interhospital transfer time from arrival at the referring hospital until arrival at a definitive care trauma center was 3.9 hours. Patients with longer interhospital transfer times had lower odds of ventilator use or ICU admission, and the likelihood of death decreased as interhospital transfer time increased. Patients who had a complication due to the initial injury or treatment were more likely to require mechanical ventilation, be admitted to the ICU, need rehabilitative care, or die than patents without complications. The average total transport time from receipt of the emergency call by the EMS dispatch center to the time of arrival at the emergency department of the final medical center was 3.1 hours. Patients with longer total transport times tended to have slightly longer stays in the hospital. Patients with high injury severity scores had longer stays in the ICU and longer periods of time on mechanical ventilation, as well as greater odds of discharge to a rehabilitation facility.

Investigators and Project Personnel - Information/Qualifications

Principal Investigator - Gary A. Smith, MD, DrPH. - Dr. Gary Smith is an Associate Professor of Pediatrics of the Ohio State University College of Medicine with joint faculty appointments in the Division of Epidemiology, College of Public Health, and in the Department of Emergency Medicine. He is founder and Director of the Center for Injury Research and Policy (CIRP) and is a pediatric emergency medicine physician at Nationwide Children's Hospital in Columbus, Ohio. Dr. Smith is board certified in the specialties of pediatrics and general preventive medicine and public health, and in the subspecialty of pediatric emergency medicine. In addition to his clinical training, Dr. Smith holds Master of Public Health and Doctor of Public Health degrees from the Johns Hopkins Bloomberg School of Public Health. He is immediate past chairperson of the national Committee on Injury, Violence, and Poison Prevention of the American Academy of Pediatrics (AAP) and was a member of the Initial Review Group of the National Center for Injury Prevention and Control, CDC, from 2003-2006. Dr. Smith is the principal investigator of the Ohio CODES program and several other ongoing injury research projects.

Co-Investigator - Huiyun Xiang, MD, PhD, MPH. - Dr. Xiang is an Assistant Professor of Pediatrics in the Ohio State University College of Medicine and a research faculty member in CIRP. Dr. Xiang is an injury epidemiologist with advanced training in biostatistics. He has more than 15 years experience in large data management and statistical analysis. Dr. Xiang is the PI of several ongoing injury research projects, and is Co-PI of the Ohio CODES Program.

Co-Investigator – Jonathan I. Groner, MD. - Dr. Groner is a Clinical Associate Professor of Surgery at the Ohio State University College of Medicine, the Medical Director of the Level 1 Pediatric Trauma Program at Nationwide Children's Hospital, and an affiliate research faculty member in CIRP. He was president of the Central Ohio Trauma System, and is a member of the Ohio Emergency Medical Services Board.

Project Research Manager – Lynne Rochette, MS. - Ms. Rochette has a master degree in experimental psychology from Ohio University. She has experience in conducting research, performing data analysis, peer-reviewed publication, and teaching research methods and statistics.

Data Linkage Supervisor – Ashley Swert, MAS. - Ms. Swert has a master degree in applied statistics. She has experience in data analysis and experimental design, as well as with the probabilistic data linkage methodology used in this research project.

Data Analysis Supervisor - Brenda J. Shields, MS. - Ms. Shields has more than 17 years of experience with managing and analyzing large and complex datasets. She is lead or co-author of numerous research studies on injury-related topics published in the peer-reviewed scientific literature.

Literature Review

The concept of the "Golden Hour" has fueled the development of trauma systems. Its premise is that there is a group of patients with serious trauma whose survival depends on the receipt of early (within the first hour) definitive trauma care. The Golden Hour concept has a physiologic basis supporting its plausibility, with inadequate initial resuscitation and prolonged diagnostic work-up leading to prolonged hypoperfusion, hypoxemia, hypothermia, and acidosis, which results in tissue necrosis, organ failure and an increased incidence of infection. Experienced trauma surgeons, emergency medicine physicians, and other emergency personnel can all provide stories of cases of preventable trauma deaths due to delay in provision of definitive trauma care.

Access to advanced care in a trauma center by patients with acute major injury has been shown to improve patient survival[2-3] and functional outcome.[4] Delays in access to definitive trauma center care have generally been associated with increased mortality rates, whether these delays were due to prolonged stays in local community hospitals[5-9] or due to increased pre-hospital time.[10-11] One study from Grant Medical Center in Columbus, Ohio reviewed all their injured patients transported by air in 1996, and determined that "patients transferred from a referring hospital took almost six times longer to reach definitive care and may have suffered an increased morbidity and mortality on this basis."[12] Some investigators have not been able to show a difference in clinical outcome between trauma patients initially treated in a local community emergency department and those transferred directly to an advanced trauma center.[13-16] However, some of these studies had limitations, such as a small sample size (and therefore, inadequate statistical power to show differences), or evaluated a selected population of trauma patients in an urban trauma system (and therefore, limited external validity).

Although there is consensus that delay in access to definitive trauma center care is detrimental, there is a lack of solid evidence in the literature to determine an appropriate timeframe for the Golden "Hour". It has been recommended that patients with significant traumatic brain injury receive neurosurgical intervention within four hours from the time of injury, especially those requiring evacuation of an intracranial hematoma.[17-22] The Golden Hour is best conceptualized as a Golden Window, the temporal dimensions of which are influenced by both extrinsic (trauma system) and intrinsic (patient) factors. The time interval for this window classically commences at the time of injury; however, a trauma system quality indicator commonly used is the time elapsed in the initial emergency department prior to transfer to a higher level trauma center. This measures a portion of the window that is potentially subject to control through transfer protocols, training and other interventions. The time cutoff used by the Ohio Trauma System for this portion of the window is two hours, but there is little evidence, at best, in the literature for this cutoff value. As observed in the Ohio trauma system, prolonged stays in local community hospitals prior to transfer to a higher level trauma center are common in other trauma systems nationally.[23]

Historical Perspectives

Injury is among the most compelling public health problems facing our nation. It is the leading cause of death among children and young adults in the United States.[24] Clearly, research leading to a better scientific understanding of the factors contributing to optimal systems of care for management of acute traumatic injury deserves special focus and attention. The principles upon which current trauma systems in the United States are based were primarily developed by the military from its experience with wartime casualties.[25-26] The benefits of trauma systems and components of trauma systems on survival of severely injured patients have been demonstrated.[27-28] However, the scientific evaluation of many aspects of existing trauma systems, including system protocols and quality indicators, remains to be done.

Current Status in Ohio

Emergency Medical Services in Ohio

There are approximately 1,700 EMS agencies in Ohio, but there is considerable variation in EMS coverage in the state. Ohio has large rural areas, and in rural counties, EMS coverage is stretched thin with longer response and transfer times. This contrasts with urban areas, such as Columbus in Franklin County. There are approximately 3,700 Emergency Medical Technicians (First Responder to EMT-Paramedic), who staff the more than 60 emergency vehicles providing service to residents of Franklin County. Within Franklin County there are 21 city or township EMS departments including the City of Columbus. The 21 departments function independently, but frequently assist one another with a "mutual aid" agreement. In 2000, Columbus became the first major metropolitan area to have an ambulance at every fire station. There are more than 100,000 EMS runs annually with approximately 40% being ALS and with an average response time of 5.4 minutes. Columbus is also home base to a regional helicopter transport service, MedFlight. MedFlight of Ohio has 5 helicopters based across Central, Southeast and Eastern Ohio. Each helicopter is staffed 24 hours a day with a flight nurse, flight paramedic, and a pilot. MedFlight helicopters have scene response as well as inter-facility transport capability. MedFlight also controls 2 fixed wing aircraft carrying a medical staff of a flight nurse and flight paramedic. This statewide variation in pre-hospital response and transfer times will assist in testing the study hypotheses.

Ohio Trauma System

House Bill 138, enacted by the 123rd General Assembly in 2000, mandated the development of a statewide trauma system, including a trauma registry. Ohio has 10 trauma regions. These regions were originally designated by the U.S. Health Resources and Services Administration as EMS regions, and then were integrated into the state trauma plan.

According to the Ohio EMS Injury Prevention (Priority 2) Research Grant Announcement, preliminary data from the Ohio Trauma Registry (OTR) demonstrate that 85% of injured patients who meet OTR inclusion criteria have an emergency department length of stay greater than two hours prior to transfer to a higher level trauma center. Indeed, the mean length of stay in the initial emergency department among these patients in 2004 was approximately 7 hours (Trauma System Quarterly Trends, EMS Data Center, based on data submitted as of July 6, 2006). The Ohio Trauma Committee considers this to be higher than acceptable, based on national standards. However, the scientific literature supporting this two-hour trauma system quality indicator is, at best, weak.

Regional and National Trends

The Model Trauma System Planning and Evaluation document released in February 2006 by the Health Resources and Services Administration reinforces the need for early appropriate trauma center care.[29] It refers to the Golden Hour and states that "enforcement of trauma treatment, triage, and transfer protocols will assist in ensuring that injured patients receive the appropriate medical care at the right facility and in the right time frame based on their injuries. When injured patients arrive at a medical facility that cannot provide the appropriate level of definite care, an organized and regularly monitored system must ensure that patients are expeditiously transferred to the appropriate trauma facility."[29]

Financial Considerations

Not applicable to this research project.

Education and Training Considerations

Not applicable to this research project.

