Understanding State-wide Pediatric Trauma Under-triage

Final Report for
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Information / Qualifications: Principal and Co-Investigators

This study was led by members of Trauma Services / Comprehensive Children's Injury Center at Cincinnati Children's Hospital, in conjunction with the Biostatistics and Epidemiology.

The principal investigator**, Lynn Haas, RN, MSN, CNP**, is the Trauma Program Manager at Cincinnati Children's. Ms. Haas has extensive experience as a pediatric trauma Program Manager and has been actively involved in numerous performance improvement initiatives and clinical research projects. Ms. Haas was the PI on the State Trauma Systems ACS Evaluation grant completed in 2013.

Richard A. Falcone, Jr., MD, MPH, is an Associate Professor of Surgery and the Trauma Medical Director at Cincinnati Children's. He has an extensive background in trauma research including epidemiologic studies, quality of care studies, and design and evaluation of injury prevention programs.

Md. Monir Hossain, PhD. is an Associate Professor of Pediatrics in the department of Biostatistics and Epidemiology at Cincinnati Children's. In addition to his PhD in Statistics, he also completed postdoctoral fellowships in health services and outcomes research and in spatial statistics and disease mapping. Dr. Hossain has more than 10 years research experience on these topics with multiple publications, along with obtaining federal funding.

Mohammad Alfrad Nobel Bhuiyan, is currently a Graduate Research Assistant in the department of Biostatistics & Epidemiology, Cincinnati Children's Hospital and a PhD student in the department of Environmental Health (Biostatistics) at the University of Cincinnati.

Suzanne Moody, MPA, CCRP, is the Clinical Research Coordinator for Trauma Services at Cincinnati Children's Hospital. She has extensive experience in trauma data management, data analysis, and project management.

Misty Troutt, MS, MBA, is the Clinical Research Manager for General Pediatric and Thoracic Surgery at Cincinnati Children's Hospital. She has more than 10 years' experience in translational and clinical research along with data analysis and interpretation.

<u>Data Definitions</u>

Primary triage = injured patients transferred from the prehospital / scene to the initial hospital

Secondary triage = injured patients transferred from the initial hospital to a receiving hospital

ATC = Adult Trauma Center

PTC = Pediatric Trauma Center

NTC = Non Trauma Hospital

TC = Trauma Center, which would include both ATC and PTC

Unstable patient = an injured patient at the scene who had any of the following: 1) CPR in the field or during transport to a hospital, 2) systolic blood pressure less than 40 mm/HG, or 3) had a surgical airway placed in the field

Severely injured pediatric patient = all children < 16 years of age who were included in the Ohio Trauma Registry with a ICD-9 code between 800-959.9 or who died due to an injury

OTR = Ohio Trauma Registry

Primary Under-triage = transfer of children to ATC or NTC from the scene when there is a PTC within 30 minutes

Secondary Under-triage = injured children who are never transferred from a NTC or an ATC to a PTC and those who are transferred with a > 2 hour time between hospital arrival times

Overall Under-triage Rate = to include both primary and secondary under-triage groups

Overall Under-triage Rate (4 hours) = variation using a > 4 hour transfer time instead of > 2 hours

ISS = Injury Severity Score; AIS = Abbreviated Injury Score

Executive Summary

Under-triage is the failure to transport a patient to a trauma center when they require that level of care and can have a negative impact on the patient's outcome. Primary or field triage which consists of transport from prehospital / scene to the first hospital, and secondary triage which centers on inter-hospital transfer are the two triage parameters, which when combined, are used for the calculation of an under-triage rate for the trauma system being evaluated.

This under-triage research study was divided into three specific aims: 1) to determine pediatric under-triage rates for the state of Ohio and eight Ohio regions; including primary under-triage, secondary under-triage, regional, and overall under-triage rates; 2) to describe the variations in pediatric under-triage rates based on transport distance from the injury site to a PTC; and 3) to compare injury and patient characteristics between children appropriately triaged and those under-triaged.

This was a retrospective study of pediatric trauma patients in the state of Ohio utilizing data from the Ohio Trauma Registry (OTR). Patients were limited to those less than 16 years of age who were admitted to an Ohio hospital with an ICD-9 of 800-959.9, excluding burns and had a > 48 hours length of stay or death from a traumatic injury. Six years of data were obtained between the years of January 2007 through December 2012.

Therefore, the findings of Aim 1 conclude the following: the overall pediatric trauma under-triage rate, using a two hour transfer time was 52%, adjusting to 35% with a four hour transfer time; conversely, only 48% of severely injured children reached a pediatric trauma center within two hours, increasing to 65% if given four hours.

Aim 2 centered on evaluating under-triage around the PTCs in the state. When the under-triage rate was adjusted for distance (15 mile increments), even for those patients within a close range 0 – 15 miles to a PTC, the average pediatric under-triage rate was 25.1% with the rate increased to 44.1% when the range increment was increased 15- 30 miles from a PTC. Overall, 29% of the children had access to a

PTC within 30 minutes. Unfortunately, proximity of a PTC within 30 minutes did not prevent 55% of injured children from being transported to a non-PTC primarily (representing 16% of the overall population).

The goal of Aim 3 was to compare injury and patient characteristics between the children appropriately triaged to those under-triaged. The overall death rate for the six year timeframe was 2.9%. The death rate for those appropriately triaged was 5.3% while the death rate was 0.7% for those under-triaged. Factors that favorably impact appropriate triage to a PTC included the following: age less than 1 year, race of black, Medicaid insurance, injury mechanism of cut, drowning, firearm, motor vehicle, and population density (high). Conversely, age greater than five, race of non-black, commercially insured, mechanism of injury including fall and struck by an object, and resided in a medium to low density region, negatively impacted the likelihood of being triaged appropriately.

Regardless of contributing factors, the presence of trauma under-triage for the pediatric population in Ohio remains an issue that needs to be addressed. The positive outcome is that many children are receiving their injury care at a PTC. The opportunities exist that these patients could be initially transported bypassing a NTC or they could transferred between hospitals in a more timely manner.

