



Pediatric Traumatic Brain Injury: Impact of Under-Triage

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Table of Contents

Information / Qualifications: Principal and Co-Investigators.....	pg. 3
Executive Summary.....	pg. 4
Introduction.....	pg. 6
Review of Literature.....	pg. 7
Methodology / Database Characteristics.....	pg. 10
Analysis of Research Findings.....	pg. 11
Discussion / Conclusion.....	pg. 17
Limitations.....	pg. 20
Recommendations.....	pg. 21
References.....	pg. 22
Project Expenditures.....	pg. 27
Appendices.....	pg. 28

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 Department.

The principal investigator, **Lynn Haas, RN, MSN** 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 and the 2015 State-wide Under-Triage Grant.

Richard A. Falcone, Jr., MD, MPH, is a Professor of Surgery and the Trauma Medical Director at Cincinnati Children's. Dr. Falcone 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.

Paul Kim, MD, is currently a research fellow at Cincinnati Children's Hospital and a resident in the department of general surgery at University of Cincinnati.

Executive Summary

TBI is the leading cause of morbidity and mortality for children and adolescents in the United States. To optimize a child's outcome from moderate / severe TBI, it is essential that the child is appropriately triaged in a timely manner to a pediatric trauma center. A study analyzed statewide pediatric under-triage data from Ohio and found an overall pediatric under-triage rate of 54%. The state of Ohio had the unique opportunity to evaluate the outcomes of severe pediatric TBI across the state and relative to under-triage rates at the state and regional level.

This TBI / under-triage research study was divided into three specific aims: 1) Describe the epidemiology of pediatric moderate to severe TBI, including TBI mortality in the state of Ohio and across state regions. 2) Compare the pediatric severe TBI mortality rates for patients who were triaged appropriately, primarily under-triaged and secondarily under-triaged in the state of Ohio. 3) Describe associations between regional prehospital demographics (patient and EMS) and pediatric severe TBI mortality.

This was a retrospective study of pediatric trauma patients who have sustained a moderate / severe TBI in the state of Ohio. Patients were identified utilizing data from the Ohio Trauma Registry (OTR) and were limited to those less than 16 years of age who were admitted to an Ohio hospital with an ICD-9 code in the TBI subset and had a greater than 48 hours length of stay or who died from a traumatic brain injury. Six years of data were obtained through the January 2007 through December 2012. The 2010 Ohio Census data was utilized in order to report and compare TBI data across the state.

For Aim 1, 18% (n=2453) of the OTR population sustained a moderate /severe TBI. The overall rate of moderate / severe pediatric TBI for Ohio is 15.9 per 100,000 with range of 8.2 – 25.6 / 100,000 population. Of moderate/ severe TBI patients, 53% (n=1313) sustained a severe injury. This correlates to an overall severe TBI rate of 8.5 / 100,000 population or an average of 218 children per year.

Overall, 39% (156 /403) of deaths met the definition for the moderate / severe TBI category with the majority of the deaths, (96%, n=150) within the severe group. The mortality rate for moderate / severe TBI is 6.1 per 100,000 / population. A majority of the deaths were multisystem (n=112; 72%) as

compared to an isolated TBI (n=44; 28%). Of the 156 deaths, 21.8% (n=34) were categorized as under-triaged. Mortality rate 5.8% for those under-triaged was compared to 6.5% for those patients that were appropriately triaged, with no statistical difference. However, when region 1 data was excluded, the mortality rate among those under-triaged increased to 10.7% as compared to patients appropriately triage of 6.3%.

According to the Ohio Department of Public Safety (ODPS) database of EMS providers, there are 1029 EMS departments across Ohio that transport patients from the scene to a hospital. Regions were categorized as the following: 1) Mostly paid = Regions 2 and 4; 2) Mostly Mixed = Regions 3 and 6; 3) Mostly Volunteer = Regions 1, 5, 7, and 8. There appears to be no correlation between EMS pay status and mortality rates or triage rates. A regression analysis was performed on the group of severe TBI patients, excluding region 1, including key clinical variables which revealed that hypothermia, Motor GCS, ISS and age all impact mortality but under-triage does not reach significant. It should be noted however that we were unable to examine the impact on functional or long term outcome in this cohort.