Legislative and Regulatory Considerations

Not applicable to this research project

Data Considerations

Population and Methods - Two large statewide datasets for Ohio (Emergency Medical Services Incidence Reporting System (EMSIRS), and the Ohio Trauma Registry (OTR) for the years 2005-2007) were used to address the two specific aims of this study. Before probabilistic data linkage could be performed, the OTR was divided into two separate datasets for linkage. The first sub-database (Sub-OTR1) contained records of trauma patients who required transfer to another hospital for further care. The second sub-database (Sub-OTR2) contained the remaining records of patients who did not get transferred to another hospital, including patients who had arrived directly from the field as well as from

another hospital. The final destination hospitals in Sub-OTR2 represent the medical centers where definite care was provided to trauma patients. These databases (Sub-OTR1 and Sub-OTR2) were linked using a sophisticated probabilistic linkage software application to address Specific Aims 1 and 2 of this study. The EMSIRS was probabilistically linked to the Sub-OTR2 to address Specific Aims 3 and 4 of this study.

Probabilistic Data Linkage - Records for the same cases found in the statewide datasets were linked for calendar years 2005-2007. This process builds an extensive new research database from the independent datasets. Each data source exists independently, and linkage of these sources allows researchers to follow individuals through the trauma system from the field through medical treatment. Probabilistic record linkage techniques were used because the datasets of interest do not include unique case identifiers common to all files. Probabilistic linkage methods were developed several decades ago and have been well evaluated in a variety of research disciplines. In more recent years, these methods have been introduced in injury research.

Ideally, all of the found links are included in the final linked dataset for research. However, most available administrative statewide trauma-related datasets lack common complete personal identifiers, or exhibit high-levels of non-response for important quasi-identifiers or analysis covariates. Many true links can have low probabilities due to misclassification or non-response. Obvious (i.e., high-probability) links between complete records can constitute a relatively small and potentially biased sample from the population of true matched record pairs. Eliminating records with missing data, or guessing what the missing data should be, weakens the data for analysis. Instead, multiple imputation techniques were employed to create complete, representative linked datasets using Markov-Chain Monte Carlo methods. After applying a Bayesian model, this process produces posterior probabilities that each candidate linked pair of records is a true match, given all of the link fields. CODES2000 is a specialized software package, implemented as a Microsoft Access application that allows these comparisons for large volumes of records using a hierarchical Bayesian model. This analysis generates a list of the found linked pairs of records.

Privacy and confidentiality policies were implemented for the results of the probabilistic linkage. Personal and hospital identifiers are only used for linkage purposes; therefore, these sensitive variables were not included in the final datasets for statistical analyses.

IRB Approval - The Ohio Department of Public Safety and the Research Institute at Nationwide Columbus Hospital signed a Memorandum of Understanding (MOU) regarding data use and confidentiality for the CODES Project. Access and use of the data for the research described in this

current project was covered under this MOU. This research project was approved by the IRB of the Research Institute at Nationwide Children's Hospital.

Data Analyses - Our analyses for Specific Aims 1 & 2 (linked data including the Sub-OTR1 and Sub-OTR2) and for Specific Aims 3 & 4 (linked data including the EMSIRS and Sub-OTR2) were conducted separately. This allowed us to provide detailed results separately for all interhospital transfer cases and all EMS patients transported to a hospital, as these can be perceived as two separate study populations. However, analyses were conducted in parallel. For each linked database (Sub-OTR1/ Sub-OTR2, and EMSIRS /Sub-OTR2), multiple imputation was used to account for missing covariate values. Five imputed datasets were generated as in Raghunathan et al.,[30] and combining rules[31] were employed to calculate estimates and standard errors across the datasets.

The independent variable for this study was time, calculated differently for each linked database to reflect the Specific Aims. The Interhospital Transfer Time Interval was defined as the time from arrival at the initial emergency department to the time of arrival at the emergency department of the final trauma center for patients who required interhospital transfer to a higher level trauma center for further treatment of their acute injuries (Specific Aim 1 & 2). The Total Transport Time Interval was defined as the time from receipt of the emergency call by the EMS dispatch center to the time of arrival at the emergency department of the final medical center, as this is the closest available measure of the time from the injury event to arrival at the final medical center for definitive care (Specific Aim 3 & 4). The primary outcome measures for this study were death, hospital length of stay, admission to Intensive Care Unit, and Intensive Care Unit length of stay. In addition, secondary outcome measures included admission to a rehabilitation facility, required ventilation, and total ventilator days.

Descriptive statistics (frequencies, means, medians, ranges) are reported, as appropriate, for all variables. A ROC curve was constructed for the relationship between time and mortality. The association between the independent variable (time) and the continuous outcome measures (i.e., lengths of stay and ventilator days) were evaluated using general linear regression models, with log-transformed outcome variables due to skewed variable distributions (long tails to the right). The association between the independent variable (time) and the binary outcome variables (i.e., mortality, admissions to a level of care, and mechanical ventilation required) were evaluated using multiple logistic regression models. To account for variability due to potential confounding factors, our predictive regression models included other key variables (e.g., age, gender, race, metro/urban area, location where injury occurred, E-code injury group, alcohol/drug use, pre-existing co-morbidity, injury severity score, and complications) and key interactions between these variables (e.g., time by age).

Problems, Alternative Strategies, and Limitations - Due to unforeseen complications, it was necessary to modify specific aims 2 & 4 of this study, which were originally intended to investigate the influence of transfer and transport time on functional outcome among survivors of moderate to severe acute injury. In order to measure functional outcome, we planned to use the Functional Independence Measure (FIM and Wee FIM) score obtained from the Ohio Rehabilitation Trauma Database. The Ohio Rehabilitation Trauma Database began collecting data in 2005 with 25 rehabilitation facilities reporting approximately 900 cases. As with other state registries, reporting compliance to the rehabilitation database was expected to increase to include a greater number of rehabilitation facilities in Ohio, thus increasing the size of our sample and representing a greater portion of all rehabilitative patients in Ohio. After obtaining the first three years of data (2005 – 2007), we found that the opposite was occurring. While approximately 38% of the rehabilitation facilities reported during 2005, this percentage decreased to 30% in 2006 and 26% in 2007. Upon further investigation, we were informed by the Ohio Department of Public Safety, which collects and owns the database, that lack of personnel and resources in the division that collects these data has lead to poor agency follow-up in response to facility non-reporting. This disappointing and unexpected situation led us to conclude that the Ohio Rehabilitation Trauma Database was compromised to such an extent that it should not be used. Despite this hindrance, we were able to achieve our specific aims with some modifications. We were still able to evaluate the influence of transfer and transport time on important patient outcomes of survivors of moderate to severe acute injury as originally proposed. However, instead of using the FIM score as our main outcome measure for specific aims 2 & 4, we looked at length of hospital stay, admission to an Intensive Care Unit, and length of stay in the Intensive Care Unit as our main outcome measures.

This study required us to make several decisions regarding the variables needed for analyses. *Both Linked Databases (Sub-OTR1/ Sub-OTR2, and EMSIRS /Sub-OTR2):* First, not all of the records in the Sub-OTR2 linked to either the Sub-OTR1 or the EMSIRS. Thus, there were records of patients known to be transported to the hospital via EMS or to have arrived via interhospital transfer but without a corresponding linked record to determine the transfer time (53.8%) or transport time (52.7%). However, the multiple imputation process used to account for these missing time values[30] is known to give accurate estimates for missing data. Second, the Trauma Registry contained information for the Glasgow Coma Scale (GCS) gathered at the scene or taken upon arrival in the hospital. Some patients had an invalid GCS in the hospital, because they were intubated or sedated at the time of assessment. For these individuals, we used a valid scene GCS if the measure was available. However, many individuals did not have a GCS at the scene, because, for example, they were intubated at the scene (or, for transferred patients, they entered the hospital without EMS involvement). We assigned these individuals to a unique category (unknown), because we believe this is a meaningful group for comparison. Finally, we modified our original analysis plan by changing our time variable from two levels (above and below a specified cut off) to multi-level (1-hour time increments). This allowed us to investigate the variation among all time

points. However, this change in time precluded the use of propensity scores[32] in our regression models to account for non-random assignment of patients into the two time categories.

Interhospital Transfers Database (Sub-OTR1/ Sub-OTR2): First, the interhospital transfer time variable was only computed from linked records where patients were known to be transferred from an emergency department rather than another area of the hospital. This was done to assure our interhospital transfer time variable only included transfers between emergency departments, as transfers from other areas of the hospital could be for non-trauma reasons. Second, individuals who were transferred to a non-trauma center were excluded from our analysis database, because it seemed likely that the interhospital transfer occurred for a non-trauma-related reason. This included only a small percentage (1.8%) of all individuals transferred for further hospital care.