Introduction

A key aspect of an effective inclusive trauma system is to appropriately evaluate and triage the most seriously injured patients in major trauma centers in order to maximize the patient's clinical outcome. Appropriate and timely patient triage is an essential element of an effective trauma system which is focused on "getting the right patient to the right place at the right time". Transporting a patient to a trauma center who does not require that level of care is considered over-triage and results in overuse of valuable resources. Conversely, under-triage is the failure to transport a patient to a trauma center when they require that level of care. Although both types of miss-triage negatively impact care within the trauma system, under-triage in particular can have a negative impact on the patient's outcome.

A major component of under-triage in the pediatric population is the limited access to a pediatric trauma hospital, which varies greatly by state and population density. It has been estimated that greater than 17 million children nationally do not have access to a pediatric trauma center (PTC) within 60 minutes.[1] In a perfect system, a seriously injured child would be transported directly from the scene to the appropriate trauma center even if this means bypassing closer hospitals. In reality, some degree of under-triage transpires in any trauma system due to factors such as travel distances, weather, inappropriate field triage and treatment, transport limitations, and lack of an organized trauma system.

Calculating under-triage rates continues to be a challenge since data for patients who are not treated in a trauma center are usually not collected and thus cannot be analyzed. Determining the under-triage rate for children is even more complex, as a scarcity of PTCs exists across the country, complicating the triage pattern. The state of Ohio has the unique opportunity to evaluate pediatric under-triage due to multiple factors. At the time of this study, there were six verified PTCs within the 7th most populous state, which also included a mixture of both rural and urban characteristics. Secondly, a legislative directive mandates that data from all injured patients in Ohio be submitted to the Ohio Trauma Registry (OTR) database, even those individuals that are treated at non-trauma hospitals.

This under-triage research study was divided into three specific aims: 1) Determine pediatric under-triage rates for the state of Ohio and eight Ohio regions; including primary under-triage, secondary under-triage, regional and an overall under-triage rate. 2) Describe the variations in pediatric under-triage rates based on transport distance from the injury site to a PTC. 3) Compare injury and patient characteristics between children appropriately triaged and those under-triaged.

Review of Literature

Existing literature focuses on validating two different triage parameters: 1) primary or field triage which consists of transport from prehospital / scene to the first hospital, and 2) secondary triage which centers on inter-hospital transfer. Combining both of these triage parameters is essential for the calculation of an overall under-triage rate of a trauma system. The *American College of Surgeons Resources for Optimal Care of the Injured Patient: 2014* suggests an under-triage rate of 5% or less is acceptable for both the adult and pediatric population.[2] However, this rate is frequently used in the context of an individual trauma center and not for a population-based analysis.

Research has demonstrated that treatment of injured patients at trauma centers, which consists of rapid evaluation and definitive care, has been shown to decrease morbidity and mortality.[3-13] This is further supported by the outcomes from the National Study on the Costs and Outcomes of Trauma (NSCOT), which concludes that the risk of death is 25% lower when treated at a level I trauma center than at a non-trauma center.[14] PTCs have evolved over the last three decades due to the recognition that injured children have unique needs that are not easily addressed in adult trauma centers (ATC). Children are different from adults in regard to injury patterns, propensity for different types of injury, physiological responses to injury and outcomes; therefore, benefiting from pediatric-specific care after injury. Many research studies have concluded that pediatric trauma centers have improved outcomes, especially among the most seriously injured children.[15-23] However, other studies have failed to demonstrate any differences in outcomes leading to continued controversy on the topic.

National research studies centered on triage conclude that between 30-70% of all patients with moderate to severe injuries are under-triaged and not treated at a trauma center.[24-29] Pediatric trauma research has shown that between 16-40% of severely injured pediatric patients are under-triaged and treated at non-pediatric trauma centers.[20, 30, 31] A Canadian study concluded that there is a 40% increased chance in mortality at 24 and 48 hours post injury when the injured are under-triaged.[9] For both the adult and pediatric population, higher appropriate triage rates are frequently observed in more mature trauma systems and in geographic areas that are in close proximity to trauma centers.[26, 28, 32]

Debate continues on the benefits of transporting patients to the closest hospital versus by-passing and transporting to a trauma center. The answer to this question is not clear with varied study designs leading to different answers. A recent population-based study demonstrated that injured patients may do better when directly transported to a trauma center than if they are stabilized at a non-trauma center prior to being transferred.[9] A second large multi-center NIH funded study found that direct transport from the scene to a trauma center was associated with a significantly higher discharge survival rate and improved discharged Glasgow Outcome Scale (GOS) for children with TBI.[33] Vogel noted that transferred children tend to be younger and more seriously injured than children directly triaged to pediatric trauma centers.[34]

Multiple factors which are complex in nature, enter into the decision process regarding the primary triage of a patient from the scene to the initial hospital. Field triage guidelines developed by the CDC were designed to simplify and provide direction for EMS personnel in selection of a destination hospital. A recent focus group study by Jones, noted that while prehospital guidelines were useful, EMS personnel commented that trauma field triage was not a linear process and usually not performed in a sequential stepwise manner. EMS providers noted that their first impression on the scene, incorporated with their past experiences was most valuable in triage.[35] Additional factors such as weather, regional EMS coverage and comfort level with providing care for children may also affect the patient's destination.

The increasing direction of population-based studies is allowing the issue of geography and time to definitive care to be better assessed. While patient physiology and mechanism of injury play an important part in triage, geography and time to a trauma center may be additional important factors, especially in the more rural regions. Stabilization of an injured patient prior to transfer from a community hospital when a trauma center is not closely available have been shown to improve outcomes.[14, 36, 37] Conversely, injured patients within 30 minutes transport time to a level I or level II trauma center have demonstrated beneficial outcomes if taken directly from the scene to the trauma center.[38] Currently, issues such as the process of field triage in rural settings, the impact of geography on trauma triage, proximity to trauma centers and the integration of local non-trauma hospitals for initial stability are poorly understood.