Introduction

The burden and cost of pediatric traumatic brain injury (TBI) is significant; not only to society (1-3) but also to the child and family.(4, 5) TBI is the leading cause of morbidity and mortality for children and adolescents in the United States, and is responsible for over 690,000 ED visits, 60,000 hospitalizations and 6,000 deaths annually among children and adolescents 1-19 years.(6) For injury related deaths in both the adult and pediatric population, TBI is a contributing factor 30% of the time.(6) Although focal brain lesions sustained by the child generally show favorable recovery, the diffuse brain injury appears threatening to the child's developing brain.(7-10)

To optimize a child's outcome from moderate to severe TBI, it is essential that the child is appropriately triaged in a timely manner to a pediatric trauma center, thus concentrating high-need patients to the hospital most capable of caring for them. Under-triage of the injured child is the failure to transport a patient to a pediatric trauma center (PTC) when they require that level of care. Under-triage consists of two components: 1) field triage (scene to hospital), and 2) secondary triage (inter-hospital transfer).

A study conducted by our trauma research team analyzed statewide pediatric under-triage data from Ohio and found an overall pediatric under-triage rate of 54%.(11) Recent data from the Centers for Disease Control and Prevention (CDC) indicate a large variation between states in pediatric TBI-related mortality data, with the Midwest region higher than other regions. The state of Ohio has the unique opportunity to evaluate the outcomes of severe pediatric TBI across the state and relative to under-triage rates at the state and regional level.

This TBI / under-triage research study was divided into three specific aims: 1) Describe the epidemiology of pediatric moderate to severe TBI, including TBI mortality in the state of Ohio and across state regions. 2) Compare the pediatric severe TBI mortality rates for patients who were triaged appropriately, primarily under-triaged and secondarily under-triaged in the state of Ohio. 3) Describe associations between regional prehospital demographics (patient and EMS) and pediatric severe TBI mortality.

Review of Literature

To optimize a child's outcome from moderate/severe TBI, it is essential that the child is appropriately triaged in a timely manner to a pediatric trauma center (PTC). This concept is supported by outcomes from the National Study on the Costs and Outcomes of Trauma (NSCOT), which concludes that the risk of death is 25% lower when appropriately triaged to a level I trauma center than at a non-trauma center.(3) Data has clearly shown that pediatric trauma centers improve outcomes among seriously injured children (12-16) and that the destination of where a pediatric trauma patient receives care is of prime importance.(17-19) Ohio, as compared to other states, is unique as there is a high number of PTCs within the state. At the time of this study, there were five verified PTCs within the 7th most populous state, which includes a mixture of both rural and urban characteristics.

Although this study focuses on pediatric mortality from TBI, either at the scene or within the hospital, research demonstrates that the long term consequences for survivors is significant. The downstream effects of TBI are frequently referred to as the silent epidemic.(20, 21) Cognitive and behavioral sequela from moderate to severe TBI may be profound for many years.(22-24) This frequently leads to long-term reduction in the quality of life, participation in activities, and ability to communicate and care for themselves.(25, 26) In addition to not recovering life skills that a child previously demonstrated, a child may fail to acquire new skills at the developmentally appropriate rate(7, 27, 28), leading to long term sequela. Adverse consequences of pediatric TBI also extends beyond the child to the extended family. A growing number of researchers have documented increased injury-related stress and burden, parental anxiety and depression, and family dysfunction following a child's injury.(29-34)

A child's outcome after TBI depends on factors such as age, pre-injury behavior, injury severity and intent of injury (25, 35-37) but also on timely and high quality care in the early phases after injury.(38-42) Secondary brain injury, which evolves over ensuing minutes, hours and days after the injury,(43) is a major cause of brain damage or death after moderate or severe TBI. Post-injury hypoxia and hypotension are major factors in inducing secondary brain injury and are directly associated with increased morbidity and mortality in children.(44-50) A study by Zebrack, et. al. noted that

approximately one third of children with severe TBI were not properly treated for hypotension or hypoxia in the early prehospital phases of care.(38) Therefore, timely and appropriate prehospital interventions by EMS personnel, as well as initial hospital interventions, can reduce the morbidity or mortality of the head injured child.(51-60)

Appropriate triage is an integral component of prehospital management for the pediatric TBI patient. The American College of Surgeons Committee on Trauma (ACS-COT) defines appropriate triage as transporting patients to the most appropriate level of care in the defined system. The 2011 Guidelines for Field Triage of Injured Patients recommend the direct transport of patients with a field Glasgow Coma Score (GCS) score of 13 or less or with penetrating injuries to the head to the highest level trauma center within the defined trauma system.(61) In addition, the Brain Trauma Foundation Guidelines for Prehospital Management of Traumatic Brain Injury recommend direct transport of TBI patients to a facility with immediately available CT scanning, prompt neurosurgical care, and the ability to monitor intracranial pressure (ICP), and treatment of intracranial hypertension.(62) These guidelines support the timely transport of the child with a moderate to severe TBI to a trauma center, or a pediatric trauma center when available.