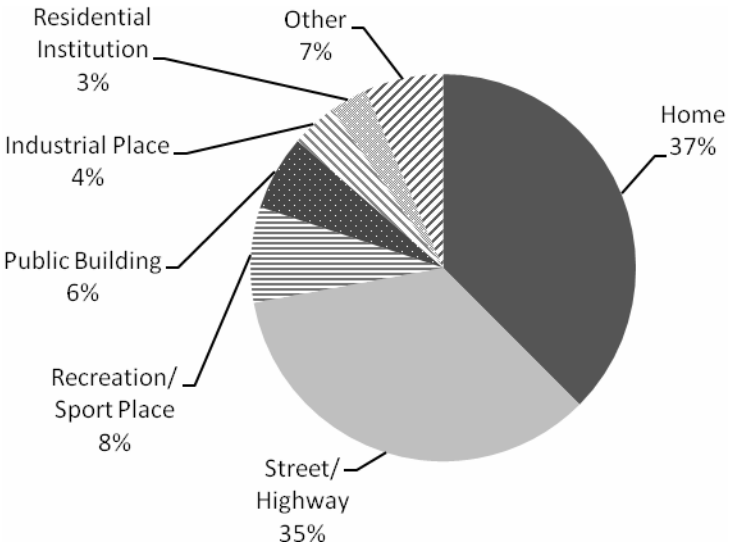
EMS Transport Database (EMSIRS/ Sub-OTR2): The linkage process allowed us to match the EMS database to only one Trauma Registry file (Sub-OTR1 or Sub-OTR2) at a time, and not simultaneously to both Sub-OTR1 and Sub-OTR2. Because our project goal was to identify the final outcome of the patient receiving treatment, we linked with Sub-OTR2, and by doing so, removed the first hospital visit for individuals who were subsequently transferred to another hospital. The Trauma Registry does not include all incidents of injury for the state of Ohio. To be included in the Trauma database, individuals must have been admitted for at least 48 hours, transferred into or out of the hospital, pronounced dead on arrival, or died at any point during care in the hospital. Thus, only individuals with severe injuries requiring extensive medical care were included in this analysis. Second, we were unable to assess the influence of helicopter transport because 47.3% of patients had unknown vehicle of transport, and only a small percentage (3.2%) of patients where the type of transport was known required air transport. Further, people who were treated at the scene and not transported or died at the scene are not included in the analyses.

Researcher Findings

Interhospital Transfer Time from Arrival at a Referring Hospital Emergency Department Until Subsequent Arrival at a Trauma Center

From 2005 through 2007, there were 23,401 interhospital transfer patients in Ohio. The two most frequent causes of injury for transferred individuals were transportation-related crashes (38.8%) and falls (34.8%). The majority (72.1%) of injuries occurred in the home or on a street/highway (Figure 1), and 40.0% of these injuries occurred in a rural area.

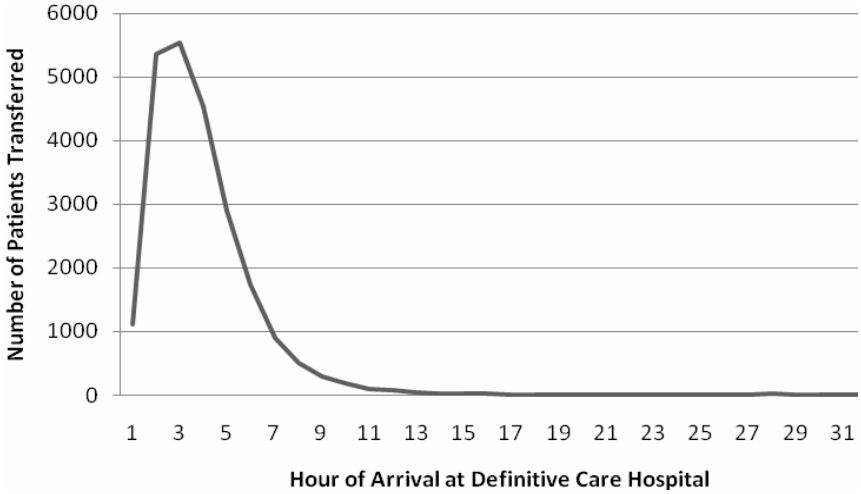
Figure 1. Location of Injury Event for Interhospital Transfer Patients, Ohio 2005 – 2007



Duration of Interhospital Transfer

The average transfer time from arrival at the referring hospital until arrival at a definitive care trauma center was 3.9 hours (median 3), with a range of under 1 hour to 32 hours (Figure 2). Only 27.7% of transferred individuals (6,470 patients) arrived at the definitive care hospital within a 2-hour timeframe. Roughly 70.8% of interhospital transfer patients reached a definitive care hospital within 4 hours and 90.6% reached a definitive care hospital within 6 hours.

Figure 2. Interhospital Transfer Time from Initial Care Facility to Definitive Care Hospital, Ohio 2005 - 2007



Half (50.4%) of the interhospital transfer patients received at least one medical or diagnostic treatment/intervention (abdominal evaluation [either abdominal/pelvic CT, diagnostic peritoneal lavage, or abdominal ultrasound], CPR, endotracheal intubation, head CT, or spinal immobilization) in the transferring hospital ED prior to their transfer to a final destination hospital. The most common treatments/interventions received were spinal immobilization or head CT, but the percentage of patients receiving the treatments varied depending on whether they had an interhospital transfer time of 2 hours or less verses greater than 2 hours (Table 1).

Table 1. Percentage of Interhospital Transfer Patients Receiving Advanced Treatment in the Transferring Hospital Emergency Department (ED) Prior to Transfer

Treatment Given in Transferring Hospital ED	% of Interhospital Patients Transferred in:		% of All Interhospital Transfers
	2 Hours or Less	Above 2 Hours	
Abdominal Evaluation	4.6%	9.0%	7.8%
CPR	0.9%	0.2%	0.4%
Endotracheal Intubation	15.3%	4.4%	7.4%
Head CT	12.0%	32.4%	26.7%
Spinal Immobilization	27.3%	25.6%	26.1%

Note: Percentages are obtained from Trauma Registry cases that linked to a first hospital ED. Values for all transfer cases (linked and unlinked) should be similar.

Demographic Profile of Interhospital Transfer Patients

During 2005 through 2007, there were 6,412 interhospital transfers among children 15 years of age or younger, which represents roughly one-quarter (27.4%) of all transfer patients (Table 2). The average age for all transfer patients was 35.4 years of age (median 30, range 0 to 103). The average age of patients transferred within ≤ 2 hours was 32.2 years of age (median 28), whereas the average age of patients with a transfer timer greater than 2 hours was 36.6 years (median 32). Two-thirds (66.9%) of transfer patients were male.

Table 2. Demographic Profile of Interhospital Transfer Patients, Ohio 2005 – 2007

	Interhospital Patients Transferred in:		All Interhospital Transfers
	2 Hours or Less	Above 2 Hours	
	Number (%)	Number (%)	Number (%)
Age			
15 years and younger	1,659 (25.6%)	4,753 (28.1%)	6,412 (27.4%)
16 – 64 years	4,150 (64.1%)	9,080 (53.5%)	13,200 (56.4%)
65 years and older	661 (10.2%)	3,128 (18.5%)	3,789 (16.2%)
Gender			
Male	4,616 (71.3%)	11,045 (65.2%)	15,661 (66.9%)
Female	1,854 (28.7%)	5,886 (34.8%)	7,740 (33.1%)
Race			
White	5,414 (83.7%)	15,052 (88.9%)	20,466 (87.5%)
Black	788 (12.2%)	1,261 (7.5%)	2,049 (8.8%)
Other	268 (4.14%)	618 (3.7%)	886 (3.8%)
Pre-Existing Co-Morbidity			
Yes	2,484 (38.4%)	6,222 (36.8%)	8,706 (37.2%)
No	3,986 (61.6%)	10,709 (63.3%)	14,695 (62.8%)

Note: Due to rounding, column percentages may not total 100%.

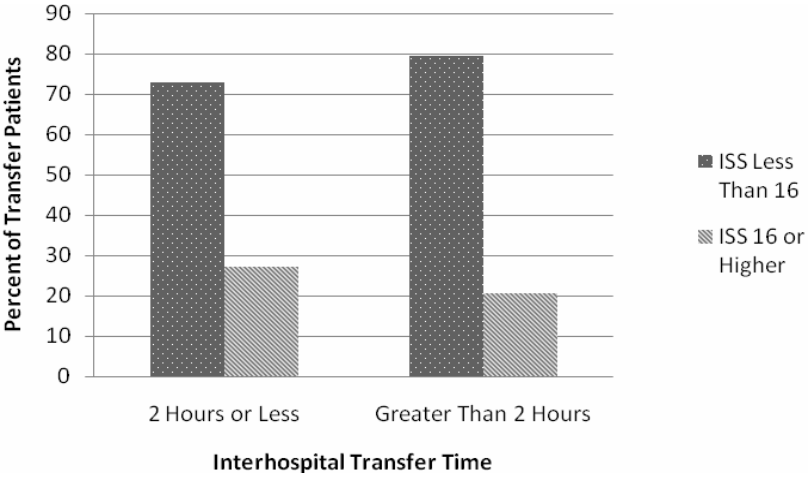
Blood alcohol and/or other drug tests confirmed alcohol and/or drug use in 20.3% of all interhospital transfer patients. Approximately 28.0% of patients transferred within ≤ 2 hours tested positive for alcohol and/or other drug use compared with 17.4% of patients who exceeded a 2-hour transfer time.

Among all interhospital transfer patients, 7.8% had a documented complication that developed as a result of the initial injury or treatment, with 11.3% of patients transferred within ≤ 2 hours experiencing a complication compared with 6.5% of patients who exceeded a 2-hour transfer time.