While prehospital triage protocols officially direct hospital destination, a significant proportion of injured patients are initially transported to a non-trauma center (NTC), only to later require transfer to a trauma center for definitive care.[25] A regional study by our research team (EMS Priority Grant 2007–2008: An Evaluation of the Impact of Outcome and the Etiology of Delayed Transport Times for Injured Pediatric Patients) indicated that 80% of injured pediatric patients initially transported to a non-trauma center did not reach an appropriate pediatric trauma center within the state goal of two hours.[39] In fact, the average transport time of these patients was 420 minutes.[39] These delays were observed even in severely injured pediatric trauma patients, including patients requiring an intensive care unit admission or an operation, all of whom met state field triage criteria for transport to a trauma center

As this debate continues, conclusive information does exist showing that a significant proportion of adults and children which are initially triaged to non-trauma center, are never transferred to a trauma center, regardless of the severity of the injury.[24, 40, 41] This fact alone, makes appropriate initial triage of critical importance. This work allowed us to evaluate the mature trauma system in the State of Ohio with a relative high abundance of pediatric trauma centers to learn more about pediatric under-triage and to help direct future work to improve functioning of an inclusive trauma system.

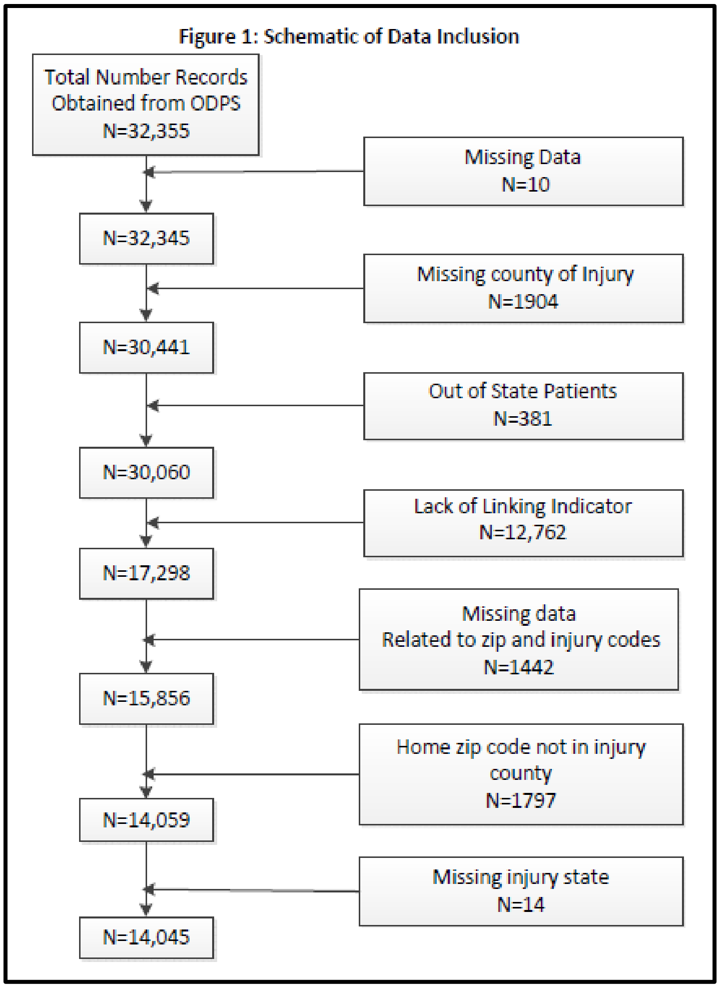
Methodology

Database Characteristics

This was a retrospective study of pediatric trauma patients in the state of Ohio utilizing data from the Ohio Trauma Registry (OTR). Patients were identified from the OTR and were limited to those less than 16 years of age who were admitted to an Ohio hospital with an ICD-9 of 800-959.9, excluding burns and had a > 48 hours length of stay or death from a traumatic injury. Six years of data were obtained between the years of January 2007 through December 2012. Each de-identified patient record included standard OTR data elements such as patient demographics, injury location, and physiologic characteristics. As specific parameters could not be released by the Ohio Department of Public Safety (ODPS) due to patient privacy laws, these parameters were calculated by the ODPS epidemiologist and released in a de-identified format. Appendix A outlines the standard data elements and the calculated data elements used for this research project. The study was approved by the Institutional Review Board (IRB # 2105-1550) of Cincinnati Children's Hospital.

The injury zip code is currently not a variable included in the OTR dataset. A preliminary review of the OTR data, indicated that 90.7% (n=32,355) of the records demonstrated that the pediatric patient home zip code is the same as the county of injury. Two research studies have validated that home location can be utilized as a proxy for injury location.[42, 43] All children whose home zip code were not within the injury county were therefore excluded as we were unable to determine location of injury.

A unique patient identifier does not exist within the OTR dataset to easily allow the same patient to be tracked through the system, from initial injury to the final hospital destination. Probabilistic linkage was performed by the ODPS epidemiologist using the following parameters: date of birth, patient zip code, race, gender, arrival date, arrival time, arrival source, transfer date, transfer time, injury date, and injury hospital name so as to track patients throughout the system. Patients that were unable to be probabilistically linked were excluded, this represented the largest group of patients that had to be excluded. Figure 1 summarizes inclusion criteria for the dataset, which started with 32,355 patient records and ended up with 14,045 patient records which we utilized for the analysis.