Debate continues on the benefits of transporting patients to the closest hospital versus by-passing and transporting directly to a trauma center. The answer to this question is not clear with varied study designs leading to different answers.(3, 14, 18, 63-67) Issues such as geography, long transport distances, adverse weather constraints, limited transportation resources and discomfort with treating children exist in varied proportion. However, conclusive information does exist showing that a significant proportion of adults and children which are initially triaged to a non-trauma center, are never transferred to a trauma center, regardless of the severity of the injury.(68-74) This fact makes appropriate initial triage of critical importance, especially for the pediatric TBI population.

The second category of under-triage centers on delayed inter-hospital transport. A regional study by our trauma research team (EMS Priority Grant 2007–2008: An Evaluation 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.[69] In fact, the average transport time of these patients was 420 minutes. [69] 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. This research is consistent with other secondary under-triage research that transfer times are frequently longer than guidelines suggest.(68, 75, 76) Studies in the US and Canada indicate that between 11% - 18% of patients die in a non-trauma hospital awaiting transfer to trauma centers.(77)

A study conducted by our trauma research team (EMS Priority Grant 2015-2016: Understanding Pediatric State-wide Trauma Under-Triage) analyzed statewide pediatric under-triage data for 14,045 pediatric patients between the years of 2007 through 2012. Utilizing a combined definition of primary under-triage (scene to hospital) with driving time of 30 minutes and secondary under-triage (inter-hospital transport) with transfer time within 2 hours, preliminary data indicated an overall pediatric under-triage rate in Ohio of 54% (N=7,581). Sub-analysis of this data indicated that 3.3% remained at a non-trauma hospital for their pediatric trauma care while 43% remained at an adult trauma center, despite five verified pediatric trauma centers in Ohio.

Another pertinent parameter to measure is that of pediatric TBI-related mortality. Recent data from the Centers for Disease Control and Prevention (CDC) indicate a large variation between states in pediatric (< 18 years) TBI-related mortality data. Mills, et. al. concurred with the CDC data and noted a large variation in TBI-related mortality between regions in the country. Pediatric TBI mortality data for the Midwest region (Ohio included) was 3.9 / 100,000 population, as compared to the Northeast region, which was 2.0 / 100,000.(78)

The effect of under-triage and delayed transport times on outcome from TBI is currently unknown. With previous study knowledge of pediatric under-triage rates in Ohio, this study allowed us to identify and study a subset population of moderate to severe TBI patients, assessing for a relationship between pediatric TBI and under-triage. This work provided information on that specific population of

injured children that is at high risk of sustaining long term and / or permanent sequela.

Methodology

Database Characteristics

This was a retrospective study of pediatric trauma patients who have sustained a moderate to severe TBI in the state of Ohio. Patients were identified utilizing data from the Ohio Trauma Registry (OTR) and were limited to those less than 16 years of age who were admitted to an Ohio hospital with an ICD-9 code in the subset of 800, 801, 803, 804, 850, 851, 852, 853, 854, or 959.01 and had a greater than 48 hours length of stay or who died from a traumatic brain injury. This OTR dataset, which has been analyzed during our previous research, includes patients from the years of January 2007 through December 2012 and served as the population for this study. Each de-identified patient record included standard OTR data elements such as patient demographics, injury location, and physiologic characteristics. Details of the database and specific limitations were discussed within the previous report. See *Understanding State-wide Pediatric Trauma Under-triage*, Ohio Trauma EMS Research Grant 2015-2016. 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. The study was approved by the Institutional Review Board (IRB # 2016-2678) of Cincinnati Children's Hospital.

2010 Ohio Census data was utilized in order to report and compare TBI data across the state. TBI statistics, both incidence and mortality are reported as a rate per 100,000 children. Pre-determined Ohio EMS / Homeland Security Regions were utilized for regional comparison. See Appendix A for composition of regions.

Analysis of Research Findings

Aim 1: Describe the epidemiology of pediatric moderate to severe TBI, including TBI mortality in the state of Ohio and across state regions.

In this study, severe head injury was defined as patients who sustained at least one ICD-9 code within the head injury subset and had an Abbreviated Injury Score (AIS) within the head region of 3 or greater for that specific ICD-9 diagnosis code. Moderate head injury was defined as those patients who sustained at least one ICD-9 code within the head injury subset and had an AIS score of 2. When multiple ICD-9 head injury codes existed on a single patient, the highest AIS head injury score was used to categorize the patient between the severe and moderate head injury category.

