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ASSOCIATION OF HEAD AND CERVICAL INJURIES IN PEDIATRIC OCCUPANTS
INVOLVED IN MOTOR VEHICLE COLLISIONS

(Thesis format: Monograph Article)

by

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Graduate Program in Pathology

A thesis submitted in partial fulfillment
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Abstract

The leading cause of death for children in the age group of 1-14 years is accidental injury. Motor vehicle accidents make up 63% of all accidental injury deaths in this age category. Furthermore, traumatic brain injury causes the highest number of deaths among children involved in motor vehicle collisions. Although cervical spine injuries are less frequent, they do cause death in children. Using a retrospective database, the objective of this pilot study was to determine whether there was a relationship between head injuries and cervical spine injuries and if cervical spine injuries had a higher frequency in younger pediatric passengers. Data were gathered on the types of injuries in passengers and pedestrians from postmortem and police reports for children 12 years and under involved in motor vehicle collisions. The influence of age and gender on the frequency of sustaining a head and spine injury was analyzed. The results showed that the younger individuals of both sexes had higher odds of sustaining head injuries and lower odds of sustaining neck injuries. This study also showed that head and neck injuries were relatively independently related for all sample groups tested suggesting different factors were involved in their causation. By understanding the relationship between head and spine injuries in different age and gender groups, the variables responsible for these injuries must be further defined prospectively when designing motor vehicle research protocols and safety regulations and investigating child deaths in motor vehicle collisions. Serious head and neck injuries and deaths in children can be reduced by preventative safety measures which address the etiologic factors responsible for these injuries in motor vehicle collisions.

Keywords: Pediatric, head, injuries, cervical, spine, motor vehicle collisions, odds ratio, phi coefficient

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1 Introduction

1.1 Epidemiology of Motor Vehicle Crash Injuries and Fatalities in Children

Unintentional injury is the leading cause of fatalities, serious injury and long term disabilities for children from 1 to 14 years of age (CDCP WIS 2009). In 2008, the World Health Organization (Peden 2008) reported that worldwide, road traffic injuries were the second leading cause of death for 5-14-year-olds; 65% of these deaths were vehicular occupants (CDCP WIS 2009). For children and young adults 5 to 24 years of age, 63% of deaths were motor vehicle (MVC)-related (CDCP WIS 2009). MVC- related injuries were among the top ten non-fatal types of trauma in 5 to 24 year old individuals treated in hospital emergency departments (CDCP WIS 2009). Prevention of injuries, disabilities and fatalities related to MVCs is an important public health initiative.

MVC injury prevention and control efforts during the last two decades have had a degree of success. In 2009, there was a 41% reduction in the death of children ages 14 and under in MVCs compared to 1996 (CHOP 2008; Arbogast et al. 2013). Among 1 to 4 year old children, non-fatal injuries sustained in MVCs were reduced from 2007 to 2008, moving this type of trauma from the top ten list for this age group (CDCP WIS 2009). Various interventions and measures can be credited for these reductions. Reduction of morbidity and mortality can be linked to the increase in proper age- appropriate restraint use (Arbogast et al. 2004; Braver et al.1997; Durbin et al. 2003, 2005; Elliott et al. 2006), and enhanced enforcement of more effective laws requiring proper use of these restraints (Segui-Gomez et al. 2001; Winston et al. 2007). There has been a threefold increase in the use of child restraint systems among 3 to 8 year old children involved in crashes, and educational campaigns have emphasized using booster seats for this age group (CHOP 2008). Children seated in the front passenger seat have been killed by airbag deployment which has led to a recommendation that they be seated in the rear seat of vehicles (Arbogast et al, 2013). In 2008, approximately 90% of children up to 7 years of age rode in the rear seat (CHOP 2008); however, one-third of children aged 8 to 12 years rode in the front seat, and as recently as 2009, 45% of 0 to 7 year-olds were not properly restrained

<div align="center">1</div>

according to their age-specified requirements (Pickrell and Ye 2010). These observations are evidence that there is still room for improvement in reducing child mortality and morbidity due to MVCs by proper seating and use of age-appropriate restraints.

1.1.1 Rear-Facing Child Restraints

The American Academy of Pediatrics recommends a rear-facing child restraint system (RFCRS) for toddlers and infants until they are either 2 years of age or they have reached the height and weight recommended by the CRS manufacturers (Durbin, 2011). These CRSs must support a child's head, neck, posterior torso and pelvis and diffuse crash forces over the entire body. The nature of cervical spine development in young children places them at risk for spinal column and cord injury. An effective rear-facing CRS supports the child's head and reduces loading on the neck. Rear-facing CRSs have reduced fatal injury in children <1 year by 71% in passenger cars and by 58% percent in light trucks (Hertz 1996).

Few children stay in rear-facing CRS past their first birthdays. In the United States, about 40% move into a front-facing CRS (Henary et al. 2007). Swedish guidelines have children in a rear-facing CRS until the age of 4 years, when they transition to booster seats. This measure has been reported to reduce Abbreviated-Injury Scale (AIS) Score 2+ injuries (the scale ranges from 1=minor to 6=maximum damage injury) by 90% relative to unrestrained children (Isaksson-Hellman et al. 1997; Jakobsson et al. 2005; AAAM 1998).

