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Injuries to Child Pedestrians Admitted to an Urban Pediatric Trauma Center

Abstract

This study examines the severity and types of injuries sustained by child pedestrians aged 18 years and below in order to identify the body regions at greatest risk for injury in a pedestrian accident. Detailed medical diagnoses were reviewed retrospectively for 572 child pedestrians admitted to an urban pediatric trauma center with injuries during the time period from January 2001 to December 2005. Eighty percent of these children sustained AIS 2 or greater injuries, most commonly to the lower extremity (41%) and head (34%). Forty-four percent of admitted children had more significant AIS 3 or greater injuries primarily to the head (58%), thorax (17%) and lower extremities (14%). Testing procedures to assess the child's interaction with the motor vehicle should include injury assessment for the pediatric head, thorax and lower extremities. This understanding of how child pedestrians interact with motor vehicles may provide insight into effective countermeasures with potential for implementation in vehicle designs world-wide.

Notation

CHOP The Children's Hospital of Philadelphia

AIS Abbreviated Injury Scale

Introduction

An estimated 1.2 million traffic fatalities occur per year world-wide and an additional 20 to 50 million people are injured. The rates of death and injury are highest for low and middle income countries and these rates are expected to increase without appropriate interventions. Vulnerable road users such as pedestrians are at particular risk of death and injury [1]. While low and middle income countries show the greatest pedestrian fatality rates, all countries demonstrate the need to protect vulnerable road users. In the United States in 2004, more than 10 percent of all traffic fatalities were pedestrians, accounting for more than 4,600 deaths per year. Of the pedestrian fatalities, more than 8 percent were children under the age of 16. When considering injured pedestrians, children under 16 years old account for more than 29 percent of all injured pedestrians [2]. Since children offer a unique design challenge because of their small stature and stage of development, an understanding of the most prevalent and serious injuries they sustain is a critical first step before appropriate countermeasures can be designed.

Previous studies have examined this issue using trauma registry data from hospital admissions between 1988 to 2003 [3-5]. These studies identified the head and external soft tissue injuries as the most common when considering all injury severities [4, 5]. When only severe injuries are considered, the head is still the most frequently injured body region, followed by the lower extremities, then thorax [5]. This current study builds on this previous work and with a more recent data set, examining the severity and types of injuries sustained by child pedestrians aged 18 years and below in order to identify the body regions at greatest risk for injury in a pedestrian accident. These data provide insight into the injuries children are currently sustaining, particularly as the vehicle fleet in the United States changes to include vehicles with a higher center of gravity and more aggressive frontal planes, such as sport utility vehicles and light trucks.

Methods

Detailed clinical data were obtained from all children aged 0-18 years admitted to the Children's Hospital of Philadelphia (CHOP) from January 2001 to December 2005 as a result of injuries sustained as a pedestrian struck by a motor vehicle. CHOP is a Level 1 Pediatric Trauma Center and is situated in an urban setting of 5.2 million people. The data were collected through the CHOP Trauma Registry, an electronic database of detailed medical diagnoses, procedures, and clinical data of all children admitted to the trauma program at the hospital. Specific medical diagnoses based on Abbreviated Injury Scale (AIS) codes were documented for each case. These codes provided

a detailed description of the injury diagnoses through a structured coding system and are available for each child as part of the standard data collected in the trauma registry. These data were then analyzed to determine the distribution of injuries by body region and age. The Institutional Review Board at CHOP approved of this retrospective review of clinical data.

Results

Detailed medical diagnoses were reviewed retrospectively for 572 child pedestrians admitted to CHOP during the time period from January 2001 to December 2005. The children ranged from 0 to 18 years in age (average: 8.6 years) and 65% were male. Age 7 was most common pedestrian age and children aged 4 to 7 years accounted for more than a third of all pedestrians. Figure 1 shows the age and gender distribution of the child pedestrians.