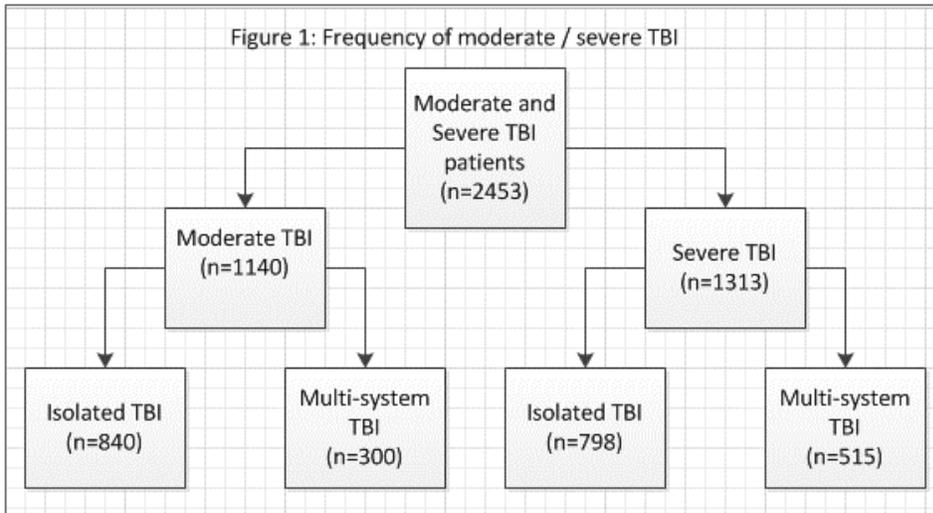
Of the 14,045 patients within the OTR over a 6 year time frame, 18% (n=2453) sustained a moderate / severe TBI. The overall rate of moderate / severe pediatric TBI for Ohio is 15.9 per 100,000 population of children less than 16 years (Table 1), based on 2010 census data.

Table 1: Rate of Ohio Pediatric Moderate/ Severe TBI Hospitalization between 2007-2012 per 100,000 pediatric population

Category Description	All Patients	Regions							
		1	2	3	4	5	6	7	8
Rate of moderate and severe TBI	15.9	25.6	16.4	16.2	15.3	14.8	12.0	8.2	16.8
Rate of moderate TBI	7.4	16.3	7.8	6.0	5.6	7.1	4.4	3.4	9.4
Rate of severe TBI	8.5	9.3	8.6	10.2	9.7	7.7	7.6	4.8	7.4

A regional variation exists with a lowest rate in region 7 (8.2 / 100,000 population) to highest overall moderate / severe TBI rate in region 1 (25.6 / 100,000 population). Of the 2453 patients who sustained a moderate / severe TBI, 53% (n=1313) sustained a severe injury. This correlates to an overall severe TBI rate of 8.5 / 100,000 population or an average of 218 children severely injured each year in the state of Ohio.

More children sustained an isolated head injury versus a head injury with other injuries (67% vs, 33%). A patient is considered to have an isolated TBI when all other injuries have an AIS of 1 or less. A multisystem TBI is when the patient that meets the head injury inclusion criteria, but there is a



concomitant injury with an AIS of 2 or greater in AIS region in addition to the head region. Figure 1 details the breakdown of these groups.

The moderate TBI rate is 7.4 / 100,000 population with a range from a low of 3.4 in region 7 to a high of 16.3 in region 1. See Table 2 for breakdown of moderate injuries. Region 1 shows higher rates of moderate TBI, across both the isolated and multisystem injuries.

Table 2: Rate of Moderate TBI Hospitalizations, isolated vs. multi-system, from 2007 - 2012, per 100,000 pediatric population

Category Description	All Patients	Regions							
		1	2	3	4	5	6	7	8
Rate of moderate TBI	7.4	16.3	7.8	6.0	5.6	7.1	4.4	3.4	9.4
Rate of moderate TBI (isolated)	5.5	11.7	6.3	4.4	4.1	5.2	2.9	2.9	5.1
Rate of moderate TBI with multi-system injuries	1.9	4.6	1.5	1.6	1.5	1.9	1.5	0.5	3.3

The rate for severe TBI at 8.5 / 100,000 population is slightly higher than the moderate TBI category at 7.4 / 100,000 pediatric population. Minimal variation is noted between the regions and the overall state rate. See Table 3.