Injury Severity of Interhospital Transfer Patients

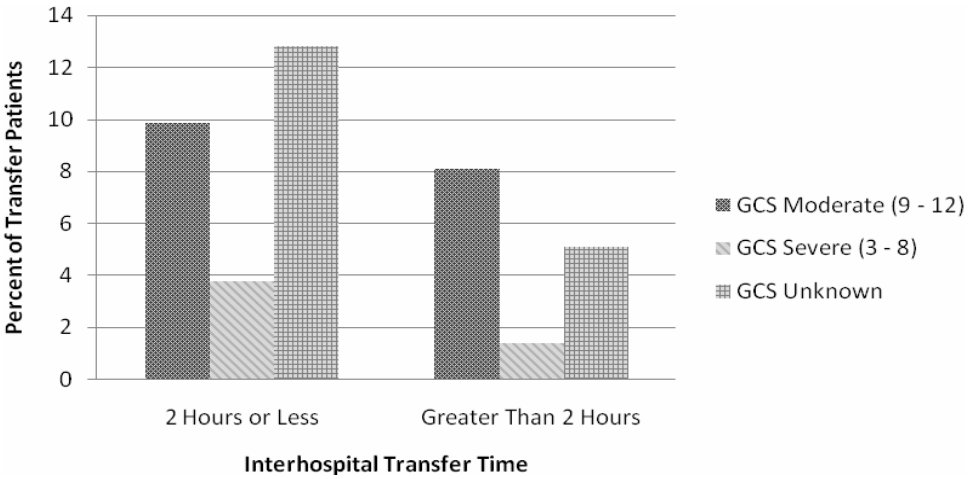
During 2005 through 2007, there were 5,256 interhospital transfer patients (22.5%) who had an injury severity score (ISS) of 16 or greater. Among patients transferred within ≤ 2 hours, 27.1% had a high ISS (≥ 16), whereas a smaller percentage of patients exceeding a 2-hour transfer time (20.7%) had a high ISS (Figure 3).

Figure 3. Injury Severity Score (ISS) among Interhospital Transfer Patients by Transfer Time, Ohio 2005 - 2007



Similarly, a larger percentage of patients (13.6%) transferred within ≤ 2 hours had moderate to severe deficits in level of consciousness (Glasgow Coma Scale score of 3 - 12) compared with patients exceeding a 2-hour transfer time (9.5%, Figure 4). Glasgow Coma Scale scores of 13 - 15 were found for 73.6% of patients transferred within ≤ 2 hours and 85.4% of patients with a transfer time greater than 2 hours. Additionally, 12.8 % of patients transferred within 2 hours had unknown Glasgow Coma Scale scores, because they were intubated or sedated at the time of assessment, compared with only 5.1% of patients exceeding a 2-hour transfer time.

Figure 4. Glasgow Coma Scale Scores among Interhospital Transfer Patients by Transfer Time, Ohio 2005 - 2007



Medical Outcome of Interhospital Transfer Patients

The average hospital length of stay for all transferred patients was 5.0 days (median 3 days, range 1 – 378 days), with patients transferred within ≤ 2 hours having a slightly longer hospital stay compared with patients who exceeded a 2-hour transfer time (mean: 5.8 vs. 4.7 days).

Interhospital transfer time was significantly related to LOS, but this relationship was not clinically meaningful. For example, an increase in 1 hour of interhospital transfer time resulted in a decrease in LOS by a factor of 0.99 for individuals with a high ISS (≥ 16)—this is essentially no change. However, the influence of injury severity on LOS varied depending on time. Among individuals whose interhospital transport time was 2 hours, LOS increased by a factor of 1.78 for individuals with a high ISS compared with a low ISS (< 16), but among individuals whose interhospital transport time was 4 hours, LOS increased by a factor of 1.53 for individuals with a high ISS compared with a low ISS. The mechanism of injury also influenced LOS, but the relationship varied depending on gender of the transferred patient. Among female patients, a transportation-related injury increased LOS by a factor of 1.16 compared with a fall-related injury, but among male patients, a transportation-related injury increased LOS by a factor of 1.05 compared with a fall-related injury. Among all interhospital transfer patients, LOS increased by a factor of 2.38 for patients who had a documented complication that developed as a result of the initial injury or treatment compared with patients without any documented complications.

Of all interhospital transfer patients, 21.6% were admitted to the ICU, and 10.3% required mechanical ventilation (Table 3). Among patients admitted to the ICU, the average ICU length of stay was 4.7 days (median 2, range 1 - 111). Among patients requiring mechanical ventilation, the average number of days of ventilator use was 5.5 days (median 2, range 1 – 84).

Table 3. Number and percentage of Interhospital Transfer Patients Requiring Mechanical Ventilation or Admission to an Intensive Care Unit by Transfer Time, Ohio 2005 - 2007

	Interhospital Patients Transferred in:		All
	2 Hours or Less	Above 2 Hours	Interhospital Transfers
	Number (%)	Number (%)	Number (%)
Admitted to ICU			
Yes	1,835 (28.4%)	3,221 (19.0%)	5,056 (21.6%)
No	4,635 (71.7%)	13,710 (81.0%)	18,345 (78.4%)
Required Ventilation			
Yes	1,274 (19.7%)	1,131 (6.7%)	2,405 (10.3%)
No	5,196 (80.3%)	15,800 (93.3%)	20,996 (89.7%)

Note: Due to rounding, column percentages may not total 100%.

Interhospital transfer time was associated with whether someone was admitted to the ICU, such that each 1 hour increase in transfer time resulted in 0.90 times lower odds of admission to the ICU. Thus, as transfer time decreased by 1 hour, the likelihood of admission increased by 1.11. Patients with a high ISS (≥ 16) were 4.69 times more likely to be admitted to the ICU than patients with a low ISS (< 16). Patients who had a documented complication that developed as a result of the initial injury or treatment were 1.90 times more likely to be admitted to the ICU than patients without documented complications. Among patients who were admitted to the ICU, interhospital transfer time was significantly associated with the number of days spent in the ICU. Although this relationship was statistically significant, it was not clinically meaningful; a 1-hour increase in transfer time resulted in fractional decreases in ICU days. The influence of injury severity on ICU days varied depending on time. Among individuals whose interhospital transport time was 2 hours, ICU days increased by a factor of 1.53 for individuals with a high ISS compared with a low ISS; but among individuals whose interhospital transport time was 4 hours, LOS increased by a factor of 1.34 for individuals with a high ISS compared with a low ISS. Among all patients who were admitted to the ICU, ICU days increased by a factor of 2.73 for patients who had a documented complication that developed as a result of the initial injury or treatment compared with patients without any documented complications.

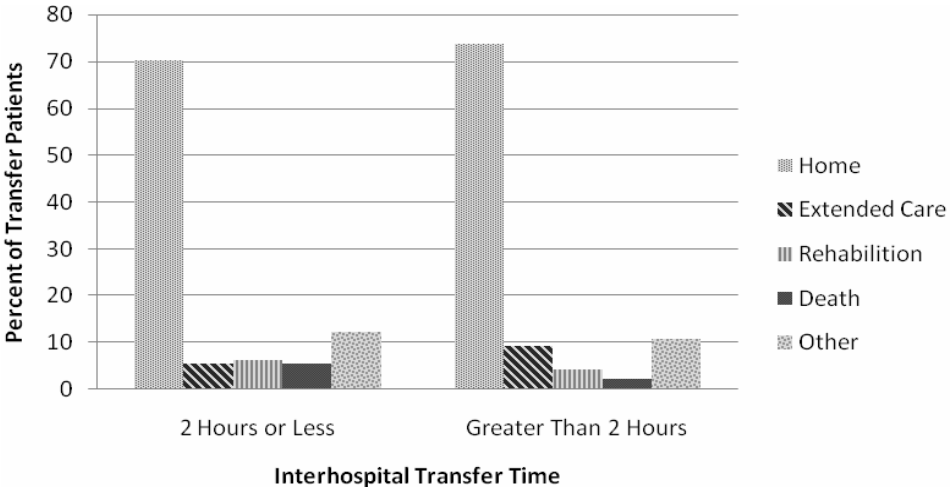
Results regarding whether a patient required mechanical ventilation were similar to the above-mentioned ICU findings. Interhospital transfer time influenced mechanical ventilation, such that each 1 hour increase in transfer time resulted in 0.72 times lower odds of ventilator use. Thus, as transfer time decreased by 1 hour, the likelihood of ventilator use increased by 1.40. Patients with a high ISS (≥ 16) were 4.85 times more likely to use a ventilator than patients with a low ISS (< 16). Patients who had a documented complication that developed as a result of the initial injury or treatment were 9.04 times more likely to be admitted to the ICU than patients without documented complications. Among patients who required mechanical ventilation, interhospital transfer time did not influence the number of days of ventilator use, but other factors were influential in predicting ventilator days. Ventilator days increased by a factor of 1.50 for individuals with a high ISS compared with a low ISS. Ventilator days increased by a factor of 2.51 for patients who had a documented complication that developed as a result of the initial injury or treatment compared with patients without any documented complications.

Discharge Disposition of Interhospital Transfer Patients

There were 1,937 interhospital transfer patients who were discharged to extended care, 1,105 who were discharged to rehabilitation, and 715 fatalities. A larger percentage of patients exceeding a 2-hour transfer time were discharged to nursing/extended care facilities compared with patients transferred within ≤ 2 hours (9.3% vs. 5.5%). However, 6.3% of patients transferred within ≤ 2 hours needed

rehabilitative care and 5.6% died compared with patients exceeding a 2-hour transfer time, among whom 4.1% needed rehabilitation and 2.1% died (Figure 5).