Location of trauma centers categorized as PTC, ATC or NTC for each year of the research study (Appendix B) was added to the dataset, and Google maps API was used for geocoding these locations. We added the centroid of the residence zip code to the dataset. The distance between the centroid of residence zip code and the geocoded location of each trauma center was calculated by great-circle formula which takes into account the varying radius of curvature with direction. The driving speed for this distance was derived from the Rural Urban Commuting Area (RUCA) codes. The RUCA code by zip code was added to the dataset. We took the average of two RUCAs; one at the residence zip code and the other one at the ATC/PTC zip code. When the arrival is at NTC, we assumed the RUCA code as 2.5 (suburban area) for the NTC and then took averages as previously noted. Appendix C outlines urbanization details for Ohio according to RUCA codes. The driving speed was derived by the rule: 20.1mile/hour if the average RUCA is less than or equal to 1 (urban area); 47.5 mile/hour if it is in between two to three (suburban); and 56.4 mile/hour if greater than three (urban area). Therefore, all distances from the scene to the initial hospital were converted to time using the RUCA codes. These driving speeds are published standards.[44, 45] The population density by county was acquired from the 2010 US Census data and it was categorized as high density if >1000 people/sq. mile; medium-high 300-999 people/sq. mile; medium-low if 100-299 people/square mile; and low if <100 people/square mile.

Analysis of Research Findings

Aim1: Determination of Pediatric Under-Triage Rates in Ohio

A: Description and Methods

The goal of Aim 1 was to determine the pediatric under-triage rate for the state of Ohio; including primary (EMS to hospital) and secondary (hospital to hospital). In addition, under-triage rates were examined at both the state and regional levels. Each of the 14,045 included patients were assigned to an appropriate pathway within the patient flow algorithms (Appendix D) allowing the appropriateness of triage to be determined. Data was calculated in correlation with status of trauma centers and non-trauma centers for each year. Stable versus unstable patients were assessed differently for primary and secondary triage due to the inability to assess readiness for transfer. Unstable patients were deemed to be appropriate primarily triaged when they were transferred to the closest hospital for definitive care. For those unstable patients who survived, transfer to a PTC at any point was considered appropriate secondary triage. The patient flow algorithm, annotated with number of patients for each decision point is located within Appendix D. Appendix E outlines the eight Ohio regions utilized for this study.

B: Results

Of the patients that met inclusion criteria, the overall pediatric trauma under-triage rate was 52.4%. If the transfer time was increased to four hours, the overall under-triage rate remained high at 35.4%. Regional variation existed in both these parameters and is outlined in Table 1.

Table 1: Pediatric Under-Triage Rates

Category	All Patients	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Region 7	Region 8
Total Under-triage (Primary and Secondary - 2 hours)	52.4% (7352 / 14,045)	93.6% (1481/1583)	49.4% (1387 / 2810)	50.3% (599 / 1192)	39.7% (982 / 2475)	53.3% (1407 / 2638)	41.6% 801 / 1925)	48.4% (341 / 705)	49.4% (354 / 717)
Total Under-triage (Primary and Secondary - 4 hours)	35.4% (4966 / 14,045)	88.8% (1405 / 1583)	38.5% (1082 / 2810)	31.5% (375 / 1192)	20.6% (509 / 2475)	35.8% (944 / 2638)	22.9% (441 / 1925)	14.0% (99 / 705)	15.5% (111 / 717)

The demographics of each region varies with the number of TCs, presence of a PTC, distance between existing trauma centers and the population density. Table 2 outlines the demographics of each region. No PTCs exist in 3 Ohio regions – Region 1, Region 7 and Region 8. Interestingly, Region 1 has a significantly higher under-triage rate ($P<0.001$) than other non-PTC regions (Regions 7 & 8). Region 7 & Region 8 have similar under-triage rates to the regions that do contain PTCs when the two hour transfer time is utilized but lower rates when the transfer time is extended to four hours. Of note, a non-verified pediatric hospital in Region 1 was functioning in the roles of a PTC during the years of this research project. Population density by regions also varied, with Region 7 and 8 being predominantly low density population without any high density county. In contrast, Region 2 and Region 3 were predominately high and medium density counties.

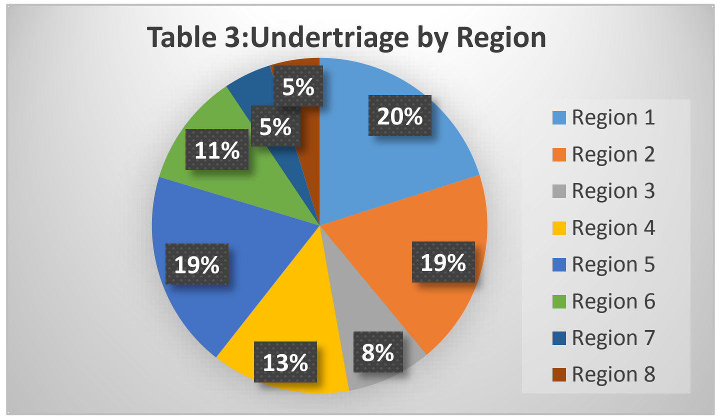
Table 2: Regional Characteristics

				Population Density of Regions by County		
Region	# Ohio Counties within Region	# PTC	# ATC	# High Density Counties	# Medium Density Counties	# Low Density Counties
1	18	0	11	1 (6%)	10 (56%)	7 (39%)
2	5	2	7	2 (40%)	3 (60%)	0
3	8	1	4	1 (13%)	4 (50%)	3 (38%)
4	15	1	4	1 (7%)	9 (60%)	5 (33%)
5	13	1	11	1 (8%)	11 (85%)	1 (8%)
6	8	1	3	1 (13%)	4 (50%)	3 (38%)
7	11	0	0	0	4 (36%)	7 (64%)
8	10	0	4	0	3 (30%)	7 (70%)

High Density = > 1000 people / square mile
Medium High and Medium Lows Density = 100 - 999 people / square mile
Low Density = < 100 people / square mile

Regions 1, Region 3, Region 4, and Region 6 had similar demographics with a blend of all three density populations. Appendix F summaries the counties which are high, medium-high, medium-low and low density.

Across the state for the six years of the study, 7,352 children met criteria for pediatric under-triage. When evaluating the location of under-triaged children, the highest frequency is located in Region 1, Region 2, and Region 5 (Table 3).



Ultimately, 81.3% (n=11,422) of injured children who required a 48 hour hospitalization or who died, received their care at a PTC. Of these patients, 31.0% (n=3536) reached the PTC within 2 hours, 27.4% (n=3126) between two to four hours and 6.5% (n=745) after more than four hours. Table 4 summarizes the final destination of care received with no time factor considered in the analysis.