Table 3: Rate of Severe TBI Hospitalizations, isolated vs. multi-system, from 2007 - 2012, per 100,000 pediatric population

Category Description	All Patients	Regions							
		1	2	3	4	5	6	7	8
Rate of severe TBI	8.5	9.3	8.6	10.2	9.7	7.7	7.6	4.8	7.4
Rate of severe TBI (isolated)	5.3	5.5	5.7	5.9	5.2	5.4	4.0	2.8	6.5
Rate of severe TBI with multi-system injuries	3.4	3.8	2.9	4.3	4.5	2.3	3.6	2.0	0.9

Overall, 39% (156 /403) of deaths met the definition for the moderate / severe TBI category with the majority of the deaths, (96%, n=150) within the severe group. See Table 4. The mortality rate for moderate / severe TBI is 6.1 per 100,000 pediatric population with a regional low rate of 0.0 / 100,000 in region 7 to a high of 8.9 / 100,000 in region 3. The overall number of TBI deaths were fairly consistent between regions 1 through 6 (range of 20 to 35) but were low in region 7 (n=0) and region 8 (n=4). The overall number of pediatric deaths during this 6 year timeframe was 403. Therefore, the percentage of deaths with a moderate / severe TBI diagnosis code was calculated for the state and each region.

Table 4: Pediatric TBI Deaths in Ohio between 2007 - 2012

Category Description	All Patients	Regions							
		1	2	3	4	5	6	7	8
# of deaths within TBI moderate / severe category	156	25	20	22	35	21	29	0	4
% of TBI vs overall deaths	39.7% (156 / 403)	43.9% (25 / 57)	35.7% (20 / 56)	36.7% (22 / 66)	44.9% (35 / 78)	35.6% (21/59)	36.7% (29 / 79)	0% (0 / 4)	40% (4/10)
# Deaths within moderate TBI category	6	2	0	1	2	0	1	0	0
# Deaths within severe TBI category	150	23	20	21	33	21	28	0	4
Rate per 100,000 pediatric population	6.1	8.2	4.6	8.9	7.1	4.3	7.1	0.0	4.6

Except for region 7 that had no deaths, this percentage ranged regionally between 36% - 45%. A majority of the deaths were multisystem (n=112; 72%) as compared to an isolated TBI (n=44; 28%). No multisystem deaths were noted both in regions 7 and 8; however, region 8 did have 4 isolated severe head injury deaths.

Aim 2: Compare the pediatric severe TBI mortality rates for patients who were triaged appropriately, primarily under-triaged and secondarily under-triaged in the state of Ohio and for the regions.

Utilizing previously characterized triage determinations, a moderate / severe TBI rate of 22.8 / 1000,000 was determined for those patients that were under-triaged. See Table 5.

Table 5: Undertriage Related to Moderate / Severe TBI Patients Hospitalized in Ohio between 2007 - 2012

Category	All Patients	Regions								All pts, exclude region 1
		1	2	3	4	5	6	7	8	
# Moderate / Severe TBI pts	2453	471	424	240	455	434	291	50	88	1982
# Undertriage	586	436	22	25	11	77	13	0	2	150
% Undertriage	23.9%	92.6%	5.2%	10.4%	2.4%	17.7%	4.5%	0.0%	2.3%	7.6%
Rate Undertriage / 100,000	22.8	142.2	5.1	10.1	2.2	15.8	3.2	0.0	2.3	6.6
# Moderate TBI patients	1140	300	203	89	166	207	105	21	49	840
# Undertriage	360	291	13	9	2	41	3	0	1	69
% Undertriage	31.6%	97.0%	6.4%	10.1%	1.2%	19.8%	2.9%	0.0%	2.0%	8.2%
Rate Undertriage / 100,000	14.0	94.9	3.0	3.6	0.4	8.4	0.7	0.0	1.1	3.1
# Severe TBI pts	1313	171	221	151	289	227	186	29	39	1142
# Undertriage	226	145	9	16	9	36	10	0	1	81
% Undertriage	17.2%	47.3%	4.1%	10.6%	3.1%	15.9%	5.4%	0.0%	2.6%	7.1
Rate Undertriage / 100,000	8.8	47.3	2.1	6.5	1.8	7.4	2.5	0.0	1.2	3.5

At the time of this study, region 1 did not have an ACS verified pediatric trauma center; however many children were cared for at a children’s hospital in that region. When re-calculating the rate to exclude region 1 data, the overall moderate / severe under-triage TBI rate decreased to 6.6 / 100,000 pediatric population. Data from region 5 was considerable higher in the area of under-triaged TBI patients, both for the moderate and severe populations. On further sub-analysis of region 5 data, it was noted that these higher percentages were only present for the isolated TBI patients but not for the multi-system TBI patients.