Figure 5. Discharge Status among Interhospital Transfer Patients by Transfer Time, Ohio 2005 - 2007

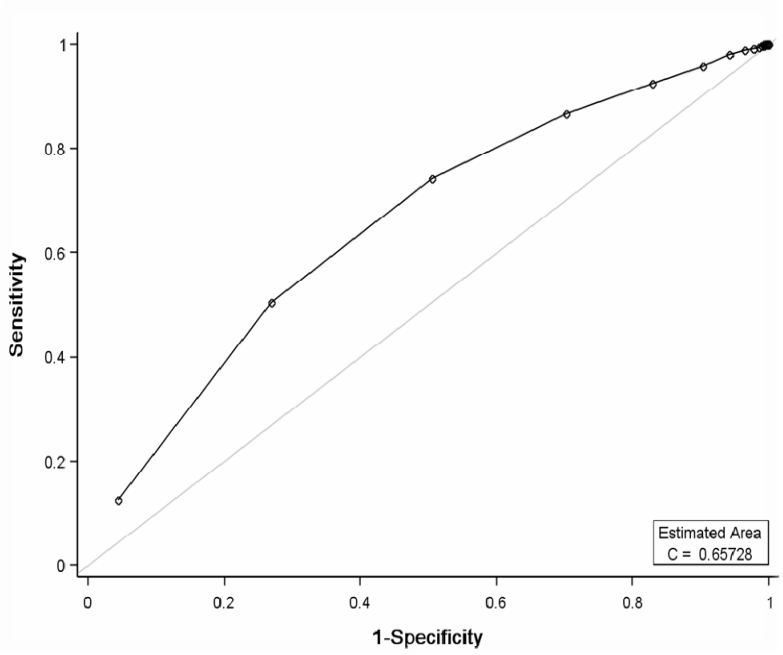


Interhospital transfer time did not predict whether someone was discharged to rehabilitative care, but several other factors were significant. Interhospital transfer patients who had a high ISS (≥ 16) were 4.15 times more likely to need rehabilitative care than patients with a low ISS (< 16). Injuries occurring in a metropolitan area were 1.22 times more likely to need rehabilitation than those occurring in a rural area. Both injury mechanism and alcohol and/or drug use were associated with the need for rehabilitative care, but the relationship varied depending on the age of the injured patient. For example, 20-year-old patients with a transportation-related injury were 3.79 times more likely to need rehabilitation compared with 20-year-old patients with a fall-related injury, but 60-year-old patients with a fall-related injury were 1.60 times more likely to need rehabilitation compared with 60-year-old patients with a transportation-related injury. Among 20-year-old patients, those with documented alcohol and/or drug use were 1.20 times more likely to need rehabilitation compared with those without documented use, but among 60-year-old patients, those with documented alcohol and/or drug use were 2.51 times more likely to need rehabilitation compared with those without documented use. Regardless of age, patients who had a documented complication that developed as a result of the initial injury or treatment were 2.28 times more likely to need rehabilitative care than patients without documented complications.

A Receiver Operating Characteristic (ROC) curve was created to graphically demonstrate the accuracy of interhospital transfer time at predicting death (Figure 6). The Area Under the Curve (AUC) was 0.657, which means that interhospital transfer time had poor accuracy (i.e., it was neither sensitive nor specific) at predicting death. Note that an AUC = 0.5 represents a complete lack of discrimination, that is, zero

sensitivity and zero specificity. However, regression analysis showed time was still a significant predictor of death outcome. Among interhospital transfer patients who had a high ISS (≥ 16), each 1 hour increase in transfer time resulted in 0.67 times lower odds of death, and among patients with a low ISS (< 16), the odds of death decreased by 0.78 times for each 1 hour increase in transfer time. Thus, as transfer time decreased by 1 hour, the likelihood of death increased by 1.47 for patients with a high ISS and by 1.28 for patients with a low ISS. Individuals without alcohol and/or drug use were 1.46 times more likely to die than individuals with documented alcohol and/or drug use. Age was also a significant predictor of death, and this relationship was influenced by gender. Male patients were 1.39 times more likely to die than male patients 10 years younger and 1.94 times more likely to die than male patients 20 years younger, whereas female patients were 1.27 times more likely to die than female patients 10 years younger and 1.61 times more likely to die than female patients 20 years younger. Patients who had a documented complication that developed as a result of the initial injury or treatment were 4.33 times more likely to die than patients without documented complications.

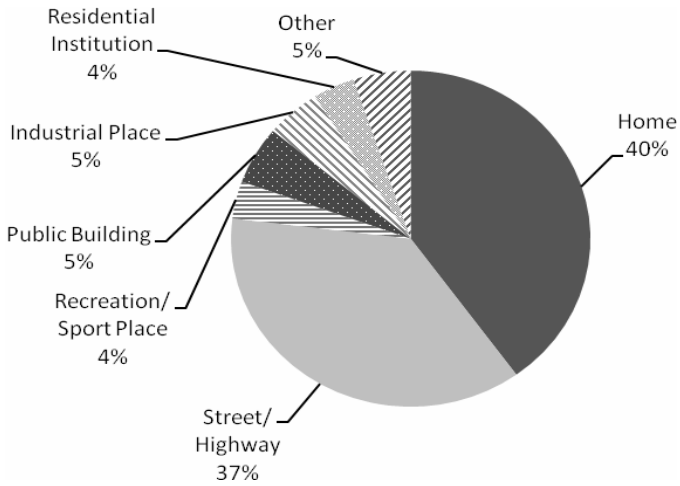
Figure 6. Receiver Operating Characteristic (ROC) Curve for Interhospital Transfer Time as a Predictor of Death among Interhospital Transfer Patients, Ohio 2005 – 2007



Emergency Medical Services Transport Time from the Traumatic Event until Arrival at the Final Medical Center for Definitive Care

From 2005 through 2007, there were 61,226 trauma patients who were transported to a final-destination medical center for definitive care in Ohio by Emergency Medical Services. The two most frequent causes of injury for these patients were falls (43.0%) and transportation-related events (36.5%). The majority of these injuries occurred in metropolitan areas (79.3%), and most injuries occurred in the home (40.0%) or on a street/highway (36.9%).

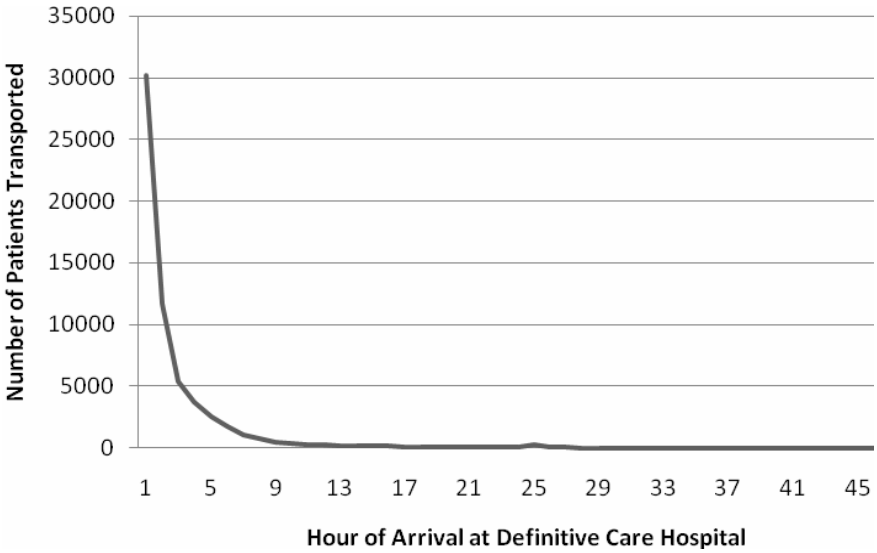
Figure 7. Location of Injury Event for EMS Transport Trauma Cases in Ohio, Ohio 2005 – 2007



Duration of EMS Transport Time

The average EMS transport time from the traumatic event until arrival at the final medical center for definitive care was 3.1 hours (median 2 hours), with a range of under 1 hour to 48 hours (Figure 8). Of all trauma patients transported to final-destination medical centers by EMS, 49.3% (30,211 patients) arrived at the definitive care hospital within 1 hour of the traumatic event, as suggested by the “Golden Hour”. About 90.4% of all EMS-transported trauma patients arrived at the definitive care hospital within 6 hours.

Figure 8. Total Transport Time from EMS Notification to Arrival at Definitive Care Hospital, Ohio 2005 - 2007



Almost half (48.6%) of EMS-transported trauma patients received medical treatment at the scene prior to transport. The most common treatments at the scene were administration of intravenous fluids (34.2%) and spinal immobilization (34.1%). Among trauma patients transported by the EMS, 1.0% of patients received CPR at the scene before transport to a definitive care hospital. Approximately 1.4% of patients whose total transport time was 1 hour or less received CPR at the scene, while only 0.6% of patients with transport times exceeding 1 hour received CPR at the scene. Approximately 2.8% of all transported trauma patients were intubated before arriving at a definitive care hospital, with 3.0% of patients transported within 1 hour being intubated and 2.6% of patients whose total transport time was greater than 1 hour being intubated before arrival at the definitive care hospital.