Table 4: Destination of Care Received

	#	%
Discharged from PTC	11,422	81.3%
Discharged from ATC	2148	15.3%
Discharged from NTC	475	3.4%

With the current dataset, initial instability was difficult to ascertain. Using the presence of CPR by prehospital personnel and a low systolic blood pressure, 2.9% (n=410) were deemed unstable with 70 patients (0.5% overall) categorized within the under-triage population due to lack of subsequent transfer to a PTC from either an ATC or NTC. Analysis shows 302 unstable children (overall 2.2%) were treated at a PTC, 73 patients at an ATC (0.5% overall) and 35 patients at a NTC (0.2 % overall).

Another method of assessing need for definitive trauma care for the injured child is to assess the immediate need for an operation. Overall, 224 patient (1.6% overall) required operative intervention within 2 hours of ED arrival with 148 patients treated at a PTC, 69 patients at a ATC and seven patients (<0.1% overall) at a NTC. Of the 224 patients that required an operation within two hours, 93 patient were within the under-triage population. Of the studied population, 13.6% (n=1909) needed an operative procedure during the child's hospitalization, which occurred 75% of the time at a PTC. Of interest, over 2% of the patients who required an operative procedure, received this intervention at a NTC.

Therefore, the findings of Aim 1 conclude the following:

- the overall pediatric trauma under-triage rate, using a two hour transfer time was 52.4%, adjusting to 35.4% with a four hour transfer time; conversely, only 47.6% of severely injured children reached a pediatric trauma center within two hours, increasing to 64.6% if given four hours;
- 18.7% of the children never made it to a PTC.

Aim 2: Descriptive Analysis of Under-Triage as a Function of Transport Distance

A. Description and Methods

The goal of Aim 2 was to describe variations in pediatric under-triage rates based on transport distance from injury site to a pediatric trauma center. Using the previously developed primary and secondary under-triage rates and distances, a set of concentric circles in 15 miles increments expanding away from each verified PTC was developed. The child's home zip code was used as the basis for the analysis. As all the PTCs in Ohio are within urban locations, expansion outward of these concentric circles moved from urban toward the suburban and rural regions of the state. Under-triage rates were analyzed for each concentric circle. As one urban region had two PTCs in close proximity, data from this area was combined.

B: Results

When the under-triage rate was adjusted for distance (15 mile increments), even for those patients within a close range 0 – 15 miles to a PTC, the average pediatric under-triage rate was 25.1% with a regional range from 12.5% to 34.3%. The average under-triage rate increased to 44.1% when the range increment was increased 15- 30 miles from a PTC. No further increase was seen when the increment was increased to 30-45 miles. Regional variations are shown in Table 5.

TABLE 5:	**% of undertriagte patients within concentric circles around the PTC (2 hour transfer time)**		
PTC	0-15 mile radius	15-30 mile radius	30-45 mile radius
Region 2	34.3% (588 / 1715)	38.9% (516 / 1325)	36.3% (263 / 725)
Region 3	25.7% 127 / 494)	55.0% (428 / 778)	35.2% (357 / 1013)
Region 4	22.6% (230 / 1016)	38.2% (202 / 528)	47.3% 549 / 1160
Region 5	12.5% (70 / 562)	42.9% (906 /2113)	48.4% (944 / 1950)
Region 6	18.1% (162 / 895)	49.7% (332 / 668)	37.7% (147 / 390)
SUMMARY	**25.1% (1177 / 4682)**	**44.1% (2384 / 5412)**	**43.1% (2260 / 5238)**

When the dataset was broken down further into groups based on distance from a trauma center, the data indicated that a trauma center (PTC or ATC) was within 30 minutes distance for 65.5% (n=9,203) of the injured pediatric population. Even with the close proximity of a trauma center, significant percentage of children were first transported to a NTC. This was consistent across Regions 1-6, but with a lower percentage in the more rural southern regions of the state (Region 7 and Region 8), as shown in Table 6.

Table 6: Trauma Center Within 30 minutes

Category	All Patients	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Region 7	Region 8
Primary Under-triage (either ATC or PTC within 30 min, went to NTC first)	31.7% (2913/ 9203)	25.4% (340 / 1337)	36.9% (877/ 2375)	47.4% (321 / 677)	37.2% (450/ 1211)	21.2% (432 / 2043)	36.6% (428/ 1169)	12.5% (2/16)	16.8% (63 / 375)

Overall, 28.6% (n=4022) of the children had access to a PTC within 30 minutes. Unfortunately, proximity of a PTC within 30 minutes did not prevent 55% of injured children from being transported to a non-PTC primarily (representing 16% of the overall population). Table 7 summarizes the regional variation. Region 1, Region 7, and Region 8 had no PTC within 30 minutes.

Table 7: Trauma Center (PTC) Within 30 minutes

Category	All Patients	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Region 7	Region 8
Primary Under-triage (PTC within 30 min but went to ATC or NTC)	54.6% (2194/4022)	NA	60.6% (715 / 1179)	57.1% (286 / 501)	43.7% (353 / 807)	61.4% (538 / 876)	45.8% (302/ 659)	NA	NA

Within this dataset, 53% (n=7497) of children required an inter-hospital transfer to a PTC. Of those patients transferred to a PTC within the stable pathway of the algorithm, 52.8% (28% overall) had a > 2 hour transfer time to a PTC. Breaking this down, 42.9% of injured children were transferred to a PTC between two to four hours with 9.9% greater than four hours for transfer. Table 8 outlines transfer data for the stable children with regional data included. All regions demonstrated consistent transfer times with only slight variation.