Over the six year time frame, there were 156 deaths within the moderate / severe TBI category and 21.8% (n=34) were categorized as under-triaged. Table 6 provides data on whether mortality rate is higher if inappropriately triaged. Overall, among moderate / severe TBI patients, there was a mortality

Table 6: Undertriage Related to Moderate / Severe TBI Deaths between 2007 -2012

Category	All Patients	Regions								All pts, exclude region 1
		1	2	3	4	5	6	7	8	
All TBI Deaths	156	25	20	22	35	21	29	0	4	131
# Undertriage	34	18	1	4	3	4	3	0	1	16
% of undertriaged pts that died	5.8%	4.1%	4.5%	16%	27%	5.2%	23.1%	0%	50%	10.7%
	34 / 586	18 / 436	1 / 22	4 / 25	3 / 11	4 / 77	3 / 13	0 / 0	1 / 2	16 / 150
% of appropriately triaged pts that died	6.5%	20%	4.7%	8.8%	7.2%	4.8%	9.4%	0%	3.5%	6.3%
	122 / 1867	7 / 35	19 / 402	18 / 215	32 / 444	17 / 357	26 / 278	0 / 50	3 / 86	115 / 1832
# Severe TBI deaths	150	23	20	21	33	21	28	0	4	127
# Undertriage	32	16	1	4	3	4	3	0	1	16
% of severe TBI undertriaged pts that died	14.2%	11.0%	11.1%	25%	33.3%	11.1%	30%	0%	100%	19.8%
	32 / 226	16 / 145	1 / 9	4 / 16	3 / 9	4 / 36	3 / 10	0 / 0	1 / 1	16 / 81
% of severe TBI appropriately triaged pts that died	10.9%	26.9%	9.0%	12.6%	10.7%	8.9%	14.2%	0%	7.9%	10.5%
	118 / 1087	7 / 26	19 / 212	17 / 135	30 / 280	17 / 191	25 / 176	0 / 29	3 / 38	111 / 1061

rate of 5.8% for those under-triaged as compared to 6.5% for those patients that were appropriately triaged. This demonstrated no statistical significance. However, when region 1 data was excluded, the mortality rate among those under-triaged increased to 10.7% as compared to patients appropriately triaged of 6.3% ($p= 0.0375$). The same data analysis was performed on the severely injured TBI population. Among the most severe TBI patients, the overall mortality rate among under-triaged was 14.2% as compared to those appropriately triaged at 10.9%. This was not statistically significant. Once again, if region 1 is excluded from analysis, the percentage of under-triaged with severe TBI that died increases to 19.8% with the appropriate triage remaining constant at 10.5% ($p=0.0104$).

Aim 3: Describe associations between regional prehospital demographics (patient and EMS) and pediatric severe TBI mortality.

According to the Ohio Department of Public Safety (ODPS) database of EMS providers, there are 1029 EMS departments across Ohio that transport patients from the scene to a hospital. Overall, 35% of the EMS departments are paid, 28% of the departments are a combination of paid and volunteer, while 37% are completely volunteer departments. See Table 7. Regions were categorized as the following: 1)

		Regions							
	Total	1	2	3	4	5	6	7	8
Total # EMS Depts	1029	131	128	97	165	214	120	72	102
% Paid EMS Dept	35%	18%	66%	39%	42%	30%	38%	26%	10%
% Mixed Paid / Volunteer EMS Dept	28%	37%	15%	43%	24%	30%	39%	14%	18%
% Volunteer EMS Dept	37%	45%	19%	18%	34%	40%	23%	60%	72%

Mostly paid = Regions 2 and 4; 2) Mostly Mixed = Regions 3 and 6; 3) Mostly Volunteer = Regions 1, 5, 7, and 8. There appears to be no correlation between EMS paid status and mortality rates or triage rates. See Table 8 for comparisons.

Table 8: Comparison of EMS Pay Status to Overall-Undertriage Rates and Mortality Rates

Category Description	All Patients	Regions							
		1	2	3	4	5	6	7	8
Highest Pay Status in region	Volunteer	Volunteer	Paid	Mixed	Paid	Volunteer	Mixed	Volunteer	Volunteer
Mortality rate per 100,000 pediatric population over 6 years	6.1	8.2	4.6	8.9	7.1	4.3	7.1	0.0	4.6
Rate Undertriage / 100,000 pediatric population over 6 years	1.33	5.87	0.93	1.62	0.6	0.82	0.74	0	1.15

TBI patients that survived versus TBI patients that expired only differed in area characteristics related to age. See Table 9 for details. A regression analysis was performed on the group of severe TBI

Category	Parameter	TBI pts that survived	#TBI mortality	P value
Gender	Male	1490	101	0.1839
	Female	802	55	
Age	<1	436	27	0.0297
	1-4	567	58	
	5-9	430	21	
	10 and 13	317	13	
	>13	536	37	
Race	Black	500	48	0.1812
	White	1579	94	
	Other	210	14	
Insurance	commercial	900	44	0.5287
	medicaid / medicare	886	57	
	self	161	25	
	ND	350	30	
Mechanism	Penetrating	21	6	0.2949
	Blunt	2274	147	
	Other	2	3	
GCS (scene)	13-15	455	2	0.2408
	9-12'	85	0	
	8 and under	160	103	
	Motor score GCS <4	86	93	
ISS	<15	1715	19	0.4148
	>=15	576	137	

patients, excluding region 1, including key clinical variables which revealed that hypothermia, Motor GCS, ISS and age all impact mortality but under-triage does not reach significant. It should be noted however that we were unable to examine the impact on functional or long term outcome in this cohort.