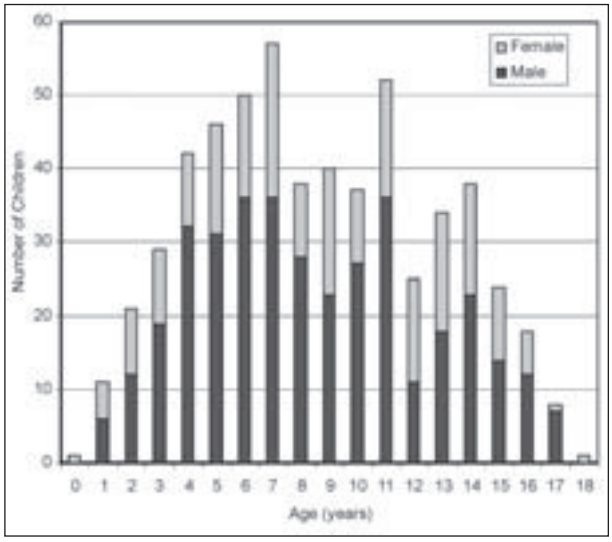

Figure 1: Age and gender distribution of all child pedestrians admitted to CHOP from 2001 to 2005

The 572 children sustained a total of 2,625 injuries; 53% of these injuries were AIS 2 or greater and 23% were AIS 3 or greater. Table 1 shows the distribution of all injuries for all ages by body region. The head accounted for 30% of all injuries, followed by the lower extremity (27%) and the face (18%).

Eighty percent of the child pedestrians sustained AIS 2 or greater injuries, most commonly to the head (41%) and lower extremity (34%). On average, these children sustained 3.0 AIS 2 or greater injuries to 1.5 body regions. Table 2 shows the body region distribution of the AIS 2 and greater injuries (n=1,391) stratified by age of the child. When examined by age groups, the patterns of injury for each group were similar to the overall body region distribution in which the head was the most commonly injured body region followed by the lower extremities for all ages 2 and older.

Forty-four percent of admitted children had more significant AIS 3 or greater injuries primarily to the head (58%), thorax (17%) and lower extremities (14%). On average, these children sustained 2.4 AIS 3 or greater injuries to 1.3 body regions. Table 3 shows the body region distribution of the AIS 3

Body Region	Injuries, n=2,625
Head	786 (30%)
Face	470 (18%)
Neck	8 (0%)
Thorax	143 (5%)
Abdomen	137 (5%)
Spine	20 (1%)
Upper Extremity	241 (9%)
Lower Extremity	702 (27%)
Whole Area	117 (4%)
Unknown	1 (0%)

Table 1: Distribution of all injuries (n=2,625) for all children aged 0 to 18 years old

	Child Age in Years						
Body Region	<2	2-3	4-6	7-9	10-12	13+	All Ages
Head	7 (41%)	40 (43%)	143 (44%)	137 (41%)	102 (39%)	136 (38%)	565 (41%)
Face	0 (0%)	5 (5%)	14 (4%)	22 (7%)	21 (8%)	13 (4%)	75 (5%)
Neck	0 (0%)	0 (0%)	0 (0%)	1 (0%)	0 (0%)	1 (0%)	2 (0%)
Thorax	5 (29%)	9 (10%)	24 (7%)	23 (7%)	15 (6%)	29 (8%)	105 (8%)
Abdomen	1 (6%)	10 (11%)	11 (3%)	14 (4%)	11 (4%)	20 (6%)	67 (5%)
Spine	0 (0%)	1 (1%)	6 (2%)	2 (1%)	1 (0%)	6 (2%)	16 (1%)
Upper Extremity	1 (6%)	9 (10%)	15 (5%)	18 (5%)	19 (7%)	23 (6%)	85 (6%)
Lower Extremity	3 (18%)	18 (20%)	112 (34%)	114 (34%)	93 (35%)	133 (37%)	473 (34%)
Whole Area	0 (0%)	0 (0%)	2 (1%)	0 (0%)	0 (0%)	1 (0%)	3 (0%)

Table 2: Distribution of AIS 2 and greater injuries (n=1,391) by child age

and greater injuries (n=606) stratified by age of the child. When examined by age group, the head was the most common injured body region followed by the thorax then lower extremity for all ages under 10 years old. For children 10 to 12 years, the thorax and lower extremity had similar frequencies of AIS 3 and greater injuries while the oldest children (13+ years) more frequently sustained lower extremity injuries.