Demographic Profile of EMS Transport Patients

The average age for all trauma patients transported to final-destination medical centers by EMS was 49.9 years (median 49 years, range 0 to 105), with approximately one-third (33.1%) of patients 65 years and older. The average age of patients transported to a definitive care hospital within 1 hour or less was 54.4 years (median 54 years), and the average age of patients with transport times greater than 1 hour was 45.7 years (median 44 years). Over half (57.1%) of transported trauma patients were male.

Table 4. Demographic Profile of EMS-Transported Trauma Patients by Total Transport Time, Ohio 2005 – 2007

	Total Transport Time		All EMS-Transported Trauma Patients
	1 Hour or Less	Greater than 1 Hour	
	Number (%)	Number (%)	Number (%)
Age			
15 years and younger	1,452 (4.8%)	3,792 (12.2%)	5,244 (8.6%)
16 – 64 years	16,946 (56.1%)	18,780 (60.6%)	35,726 (58.4%)
65 years and older	11,813 (39.1%)	8,443 (27.2%)	20,256 (33.1%)
Gender			
Male	16,089 (53.3%)	18,852 (60.8%)	34,941 (57.1%)
Female	14,122 (46.7%)	12,163 (39.2%)	26,285 (42.9%)
Race			
White	24,084 (79.7%)	26,666 (86.0%)	50,750 (82.9%)
Black	5,136 (17.0%)	3,217 (10.4%)	8,353 (13.6%)
Other	991 (3.3%)	1,132 (3.6%)	2,123 (3.5%)
Pre-Existing Co-Morbidity			
Yes	16,138 (53.4%)	14,351 (46.3%)	30,489 (49.8%)
No	14,073 (46.6%)	16,664 (53.7%)	30,737 (50.2%)

Note: Due to rounding, column percentages may not total 100%.

Blood alcohol and/or other drug tests confirmed alcohol and/or drug use in 24.5% of all transported trauma patients. Roughly 27.4% of patients transported within 1 hour or less tested positive for alcohol and/or other drug use compared with 21.7% of patients whose transport time exceeded 1 hour. Among patients with transport times of 1 hour or less, 11.4% had a documented complication that developed as a result of the initial injury or treatment, while 12.7% of patients with transport times exceeding 1 hour had a documented complication.

Injury Severity of EMS Transport Patients

From 2005 through 2007, there were 14,868 trauma patients transported by EMS (24.3%), who had an injury severity score (ISS) of 16 or greater. For patients who arrived at the definitive care hospital within 1 hour or less from the traumatic event, 23.0% had a high ISS (≥ 16), while 25.5% of trauma patients whose transport time was greater than one hour had a high ISS (Figure 9).

Of all EMS-transported trauma patients, 15.5% had moderate to severe deficits in level of consciousness (Glasgow Coma Scale score 3 – 12). A larger percentage of trauma patients (16.5%) with transport times of 1 hour or less had moderate to severe deficits in level of consciousness than trauma patients (14.6%) whose EMS transport time was greater than 1 hour. Glasgow Coma Scale scores of 13 - 15 were found for 78.5% of patients transported within 1 hour or less and 80.1% of patients with transport times greater than 1 hour. Also, 6.9% of patients transported within 1 hour or less had unknown Glasgow Coma Scale scores, because of intubation or sedation at the time of assessment, compared with only 3.4% of patients whose transport time exceeded 1 hour (Figure 10).

Figure 9. Injury Severity Score (ISS) among EMS-Transported Trauma Patients by Total Transport Time, Ohio 2005 - 2007

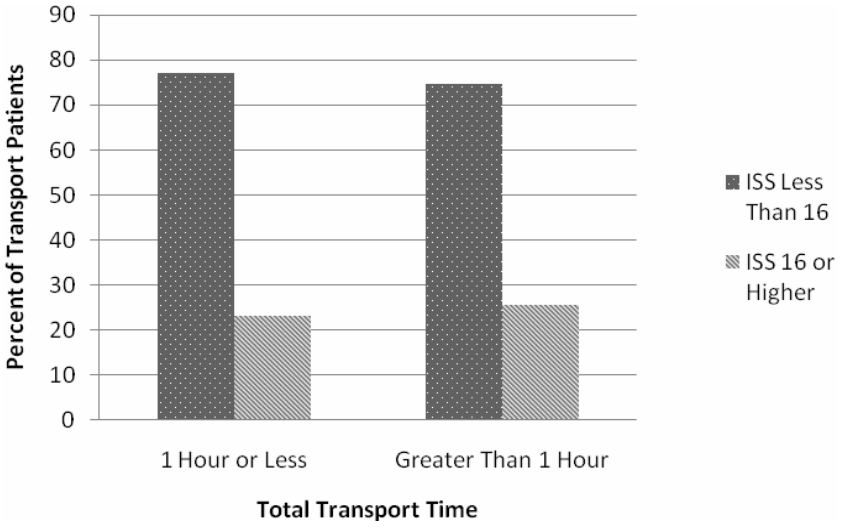
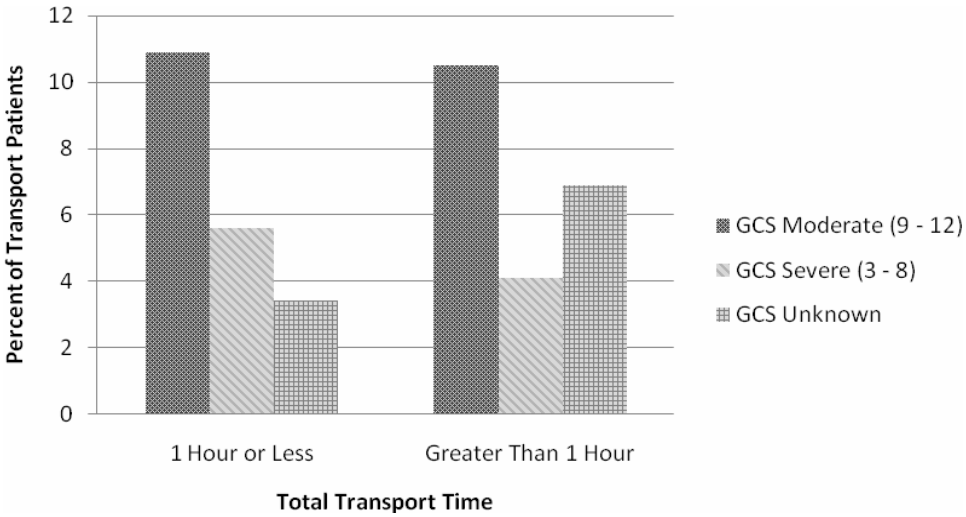


Figure 10. Glasgow Coma Scale Score among EMS-Transported Trauma Patients by Total Transport Time, Ohio 2005 - 2007



Medical Outcome of EMS Transport Patients

The average hospital length of stay for all trauma patients transported by EMS was 6.5 days (median 5 days, range 1 – 380 days). Of all EMS-transported trauma patients, 22.5% were admitted to the ICU, and 12.4% required mechanical ventilation (Table 4). Among those admitted to the ICU, the average ICU length of stay was 5.2 days (median 2 days, range 1 – 148 days). Among patients requiring mechanical ventilation, the average number of days of ventilator use was 5.9 days (median 2 days, range 1 – 170 days).

Table 5. Number and percentage of EMS-Transported Trauma Patients Requiring Mechanical Ventilation or Admission to an Intensive Care Unit by Total Transport Time, Ohio 2005 - 2007

	Total Transport Time		All EMS-Transported Trauma Patients
	1 Hour or Less	Greater than 1 Hour	
	Number (%)	Number (%)	Number (%)
Admitted to ICU			
Yes	6,392 (21.2%)	7,409 (23.9%)	13,801 (22.5%)
No	23,819 (78.8%)	23,606 (76.1%)	47,425 (77.5%)
Required Ventilation			
Yes	3,647 (12.1%)	3,919 (12.6%)	7,566 (12.4%)
No	26,564 (87.9%)	27,096 (87.4%)	53,660 (87.6%)

Note: Due to rounding, column percentages may not total 100%.

Among trauma patients transported by EMS, total transport time to the definitive care hospital had a statistically significant, but not clinically meaningful, affect on the length of stay in the hospital among patients who also had documented complications during their hospital stay. For every hour that total transport time increased, the length of stay in the hospital increased by a factor of 1.01 for patients who experienced complications during their hospital stay. Total transport time did not increase length of stay among patients who did not experience any complications. Other factors also significantly influenced hospital length of stay. Admission to the ICU increased length of stay by a factor of 1.40 over patients not admitted to the ICU. Patients who required ventilation had an increase in length of stay by a factor of 1.39 compared with patients not requiring mechanical ventilation.

Total transport time to the definitive care hospital was not a significant factor in predicting admission to the ICU, but other factors were significantly associated with admission to the ICU. Patients with a high ISS (≥ 16) were 3.10 times more likely to be admitted to the ICU than patients with an ISS of less than 16. Among patients who were initially treated in another hospital and then transferred and admitted to the definitive care hospital, patients in metropolitan areas were 1.13 times more likely to be admitted to the ICU than patients in rural areas. In contrast, among patients transported directly from the scene to the definitive care hospital, patients in rural areas were 1.15 times more likely to be admitted to the ICU than patients in metropolitan areas.