Discussion:

National statistics cite that for all injury deaths, adult and pediatric, in the United States, one in three deaths is TBI related.(6) According to Ohio data, 39% (156 of 403 deaths) were TBI related which is slightly higher than the national statistic. Most recent Center for Disease Control (CDC) statistics cite that the average number of TBI deaths in the US for children aged 0-14 years is 2,174 annually.(6) According to the OTR data between 2007 through 2012, the incidence of pediatric TBI mortality for the state of Ohio is 6.1 / 100,000 pediatric population. Annualizing this data, the statistic converts to 1.0 child / 100, 000 or 26 children per year suffered a TBI related death.

In attempting to develop a comparison between Ohio and national TBI statistics, it quickly becomes apparent that there is large variation in TBI-related mortality by state and that TBI injuries and deaths are not uniformly distributed nationally.(78) The study by Mills, et al, demonstrated results similar to the CDC. Regional variation was noted with estimates that children under the age of 18 in the Midwest region have a TBI-related mortality rate of 3.9 / 100,000.(78) At first glance, this comparison to Ohio (3.9 vs. 1.0) looks drastically higher, until the ages of each population are analyzed. The study by Mills included the adolescent 16 and 17 ages, which national data show at least a three-fold increase in TBI mortality between 15-19 years. Similarly, a retrospective cohort study of pediatric patients from the Healthcare Cost and Utilization Project studied hospitalized TBI patient \leq 19 years of age. This study concluded that the relative risk of inpatient mortality from TBI varied by as much as 2-fold between states (crude % range from 2.2% - 6.7%).(79) Once again, the age range of \leq 19 was different than the Ohio definition. However, both these studies demonstrate that significant regional variation for TBI mortality exists across each state.

Research continues in better understanding the complex reasons behind the variation in pediatric TBI mortality. While some variation is attributable to injury mechanisms and injury severity among children, other factors such as early triage, geography, timely intervention both in the prehospital and hospital phases, transport method and transfer times may impact mortality. Nationally, pediatric TBI mortality has decreased over the three decades, mainly in the area of motor vehicle crashes.(80) This may

be related to a combination of factors such as increased seat belt usage, improved car design, child safety seats, and changes to public policy and safety laws. The impact of other factors, such as improved triage, aeromedical transport, early interventions and the impact of a mature trauma system continue to be studied.

A vast majority of the TBI deaths in this study were within the severe category and except for areas in southeastern Ohio, there was minimal regional variation. Geography may have impacted the OTR dataset, as southeastern Ohio (region 7 and region 8) are within the Appalachian area, have no Level I or II adult or pediatric hospitals, and have a higher percentage of county population in poverty (10 of 25 counties > 20% population in poverty). Each of these regions had less patients / 100,000 population treated for pediatric TBI at an Ohio hospital as compared to other Ohio regions. Speculation was that these patients may have been transferred out-of-state for their care or submission of patient data may have been lacking. At this time, no cross check and validation studies of OTR data has been completed to confirm that all patient information from the region is being accurately submitted.

The incidence of moderate to severe TBI in the state of Ohio is 15.9 per 100,000 pediatric patients. This equates to 2453 patients over 6 years or an average of 408 patients / year. Once again, a standard comparison value at the national level is difficult to identify. Recent CDC statistics show that the estimated average number of TBI that occurs in the US for children between 0-14 is 35,136 hospitalizations annually.(6) Determination of TBI categories, mild, moderate, and severe, are based on different criteria depending on the research study. Stratification parameters may include any or a combination of the following: loss of consciousness (LOC), post-traumatic amnesia, Glasgow Coma Score (GCS), structural imaging and subsequent coding of injury. The Abbreviated Injury Score (AIS) is another commonly used method of assessing TBI severity level, which relies on anatomic descriptors of the injury sustained and the immediate consequences such as LOC and degree of cerebral hemorrhage. However, variation continues as some research studies utilize a score of 3 or greater for severe while others use 4 or greater.