Table 8: Transferred Patients

Category	All Patients	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Region 7	Region 8
Secondary Under-triage -(took < 2 hrs to PTC	47.1% (3536 / 7497)	38.7% (55 / 142)	45.6% (594 / 1304)	42.8% (305/713)	48.4% (730 / 1508)	44.6% (659/ 1479)	50.7% (579/ 1142)	50.8% (308 / 606)	50.8% (306 / 603)
Secondary Under-triage - (took 2-4 hrs to PTC)	42.9% (3216/ 7497)	53.5% (76 / 142)	42.2% (551 / 1304)	48.7% (347/713)	44.0% (664 / 1508)	42.1% (622/ 1479)	40.7% (465/ 1142)	40.6% (246 / 606)	40.6% (245/ 603)
Secondary Under-triage - (took > 4 hrs to PTC	9.9% (745 / 7497)	7.8% (11 / 142)	12.2% (159 / 1304)	8.6% (61/713)	7.6% (114 / 1508)	13.4% (198/ 1479)	8.6% (98/ 1142)	8.6% (52/ 606)	8.6% (52 / 603)

* Unstable group not included as it was difficult to assess when stability was achieved for transfer

Therefore, the findings of Aim 2 include:

- a significant percentage of under-triage to a PTC exists even when there is a PTC within 15 miles; and
- almost 53% of injured children took greater than two hours to arrive at a PTC.

Aim 3: Description and Methods

The goal of Aim 3 was to compare injury and patient characteristics between children appropriately triaged to those under-triaged. The frequency of distributions and the overall p-value from chi-square test for the association between each characteristic with the under-triaged status is reported.

A: Patient Characteristics

Table 9 summaries the most common variables within the dataset that were associated with under-triage and appropriate pediatric trauma triage. Factors that favorably impact appropriate triage to a PTC included the following: age less than one year, race of black, Medicaid insurance, injury mechanism of cut, drowning, firearm, motor vehicle, and population density (high). Conversely, age greater than five, race of non-black, commercially insured, mechanism of injury including fall and struck by an object, and resided in a medium to low density region, negatively impacted the likelihood of being triaged appropriately. Overall, children with higher injury status (ISS at discharge) were more appropriately triaged.

The lack of a trauma center (ATC or PTC) within 30 minutes of the injury location resulted in a positive appropriate triage relationship. This is difficult to ascertain from the dataset; however, we can speculate that aeromedical transport may contribute to this result.

Table 9: Patient and Injury Characteristics by Triage

Variables	Appropriate Triage (%)	Under-Triage (%)	P value
	n=6693 (47.7)	n=7352 (52.3)	0.0001
Gender			
Male	4305 (47.7)	4728 (52.3)	0.0001
Female	2385 (47.7)	2611 (52.3)	0.0001
Age			
<1	655 (54.4)	549 (45.6)	0.0038
1-4	1784 (49.9)	1791 (50.1)	0.9068
5-9	1720 (46.0)	2021 (54.0)	0.0001
10 and high	2516 (45.9)	2969 (54.1)	0.0001
Race			

Black	1525 (63.0)	895 (37.0)	0.0001
White	4605 (45.0)	5634 (55.0)	0.0001
Other	554 (40.9)	800 (59.1)	0.0001
Insurance			
Commercial	2497 (40.4)	3691 (59.7)	0.0001
Medicaid	2468 (51.3)	2346 (48.7)	0.0787
Self-Insured	562 (50.3)	555 (49.7)	0.8341
Mechanism			
Cut	278 (65.3)	148 (34.7)	0.0001
Drowning	121 (64.7)	66 (35.3)	0.0001
External	1526 (49.2)	1573 (50.8)	0.3985
Fall	1719 (38.4)	2763 (61.7)	0.0001
Firearm	68 (59.1)	47 (40.9)	0.0502
Motor vehicle	1220 (62.5)	732 (37.5)	0.0001
Pedal cyclist	430 (42.1)	592 (58.0)	0.0001
Struck	442 (38.7)	701 (61.3)	0.0001
GCS (scene)			
Motor score GCS >4	2121 (55.5)	1701 (44.5)	0.0001
Motor score GCS <4	382 (79.3)	100 (20.8)	0.0001
TC			
No TC (ATC / PTC) within 30 min	2814 (58.1)	2028 (41.8)	0.0001
No PTC within 30 minutes	4865 (40.5)	5158 (51.5)	0.0034
Population			
High Density	2977 (56.5)	2297 (43.6)	0.0001
Medium High Density	757 (47.9)	827 (52.2)	0.0001
Medium Low Density	1264 (37.5)	2109 (62.5)	0.0001
Low Density	1695 (44.4)	2119 (55.6)	0.0786
ISS			
<15	4865 (48.7)	5116 (51.3)	0.0001
>=15	785 (68.4)	362 (31.6)	0.0001

- Most common categories are listed

B: Results – Death Analysis

The overall death rate for the six year timeframe was 2.9% (n=403). An additional 20 deaths were located within the records that were unable to be probabilistically linked and were therefore excluded from this analysis. Overall death rate and the regional death rates are outlined in Table 10 along with the median ISS. Region 3 had the highest death rate of 5% of the studied population within the OTR. Region 7 and Region 8 had lower death rates but also had lower median ISS. Of the 403 deaths, 71.2% (n=287) expired at a PTC, 20.6% (n=83) at an ATC and the remaining 8.2% (n=33) at a NTC. The unstable category (n=259) made up 64.3% of the total deaths with scene CPR occurring in 152 of these patients. For those 403 patients that died, 88.6% (n=357) died at the first hospital with 11% (n=46) expiring after a transfer occurred.