Among patients who were admitted to the ICU, total transport time did not significantly influence the length of stay in the ICU. Injury severity influenced length of stay in the ICU, but the relationship varied depending on the mechanism of injury. Among patients injured in transportation-related incidents, patients with a high ISS (≥ 16) increased length of stay in the ICU by a factor of 1.49 compared to those with an ISS of less than 16. Among patients injured by falls, patients with a high ISS (≥ 16) increased length of stay in the ICU by a factor of 1.25 compared with patients with a low ISS (< 16).

Total transport time to the definitive care hospital was a statistically significant factor for predicting whether a patient required mechanical ventilation, but it was not a clinically meaningful factor. Increasing total transport time by 1 hour resulted in a 0.98 times lower odds of requiring mechanical ventilation. Conversely, as total transport time decreased by 1 hour, the odds of requiring mechanical ventilation increased by a factor of 1.02. Patients who experienced complications during their hospital stay were 5.59 times more likely to require mechanical ventilation, compared with patients who did not have documented complications. Mechanism of injury was also associated with the need for mechanical ventilation, but the relationship varied by the severity of the injury. Among patients who had a high ISS (≥ 16), patients injured in transportation-related incidents were 1.49 times more likely to require mechanical ventilation compared with patients injured by falls. Among patients who had an ISS less than 16, the odds of

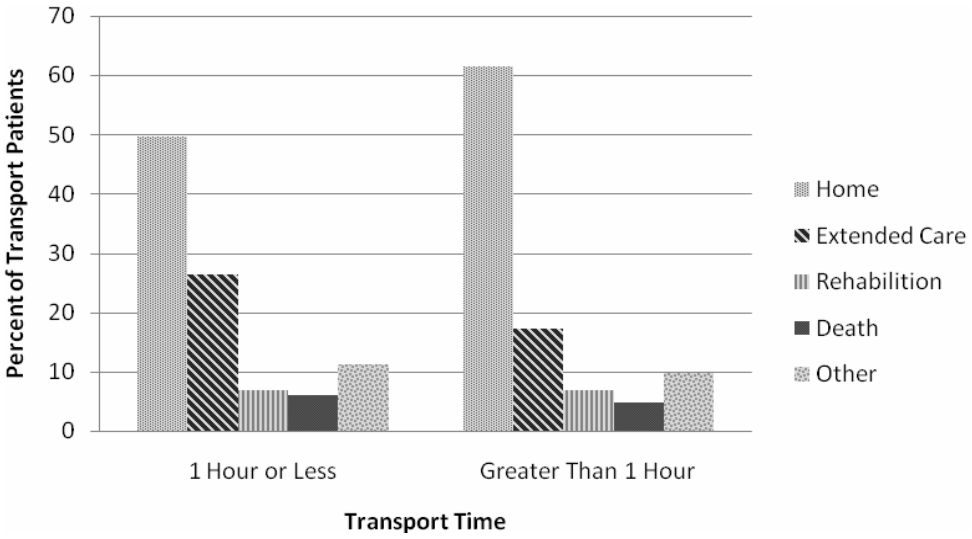
requiring mechanical ventilation increased by 1.26 times for patients injured in transportation-related incidents compared with patients injured by falls. In addition, males were 1.22 times more likely to require mechanical ventilation than females.

Among patients receiving mechanical ventilation, total transport time was not significantly associated with the number of days patients required the ventilator. However, injury severity influenced how long a patient needed mechanical ventilation, but this relationship varied depending on the mechanism that caused the injury. Patients with a high ISS (≥ 16) injured in transportation-related incidents had an increase of days on a ventilator by a factor of 1.71 compared with patients with a low ISS (< 16) who were also involved in transportation-related incidents. Patients with a high ISS injured by falls, when compared with patients injured by falls who had a low ISS, had an increase of days on a ventilator by a factor of 1.33.

Discharge Disposition of EMS Transport Patients

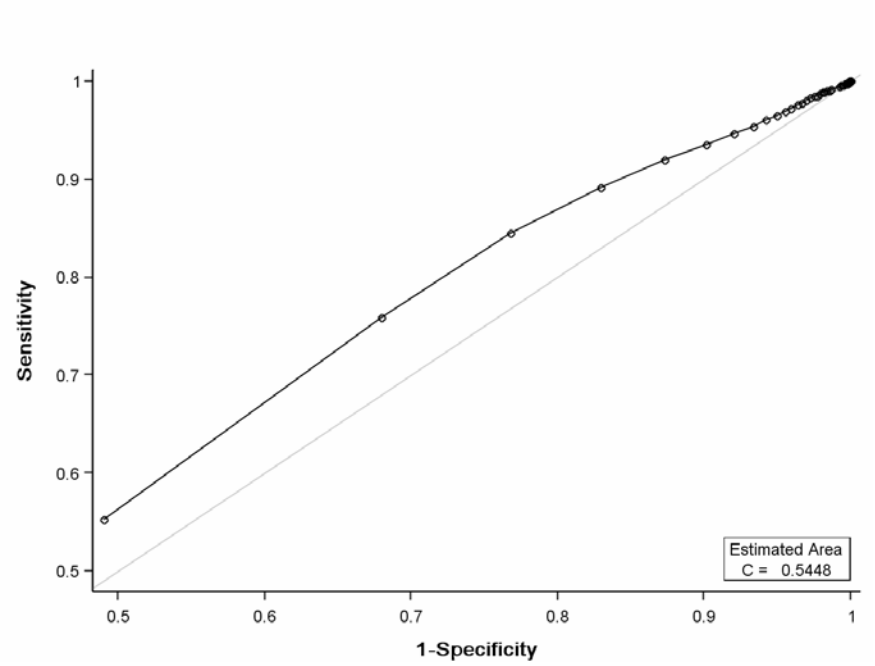
There were 13,283 transported trauma patients who were discharged to extended care facilities and 4,173 patients discharged to rehabilitation facilities. There were also 3,356 fatalities. A larger percentage of patients transported within 1 hour or less were discharged to nursing/extended care facilities (26.3% vs. 17.3%) or died (6.1% vs. 4.8%) than patients with transport times greater than 1 hour (Figure 11).

Figure 11. Discharge Status among EMS-Transported Trauma Patients by Total Transport Time, Ohio 2005 - 2007



A Receiver Operating Characteristic (ROC) curve was created to graphically demonstrate the accuracy of total transport time at predicting death (Figure 12). The Area Under the Curve (AUC) was 0.545, which means that transport time had poor accuracy (i.e., it was neither sensitive nor specific) at predicting death.

Figure 12. Receiver Operating Characteristic (ROC) Curve for Transport Time as a Predictor of Death among EMS-Transported Trauma Patients, Ohio 2005 - 2007



Among transported trauma patients, total transport time was not significantly related to death. However, other factors were significantly associated with death. Among patients who were initially treated in another hospital and then transferred and admitted to the definitive care hospital, an increase of 10 years in age was associated with a 1.37-fold increase in the likelihood of death. In comparison, among patients who were transported directly from the scene to the definitive care hospital, an increase of 10 years in age was associated with a 1.18-fold increase in the likelihood of death.

Total transport time also was not significantly associated with patients' discharge to a rehabilitation facility. However, patients admitted to the ICU were 2.10 times more likely to be discharged to a rehabilitation facility than patients not admitted to the ICU. In addition, patients who had an ISS of 16 or greater were 2.45 times more likely to be discharged to a rehabilitation facility than patients who had an ISS of less than 16.

Summary of Findings

Interhospital transfers: Transportation-related crashes and falls accounted for more than two-thirds (73.6%) of all injuries among interhospital transfer patients in Ohio, with the majority of injuries occurring in a metropolitan area. Approximately one-quarter (27.4%) of all interhospital transfer patients were children younger than 16 years, and two-thirds (66.9%) of patients were male. The average transfer time from arrival at the referring hospital until arrival at a definitive care trauma center was 3.9 hours. About half (50.4%) of patients received at least one medical or diagnostic treatment/intervention in the transferring hospital ED prior to transfer, with head CT (26.7%) and spinal immobilization (26.1%) performed most frequently prior to transfer. A slightly larger percentage of patients transferred within ≤ 2 hours (27.1%) had a high ISS (≥ 16) compared with patients exceeding a 2-hour transfer time (20.7%). Patients transferred within ≤ 2 hours also had a higher average hospital LOS. Patients with longer interhospital transfer times had lower odds of ventilator use and lower odds of ICU admission. A smaller percentage of patients exceeding a 2-hour transfer time needed rehabilitative care compared with patients transferred within ≤ 2 hours. Regardless of the ISS, the likelihood of death decreased as interhospital transfer time increased. Regardless of transfer time, patients who had a complication that developed as a result of the injury or treatment were more likely to require mechanical ventilation and ICU admission, plus have increased days of ventilator use, increased days in the ICU, increased total hospital LOS, and have greater odds of death compared with patients without complications.

EMS transports: More than three-quarters of all injuries among EMS-transported trauma patients were attributed to falls (43.0%) or transportation-related crashes (36.5%), and the majority (79.3%) of injuries occurred in a metropolitan area. Approximately one-third (33.1%) of patients were 65 years and older, and more than half (57.1%) of all transported trauma patients were male. The average EMS transport time for trauma patients, from the traumatic event until arrival at the final medical center for definitive care, was 3.1 hours, with 49.3% of patients arriving within 1 hour or less. The average age (54.4 years) of patients arriving within ≤1 hour was considerably older than the average age (45.7 years) of patients with transport times greater than 1 hour. Compared with patients who had a low ISS, patients with a high ISS (≥ 16) were more likely to spend a longer time in the ICU (for patients admitted to the ICU) or on a mechanical ventilator (for patients who required mechanical ventilation), and were more likely to be discharged to a rehabilitation facility.