The head is the most commonly injured body region for all age groups when considering all injury severity levels. Table 4 shows the types of AIS 2 and greater head injuries by age. For all ages, concussion or brief loss of consciousness (AIS 2) accounts for 27% of all AIS 2 and greater head injuries. Longer periods of unconsciousness are categorized as greater values on the AIS scale: AIS 3=3%, AIS 4=<1%, AIS 5=2%. More serious brain

	Child Age in Years						
Body Region	<2	2-3	4-6	7-9	10-12	13+	All Ages
Head	4 (40%)	26 (59%)	92 (61%)	73 (61%)	70 (63%)	89 (52%)	354 (58%)
Face	0 (0%)	0 (0%)	3 (2%)	1 (1%)	0 (0%)	1 (1%)	5 (1%)
Neck	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (1%)	1 (0%)
Thorax	5 (50%)	9 (20%)	24 (16%)	23 (19%)	15 (13%)	28 (16%)	104 (17%)
Abdomen	1 (10%)	5 (11%)	5 (3%)	6 (5%)	6 (5%)	10 (6%)	33 (5%)
Spine	0 (0%)	0 (0%)	5 (3%)	0 (0%)	0 (0%)	1 (1%)	6 (1%)
Upper Extremity	0 (0%)	1 (2%)	3 (2%)	5 (4%)	6 (5%)	3 (2%)	18 (3%)
Lower Extremity	0 (0%)	3 (7%)	18 (12%)	11 (9%)	15 (13%)	38 (22%)	85 (14%)

Table 3: Distribution of AIS 3 and greater injuries (n=606) by child age

	Child Age in Years						
	<2	2-3	4-6	7-9	10-12	13+	All Ages
Skull fracture	1	8	29	27	23	17	105
Vault	0	3	6	8	10	6	33
Base	1	5	23	19	13	11	72
Brain Injury	2	19	74	56	55	69	275
Concussion/Loss of Consciousness	3	13	39	54	23	50	182
AIS 2	2	10	32	50	20	37	151
AIS 3	0	2	3	2	2	10	19
AIS 4	1	0	1	0	0	1	3
AIS 5	0	1	3	2	1	2	9
Whole Area	1	0	0	0	1	0	2

Table 4: Distribution of AIS 2 and greater head injuries (n=564, excludes 1 unknown) by child age

	Child Age in Years						
	<2	2-3	4-6	7-9	10-12	13+	All Ages
Skeletal – Bones	3	17	107	107	90	117	441
Pelvis	1	2	24	18	7	33	85
Femur	0	6	37	31	18	15	107
Patella	0	0	0	0	0	1	1
Tibia/Fibula	2	8	44	57	54	66	231
Foot	0	1	2	1	11	2	17
Skeletal – Joints	0	0	2	5	1	10	18
Knee	0	0	1	3	1	8	13
Ankle	0	0	1	2	0	2	5
Muscles/Tendons/ Ligaments	0	0	1	1	0	5	7
Vessels	0	0	2	0	0	0	2
Other	0	1	0	1	2	1	5

Table 5: Distribution of AIS 2 and greater lower extremity injuries (n=473) by child age

	Child Age in Years						
	<2	2-3	4-6	7-9	10-12	13+	All Ages
Skeletal – Rib Cage	1	1	1	3	1	3	10
Internal Organs	4	8	23	18	14	24	91
Lung	2	4	14	7	8	13	48
Hemo/ pneumothorax	2	4	8	11	6	11	42
Diaphragm	0	0	1	0	0	0	1
Vessels	0	0	0	2	0	1	3

Table 6: Distribution of AIS 3 and greater thorax injuries (n=104) by child age

injury, which includes such intracranial injuries as hemorrhage and contusions, accounted for almost half (49%) of all AIS 2 and greater head injuries.