Table 10: Death Rate

	# of Pts	%	Median ISS
Overall	403 / 14045	2.9%	25
Region 1	57 / 1583	3.6%	25
Region 2	56 / 2810	2.0%	21
Region 3	60 / 1192	5.0%	25
Region 4	78 / 2475	3.2%	25
Region 5	59 / 2638	2.2%	25
Region 6	79 / 1925	4.1%	25
Region 7	4 / 705	0.6%	17
Region 8	10 / 717	1.4%	16

Table 11: Patient Characteristics of Deaths

	#	%
Age		
<1	90	22.3%
1-4	135	33.5%
5-9	53	13.2%
10-12	41	10.2%
13-15	84	20.8%
Gender		
Male	262	65.0%
Female	139	34.5%
Race Category		
Black	142 / 2420	5.9%
White	213 / 10239	2.1%
Other	41 / 1354	3.0%
Mechanism (top 6)		
External	94	26.3%
MVC	87	24.4%
Drowning	55	15.4%
Non-specified	39	10.9%
Suffocation	29	8.1%
Firearm	20	5.6%

The overall mortality in the appropriately triaged group was 5.3% and 0.7% in the under-triage group. Of the 403 deaths analyzed, children less than four years of age had the highest death occurrences, decreasing in the 5-12 age, then increasing during adolescence. Males had a higher incidence of death at 64.5%, which is consistent with national data. When analyzing the frequency of death by race category, 5.9% of the black injured children died vs. 2.1% of the white injured children. The leading mechanism of injury which resulted in a child's death was cited as external (26.3%). This category is frequently utilized by trauma registrars as a default when the mechanism is unknown. In addition to this group, there were a significant number of non-specified categories (10.9%), which is a secondary category for unknown. Table 11 outlines the patient characteristics of those patients that died.

ISS was unable to be calculated due to missing AIS scores in 9.7% of the deaths (n=39). Of the remaining patients who died that had an ISS score (n=364), 80.5% (n=293) had an ISS > 15, while the remaining 19.5% (n=71) had an ISS < 15. Analysis of this data is provided in Table 12 which shows regional variation.

Table 12: Injury Severity Score (ISS) for Deaths

Region	# deaths	# deaths with ISS <15	%	# deaths with ISS >15	%	# death with missing ISS	%
1	57	11	19.3%	39	68.4%	7	12.3%
2	56	19	33.9%	30	53.6%	7	12.5%
3	60	7	11.7%	49	81.7%	4	6.7%
4	78	17	21.8%	55	70.5%	6	7.7%
5	59	3	5.1%	47	79.7%	9	15.3%
6	79	10	12.7%	65	82.3%	4	5.1%
7	4	1	25.0%	1	25.0%	2	50.0%
8	10	3	30.0%	7	70.0%	0	0.0%

Additional analysis into the population of children with an ISS < 15 and death (n=71; overall 0.5%) was done as this typically is considered a less severely injured child. Within this category, only 4 patients were categorized as under-triaged while 73.2% (n=52) died at a PTC, 15.5% (n=11) died at an ATC and 11.3% (n=8) died at a NTC. Most of these children were younger in age, as greater than 53% were four years of age or under. Even with an ISS < 15, 69% (n=49) were still categorized within the unstable category. When analyzing initial scene GCS for this population, 40.9% (n=29) did not have a GCS noted. However, for the other 57 patients, 96.5% (n=55) had an initial GCS measured of eight or less indicating a high level of severity. As expected, the majority of deaths occurred in the appropriately triaged group with the most severe injury as evidenced by the high ISS and low GCS.

Discussion / Conclusion

Numerous studies have investigated the effect of prehospital time on outcomes,[46-50] closest hospital vs. direct to a trauma center, [32, 51, 52] prehospital triage issues, [35, 36, 40, 50, 53, 54] urban and rural transfer time to definitive care, [38-40, 55] all in the attempt to systematically develop a trauma system that benefits patient outcomes while balancing extrinsic factors. Applying the assumption that transport to a trauma center is more efficacious, the OTR dataset was analyzed for under-triage (both primary and secondary) with a secondary analysis for proximity to a PTC (or ATC when a PTC is unavailable). We then evaluated and described characteristics of those patients appropriately triaged as well as those under-triaged.

The state of Ohio has six pediatric trauma centers and 29% of injured children live within 30 minutes of one these centers with 33% being within 15 miles. Ultimately 81% of injured children reached a pediatric trauma center although over half of these took more than two hours to reach the trauma center. In addition, 46% of children initially arrived at a NTC to be transferred to an ATC or PTC. Only 3% of injured children received all of their care at a NTC. Of the 403 patients that expired, 33 (8.2%) of these occurred at a NTC. Even though the under-triage rate is statistically higher than preferred, patients are eventually reaching the appropriate destination of a PTC. The major issue centers on the timely arrival at the PTC.

Within Ohio, certain factors reduced the under-triage rate, these are related to both geography and patient characteristics. For example, children with severe brain injuries (GCS <8), overall high ISS, those within high density population areas all had lower rates of under-triage. However, even within these groups under-triage rates were well above the 5% suggested by the ACS. Children with a GCS <8, representing some of the most critically injured children, still had an under-triage rate of 21.5%.

With this knowledge, a determination of the underlying factors that prevent appropriate triage must be addressed. The first factor may be the determination of initial transport from the scene. In Ohio, even when a pediatric trauma center was available within 30 minutes of the injury, 55% of children were not taken directly to these centers. Several actions may be independently or more likely cumulatively impacting the decision making at the injury site. A recent focus group research reported that prehospital care personnel utilized past experience along with first impression as more important trauma triage factors than the linear field triage guideline established by the CDC.[35] Doumouras, et, al. identified positive under-triage and concluded that EMS personnel incorporate relative distances into their decision making and that differential distances of even one to two miles were associated with lower urban and rural transport compliance to a trauma center.[32] Other factors may include the initial EMS personnel assessment and perception of immediate need, lack of training regarding benefit of a transporting to a PTC if not closest facility, and/or established transport patterns within a region as distance alone does not explain the variation.