Discussion and Conclusions

The findings of the interhospital transfer segment of this study have two possible interpretations: (1) the most critically injured patients were expeditiously transferred, resulting in more extreme or poorer outcomes among the group with shorter transfer times, or (2) stabilizing a patient prior to transfer led to

improved outcomes for those patients with longer transfer times. More specific future documentation of the reasons for the time delay in interhospital transfer may help ascertain whether stabilization in the transferring hospital ED, in fact, leads to reduced likelihood of ICU care, shorter LOS, and lower risk of death after transfer to another medical center for definite care. There are other studies that have not been able to show an improvement in outcomes for trauma patients who were transported directly to an advanced trauma center compared with patients initially treated in a smaller hospital or who experienced a delay in transfer.[13-16,33] Defining transfer delay as a delay of 4 or more hours or performance of special or diagnostic treatment procedures in the primary receiving hospital, Kearney, et al. concluded that the overall outcome of blunt trauma patients was not influenced by early versus delayed transfer to a Level 1 trauma center.[13] In a relatively small study, Veenema and Rodewald found that severely injured rural trauma patients, who were triaged and stabilized at Level 3 hospitals prior to transfer to a Level 1 trauma center, experienced outcomes similar to national results.[14] Nathens and colleagues reported a similar lack of influence on clinical outcomes for interhospital transfers in an urban trauma system.[16] Using the large database from the National Study on Cost and Outcome of Trauma, Rivara, et al. compared death within one year after injury between patients with moderate to severe injuries who were transferred to a Level 1 trauma center versus admitted directly to a Level 1 trauma center. After controlling for important covariates, transfer status was not a significant predictor of outcome.[33] The findings of our investigation are similar to those of these previous studies. They may indicate that appropriate stabilization prior to transfer to a definitive care center results in better outcomes even if stabilization results in longer transfer times; however, further study is needed to corroborate this possible interpretation.

The findings of the EMS transport segment of this study imply that other factors, both related to the patient and to the injury event, have a stronger influence on trauma outcomes than the total transport time to the definitive care facility. In both segments of this study, the interhospital transfer time and EMS transport time demonstrated poor accuracy (i.e, they were neither sensitive nor specific) for predicting patient death. Although the concept of the “Golden Hour” is straightforward and has a physiological basis, its simplicity adds to its popular appeal while obscuring a highly complex set of underlying factors influencing trauma patient outcomes. The findings of this study caution us not to jump to simple explanations for complex problems, just because the indicator (time) is easy to measure. Finally, the inherent limitations of a retrospective study design should be considered during interpretation of the findings of this study. The use of administrative datasets with missing data and other potential documentation issues is also a limitation of this study. The use of sophisticated data linkage and analytic techniques mitigates, but does not eliminate, these threats to validity.

References

1. Committee on Trauma, American College of Surgeons. *Resources for the optimal care of the injured patient: 1999.* Chicago: American College of Surgeons, 1998.
2. West JG, Trunkey DD, Lim RC. Systems of trauma care A study of two counties. *Arch Surg* 1979; 114: 255-460.
3. Cales RH, Trunkey DD. Preventable trauma deaths A review of trauma care systems development. *JAMA* 1985; 254: 1059-63.
4. Nirula R, Brasel K. Do trauma centers improve functional outcomes: A national trauma databank analysis. *J Trauma* 2006; 61:268-271
5. Shackford SR, Hollingworth-Fridlund P, Cooper GF, Eastman AB. The effect of regionalization upon the quality of trauma care as assessed by concurrent audit before and after institution of a trauma system: a preliminary report. *J Trauma* 1986; 26: 812-820.
6. Sampalis JS, Denis R, Frechette P, Brown R, Fleiszer D, Mulder D. Direct transport to tertiary trauma centers versus transfer from lower level facilities: Impact on mortality and morbidity among patients with major trauma. *J Trauma* 1997; 288-295.
7. Young JS, Bassam D, Cephas GA, Brady WJ, Butler K, Pomphrey M. Interhospital versus direct scene transfer of major trauma patients in a rural trauma system. Am Surg 1998; 64:88-91.
8. Wong K, Levy RD. Interhospital transfers of patients with surgical emergencies: Areas for improvement. *Aust J Rural Health* 2005; 13: 290-294.
9. Hartl R, Gerber LM, Iacono L, Ni Q, Lyons K, Ghajar J. Direct transport within an organized state trauma system reduces mortality in patients with severe traumatic brain injury. *J Trauma* 2006; 60: 1250-1256.
10. Sampalis JS, Denis R, Lavole A, Frechette P, Boukas S, Nikolis A, Benoit D, Fleiszer D, Brown R, Churchill-Smith M, Mulder D. Trauma care regionalization: A process-outcome evaluation. *J Trauma* 1999; 46: 565-581,
11. Gonzalez RP, Cummings G, Mulekar M, Rodning CB. Increased mortality in rural vehicular trauma: Identifying contributing factors through data linkage. *J Trauma* 2006; 61:404-409.
12. Falcone RE, Herron H, Werman H, Bonta M. Air medical transport of the injured patient: Scene versus referring hospital. *Air Medical Journal* 1998; 17: 161-165.
13. Kearney PA, Terry L, Burney RE. Outcome of patients with blunt trauma transferred after diagnostic or treatment procedures or four-hour delay. *Ann Emerg Med* 1991; 20: 882-886.
14. Veenema KR, Rodewald LE. Stabilization of rural multiple-trauma patients at level III emergency departments before transfer to a level I regional trauma center. *Ann Emerg Med* 1995; 25: 175-181.
15. Rogers FB, Shackford SR, Osler TM, Vane DW, Davis JH. Rural trauma: The challenge for the next decade. *J Trauma* 1999; 47: p 802.

16. Nathens AB, Maier, RV, Brundage SI, Jurkovich GJ, Grossman DC. The effect of interfacility transfer on outcome in an urban trauma system. *J Trauma* 2003; 55: 444-449.
17. Mendelow AD, Gillingham FJ. Extradural haematoma: effect of delayed treatment. *Br. Med. J.* 1979;2:134.
18. Seelig JM, Becker DP, Miller JD, Greenberg RP, Ward JD, Choi SC. Traumatic acute subdural hematoma: major mortality reduction in comatose patients treated within four hours. *N. Engl. J. Med.* 1981;304:1511-1518.
19. Haselsberger K, Pucher R, Auer LM. Prognosis after acute subdural or epidural haemorrhage. *Acta Neurochir.* 1988;90:111-116.
20. American College of Surgeons Committee on Trauma. *Advanced Trauma Life Support for Doctors, Student Course Manual*, 6th ed. Chicago: American College of Surgeons, 1997.
21. Gabriel EJ, Ghajar J, Jagoda A, Pons PT, Scalea T, Walters BC. Guidelines for prehospital management of traumatic brain injury. *J. Neurotrauma* 2002;19:111-174.
22. Brain Trauma Foundation. *Surgical management of traumatic brain injury.* Brain Trauma Foundation [online, 2006]. Available from URL: http://www.braintrauma.org/Guidelines.
23. Harrington DT, Connolly M, Biffl WL, Majercik SD, Cioffi WG. Transfer times to definitive care facilities are too long A consequence of an immature trauma system. *Ann Surg* 2005; 241: 961-968.
24. National Center for Injury Prevention and Control, Centers for Disease Control. *CDC Acute Injury Care Research Agenda: Guiding Research for the Future*. Centers for Disease Control and Prevention, Atlanta, GA, 2005.
25. Mullins RJ. A historical perspective of trauma system development in the United States. *J Trauma* 1999;47 Suppl:S8-S14.
26. Trunkey DD. History and development of trauma care in the United States. *Clinical Orthopaedics and Related Research* 2000;374:36-46.
27. Mullins RJ, Mann NC. Population-based research assessing the effectiveness of trauma systems. *J Trauma* 1999;47 Suppl:S59-S66.
28. MacKenzie EJ, Rivara FP, Jurkovich GJ, Nathens AB, Frey KP, Egleston BL, Salkever DS, Scharfstein DO. A national evaluation of the effect of trauma-center care on mortality. *N Engl J Med* 2006;354:366-378.
29. U.S. Department of Health and Human Services. *Model trauma system planning and evaluation.* [online, 2006]. Available from URL: http://www.facs.org/trauma/hrsa-mtspe.pdf.
30. Raghunathan TE, Lepkowski JM, Van Hoewyk J, Solenbeger P. A multivariate technique for multiply imputing missing values using a sequence of regression models. *Surv Methodol* 2001;27:85-95.
31. Rubin DB. *Multiple imputation for nonresponse in surveys.* New York: John Wiley, 1987.
32. Robins JM, Hernan MA, Brumback B. Marginal structural models and causal inference in epidemiology. *Epidemiology* 2000;11:550-560.

33. Rivara FP, Koepsell TD, Wang J, Nathens A, Jurkovich GA, MacKenzie EJ. Outcomes of trauma patients after transfer to a level 1 trauma center. *J Trauma* 2008;64(6):1594-1599.