The standard TBI case definition developed by the CDC is among the most widely used for surveillance in which cases are identified using ICD diagnosis codes. The same TBI codes were used for this study except for 950 (injury to the optic pathways). This definition does have its limitation. The code of 959.01 “head injury, unspecified” was included in the CDC definition and in this research study. This code is general and does not provide adequate specific AIS. Therefore, it is unknown if these patients would have met criteria to be included in the sub-population of moderate to severe TBI.

The major question in this research study was whether a relationship between under-triage rates from the previous study to TBI mortality could be identified. Overall, using all 8 regions, 22.8% of the moderate to severe TBI patients were under-triaged. Comparison between the percentages of under-triaged that died versus the appropriately triaged patients that died, showed no difference. As previously mentioned, the pediatric trauma center in region 1 was not ACS verified but was performing in the capacity of a pediatric trauma center and in fact two centers in region 1 have since been verified as Level II pediatric trauma centers. Thus, the over-triage and statistics for region 1 were outliers. Excluding region 1 data, the comparison between the under-triaged vs. appropriately triaged children who died, indicated a statistical difference. This shows that there were significantly more children who expired when under-triaged, both in the overall TBI category and in the severe category. Numbers in the moderate category were too low to determine an association but assumptions would follow the same as the overall TBI and severe category.

One aspect of this study was to explore if EMS level of care provided to the patient could be associated with any outcome. Unfortunately, this could not be accomplished. The EMS database from ODPS, which listed departments had not been updated in many years. An attempt was made by the research team to update the data, but with the time and funding limitations, this was only partially completed. In addition, information on the number of squads running per each department was not available. Differentiation if the squad provided scene coverage or only inter-facility transports was also not available and could have skewed the overall data. Lastly, as the OTR database was de-identified and the EMS database was limited, there was no possibility of linking the EMS provider to a specific event.

Using regression analysis, multiple injury characteristics were analyzed for associations with severe pediatric TBI with hypothermia, motor GCS, ISS and age impacting mortality. For this study under-triage did not reach significance and was not considered a significant factor for pediatric TBI mortality.

Limitations

Limitations of this study should be considered when interpreting these findings. Surveillance of TBI is associated with many challenges. First, this study is not a population based study; but instead, a review of a state trauma registry that provides a comprehensive repository of hospitalized injured patients. At the time of this study, the state law mandates submission of all injured patients with a greater than 48 hour stay for an injury or a traumatic death. However, no evaluation has ever been done to validate total inclusiveness of the OTR dataset. In addition, patients may be transported to non-Ohio facilities in bordering states either due to geography or family/EMS preference and would not be included in this study. Lastly, children who die at the scene may not be transported to a hospital and would not be included in this study.

As with all review of databases, there is inherent issues of completeness and accuracy. Each hospital provides their own internal quality checks, but minimal checks are completed at the state level. It was also impossible to identify the actual cause of death without validating this through death certificates. An assumption was made that children that died with isolated severe head injuries died from the head injury. However, the population of children that died from multisystem severe head injuries could have had concomitant injuries which were the cause of the death.

Another limitation that impedes TBI research is the inconsistent definition and composition of pediatric TBI patients and what constitutes mild, moderate and severe TBI. Consistent information and data would be useful for policy makers, providers, educators and researchers trying to identify the impact of TBI in the United States.

Recommendations

Future work is needed in continuing to evaluate pediatric TBI and under-triage, looking for barriers and other issues that prevent appropriate triage. Other outcomes besides mortality need to be assessed to determine benefits of appropriate triage and the impact of delays, specifically related to TBI outcomes. State level variation in TBI and subsequent outcomes after moderate to severe TBI suggests that a more fine-grained breakdown may provide greater insight into the association between geography and mortality.

Many opportunities exist to improve the care for pediatric TBI patients. Future work toward linking both the EMSIRS dataset, the OTR dataset and the information regarding EMS personnel would assist in future epidemiological studies. It would be beneficial to all to continue to validate and improve the quality and content of the OTR dataset. General coding of TBI, using the general head injury code should be limited. Although this state trauma registry surpasses what other states have available, an attempt could be made to validate the percentage of patients that are actual submitted versus how many are actually injured.

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Project Expenditures

	Project Expenditures	Grant Funds Available
Personnel Costs (Lynn Haas, Misty Troutt and Suzanne Moody)	\$17,576.20	\$25,202.00
Data Management and Biostatistics	\$38,041.43	\$23,174.00
Computer Software	\$417.00	\$4,600.00
Printing Services	\$0	\$350.00
Total Costs	\$56,034.63	\$53,326.00

CCHMC expense reports only available through 5/31/17, final expenses were calculated using May expenses.

RPAB Regions – effective July 1, 2015