The second factor may be associated with the level of care provide by the primary receiving hospital. Research by Gomez, et al. noted that median ED length of stay (LOS) before transfer was 3.5 hours, but it took one hour longer if the referring hospital was identified as a resource rich center as compared to those with limited resources.[40] In Ohio, 47% of transferred children took greater than two hours, with 10% taking greater than 4 hours to reach a pediatric center. The two most rural regions in Ohio (Region 7 and Region 8), with the most limited resources, actually had the lowest under-triage rates (with a 4 hour window) of 14 and 15 percent respectively. Many studies show that time of stabilization, including initial assessment and diagnostics, are often time consuming, costly and delay transfer to definitive care.[39, 40, 53, 56, 57]

A third factor, frequently cited in trauma under-triage research, is that of geography or the degree of urbanization. The understanding of rural trauma or the impact of geography has been a neglected entity over the years, as a majority of trauma research has been conducted within trauma center and urban regions. There is a general perception that the risk of death is higher in the more rural regions,[58, 59] with some research linking this to increase EMS response time, greater distance to the scene and time on the scene.[60] However, our research analysis for Ohio did not substantiate negative trauma outcomes in the rural region. Overall statistics for the more rural regions were lower but the percentages were similar to the state average and other regional data. Our data also found that regions with higher population density exhibited same, or higher, under-triage as the more rural regions. In addition, as you move further away from the PTC and hence toward less population, the under-triage rate initially increased to 44% and then remained stable beyond 30 miles.

Certain patient characteristics appear to increase or decrease the rates of under-triage. In the state of Ohio children with the most severe injuries, categorized by intubation in the field, ISS over 15 or GCS less than 8 have the lowest under-triage rates (29%, 32% and 21% respectively). Given the critical nature of these children, it is important that they reach a pediatric trauma center in a timely fashion. Arguably, these rates are still too high and leave room for improvement. In addition, our research noted that minority children had higher under-triage rates which may be attributed to residing in high density regions. Conversely, children that are white, have commercial insurance or live in medium-low density communities have the highest rates of being under-triaged in the state (55%, 60% and 63% respectively). Although there may be multiple explanations for these differences, understanding these variations are critical to improving our state trauma system.

Regardless of contributing factors, the presence of high trauma under-triage for the pediatric population in Ohio remains a significant issue that needs to be addressed. This study did not demonstrate a direct correlation with outcome (mortality) based on triage status but it likely does not tell the whole story. Given that the most significantly injured of this cohort had the lowest under-triage rate and ultimately made it to the pediatric trauma center before death likely skews the data. The dataset does not allow us to determine potential for preventing death had patients bypassed non-trauma centers or made it to the pediatric trauma center even more quickly. Importantly, the dataset also does not provide other functional outcomes that could be impacted by delays in treatment or among those that never arrived at a pediatric trauma center. Long term outcomes from traumatic brain injury are certainly related to avoidance of hypoxia and hypotension and prompt treatment of elevated intracranial pressure.[61-65] If these factors are not properly managed prior to pediatric trauma center arrival, the child may still survive but have lifelong deficits that may have been preventable. Other outcomes such as radiation exposure from excess imaging or psychologic outcomes and child/family stress were also not accounted for and have both been demonstrated to be improved when care is provided at a pediatric trauma center.[66-73]

Challenges / Limitations

This current research study has certain limitations that should be considered when interpreting the findings. A significant amount of records were unable to be probabilistically linked within the OTR dataset; therefore, there is the potential of bias in the results. A review of these records to compare to the data sample was not performed. Even with the state law that all hospitals must submit injury data, no work has been done to validate total inclusiveness of the OTR dataset. With lower injury numbers in southern Ohio, there is concern that patients from that region may be missing from the dataset. As in most states, the state law does not mandate that the patient received care in their home state. Consequently, patients injured in Ohio may be receiving care in bordering states and would not be included in the state trauma registry.

Logic checks are run on the OTR dataset but data validation of content has not been performed at the state level. For example, the use of "external" for mechanism of injury should be used rarely. In this study, that data point was used over 26% of the time for describing how the child was injured. Missing OTR variables also led to difficulty in research of under-triage. The EMS field triage criteria was also excluded from this data analysis due to quality issues and a large amount of missing data.

The OTR dataset did not differentiate between ground and air transport. Without this information, it made it difficult to calculate time and distance to a PTC, which was a basic concept of this research project. There is an assumption that when the distance to a trauma center is outside the 30 minutes range and there is direct transport to a trauma center, that air transport was probably involved. However, within this dataset, it is impossible to validate that assumption. At this time, it is not mandatory for air transport to submit data to the OTR.

In this research study, the home zip code was utilized as the injury site. This served as a proxy since location of injury was not a data element collected in the OTR. This may have led to some error in distance calculation as the destination may not be exact but an approximation. However, by excluding all those where the injury county was not equal to the home zip code, this minimized this factor. Lastly, specific factors, such as weather, time of day for transport, road closures and traffic patterns were not factored into this research study and may have impacted the time and distance calculations.

Recommendations

There are certainly opportunities to improve the state triage of pediatric trauma patients and many avenues for future trauma triage research exist, both at the state and regional level. Future work is needed to understand the barriers to further improving the triage of children, including those with severe traumatic brain injuries in the state. Other outcomes beyond mortality need to be assessed to determine benefits of appropriate triage and the impact of delays, specifically related to TBI outcomes. It will also be important to understand why children in the medium to low density regions have the highest under-triage rates. Prior work by our group and others has demonstrated that excess pre-transfer imaging at non-trauma centers and concerns by EMS related to the time to transfer to the pediatric trauma center can negatively impact triage;[39, 74] developing pilot approaches to combat these issues will be important next steps.

Along with these potential improvements in pediatric trauma care, this under-triage methodology could be replicated for the adult population to understand if similar challenges are present. Opportunities may exist in the future to improve both adult and pediatric trauma care within the state. As some of the key limitations of this study are related to the available data, it will be essential to continue to enhance the quality and content of the OTR dataset. Although this state registry surpasses what many states have available, the challenges with patient linkage throughout the system as well as validity checks of certain data points and location of injury limit the power of the studies that can be conducted.

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Project Expenditures

	Project Expenditures	**Grant Funds Available**
Personnel Costs (Lynn Haas & Suzanne Moody)	$26,287.60	$24,927.00
Data management and biostatistics	$38,235.83	$38,019.00
Printing Services	$0	$350.00
Total Costs	**$64,523.43**	**$63,296.00**

Cincinnati Children's Hospital expense reports are only available through 5/31/16, final expenses were calculated using May expenses.