Table 5 outlines the AIS 2 and greater lower extremity injuries by age group. Ninety-three percent of these injuries were skeletal fractures, most commonly to the tibia/fibula (52%) and femur (24%). More clinically significant pelvic fractures accounted for 19% of these skeletal injuries.

When considering more severe injuries (AIS 3 and greater), the thorax becomes the second most injured body region accounting for 17% of the injuries for all children. Table 6 shows the types of thorax injuries sustained by age group. More than 87% of these thoracic injuries were to the internal organs, just over half of which were to the lungs.

Discussion

This analysis examined 572 children admitted to an urban pediatric trauma center and outlined the body regions injured. For all age groups, head was the most commonly injured body region at all levels of injury severity. Brain injuries such as intracranial contusion or hemorrhage composed the largest percentage of these injuries. These findings are in agreement with previously published studies [3-5]. Prevention of head injuries are particularly relevant as the effects of traumatic insult to the nervous tissue at an early age are still not fully understood and are a focus of clinical concern.

The lower extremity is the second most frequently injured body region at the less severe AIS 2 and greater injury level but 43% of the fractures are more clinically significant femur and pelvic fractures. This number is highest for the 4 to 6 year old group in which 57% of their fractures are to the femur and pelvis. While lower extremity injuries do not often present a threat to life, they can be devastating to growth and development, having significant long-term implications for the children and their families. These injuries often result in long term disability and impairment at an equal or greater extent than similar severity injuries to other body regions [6, 7]. This is an even greater concern for the pediatric population, not only because of the young age in life in which these injuries occur but also because of developmental stages of the pediatric population.

When considering more severe injuries (AIS 3 and greater), the thorax is the second most frequently injured body region for all children under 12 years old. These injuries were most often to the internal organs, specifically the lung contusions (46%) and hemo-pneumothorax (40%). Of interest, the mechanical structure of the pediatric thorax is quite different from that of an adult. Fusion of the bones of the sternum and calcification of the costal cartilage continues well into the teenage years. As a result of these changes, the overall flexibility of the pediatric thorax is substantially greater than that of an adult, contributing to the predominance of internal organ injuries over rib fractures.

The injuries seen in this data set are similar to those reported by others, despite the newer period of study, which may contain vehicles of higher and more aggressive front-end designs such as sport utility vehicles. However, since limited crash details are available in the trauma registry data, it is not possible to extract the striking vehicle type.

While this analysis shows the distribution of injuries to child pedestrians, several limitations must be considered. Children included in the trauma registry data set are admitted to an urban pediatric trauma center and represent the most seriously injured children in a geographical region. Many children with less clinically significant injuries may not be admitted to the trauma program and instead may

be discharged directly from the emergency room. In addition, CHOP serves as a referral hospital for much of the surrounding area and many trauma cases are transfers from an outside hospital, contributing to the more serious nature of the injuries admitted to CHOP. Older children and adolescents may be admitted to non-pediatric trauma centers and may not be represented in this population. Finally, while the trauma registry data contain very detailed medical information, they do not include specific crash details such as the impact configuration or striking vehicle type. Therefore, it is not possible to separate children impacted by the vehicle front or side from those who were run over or backed over. Nor is it possible to compare children struck by sport utility vehicles and light trucks with passenger cars.

Conclusions

New technologies and test procedures focused on pedestrian friendly vehicle design are primarily targeted at adults and their interaction with the vehicle but the large number of injuries to child pedestrians highlights the importance of incorporating their experience in these designs. Testing procedures to assess the child's interaction with the motor vehicle should include injury assessment for the pediatric head, thorax and lower extremities. This understanding of how child pedestrians interact with motor vehicles may provide insight into effective countermeasures with potential for implementation in vehicle designs worldwide.

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