Injuries are reduced in young children when using a rear-facing CRS in comparison to a front-facing CRS (Henary et al. 2007). In 2007 Henary et al., reported that rear-facing CRS compared to front-facing CRS offered a 76% reduced chance of serious MVC injury for children ages 0-23 months. For 12-23-month-old children, there was a five-fold chance of serious injury when restrained in a front CRS. They also reported that rear-facing CRS provide the largest benefit of protection in side crashes for children up to 23 months. Although trauma is significantly lower in RFCRS, when injuries do occur, they are limited to the head (Henary et al. 2007). The European CREST project identified five children out of 31 cases, who sustained AIS3+ injury to the head while seated in RFCRSs (Arbogast et al. 2013). European vehicles are different in that rear-facing CRSs can be used in front passenger seats (with ability to turn off airbags), so the area of the RFCRS which supports the head can be in potential contact with the

dashboard when an airbag deploys. No neck or spine injuries were reported in the aforementioned study.

1.1.2 Forward-Facing Child Restraints

Kahane et al 's study (1986) showed that any type of restraint can reduce injury and death risks up to seventy percent when compared to children who were unrestrained. The analysis of the biomechanics for children restrained in forward-facing child restraint systems (FFCRSs) indicated a benefit in controlling the head and face excursion during a crash by distributing MVC forces over the shoulder and hips of the child (Kahane et al, 1986).

The effectiveness of FFCRSs in injury reduction is difficult to accurately measure because it is mostly dependent on the variable information in retrospective real-world databases, the years that were studied and the analytical approach taken (Arbogast et al. 2013). Despite the difficulty in giving a specific value for the effectiveness of FFCRSs, all studies have indicated that FFCRSs are effective in preventing fatal and non-fatal injuries in pediatric motor vehicle occupants (Arbogast et al. 2013). Studies by Henary et al. (2007) and Elliot et al. (2006) are the most quoted in determining the effectiveness of FFCRSs. Henary et al. (2007) determined that FFCRSs reduced deaths by 54% in children between 1 and 4 years of age in passenger car collisions when compared to unrestrained children of the same age. Elliot et al. (2006) used a more recent dataset to compare the effectiveness of FFCRSs to seat belt use, in children aged 2 to 6 years of age. This study indicated that FFCRS use was associated with a 28% reduction in death risk and a 21% reduction in death risk even when a FFCRS was misused (i.e. unattached restraints, CRS harness not used, two children restrained with one seat belt). This surprising finding meant that children in misused CRSs compared to unrestrained occupants had a better chance of survival in motor vehicle collisions. Overall, recent studies have indicated that any type of restraint, either a seat belt or a FFCRS, has the ability to reduce risk of death. In addition, FFCRSs are far more superior to seat belts in reducing the death and injury risks with estimates ranging from 71% to 82% , the larger value representing the effectiveness in children below 3 years of age (Arbogast et al. 2004; Winston et al. 2000; Zaloshnja et al. 2007).

1.1.3 Booster Seats

Moving from a FFCRS to a booster seat should only be done when a child has surpassed the weight limit (25-35 pounds or 11 to 16 kg) of the FFCRS. Booster seats help position the seat belt properly over anatomical areas for effective force distribution. Proper seatbelt positioning areas include the lower belt over the child's hips or upper thighs and the shoulder belt across the center of the child's shoulder and chest. A booster seat can improve seat belt fit for a child who is undersized for a vehicle's seat belt. For older children, i.e. approximately 8 to 12 years of age, if the belt fits properly (without the use of a booster seat) over the hip/upper thighs and the center of the shoulder and the chest, then a child can be restrained in a rear occupant seat without a booster seat. The child should be able to sit with his/her back against the vehicle seat and to bend his/her knees over the seat edge which typically occurs when the child's height is at least 4' 9" (about 143 cm.) (Arbogast et al 2013).

A study by Durbin et al. (2003) indicated that the effective reduction in the odds of injury for children ages 4 to 7 years of age who used a booster seat compared to children who used seat belts was 59%. Arbogast et al. (2009) revisited this comparison due to the increase in the use of booster seats in children ages 6 to 8 years old. Their study indicated that these children in booster seats were 45% less likely to sustain injuries above AIS 2 (moderate), when compared to children using seat belts. Rice et al. (2009) indicated that booster seats didn't affect death rates when compared to seat belt usage, but they were more effective at reducing non-fatal injuries. The most common fatal injuries in children in booster seats were to the head and face (Rice et al. 2009).

1.1.4 Crash Directions

Frontal crashes from various directions are the most common type of collisions experienced by child motor vehicle occupants. Much of the recent research has been focused on this type of crash; however, the greater significance of side impacts and rollovers is evident when higher fatality rates are taken into account in these types of collisions in contrast to frontal crashes (Arbogast et al. 2013). In comparison, a study by Viano and Parenteau (2008), indicated that the ranking of collisions types for fatalities of children ages 0 to 7 years, from highest to lowest, was rollovers, frontal impacts, side impacts and rear impacts.

1.1.4.1   Side Impacts

Most of the interest in side impacts has been on which seating position is the safest. Howard et al (2004), reported that near-side crashes are far more dangerous (40% higher fatality risk) than far-side crashes. Their study also reported children ages 0 to 12 years, sitting in the seat at the near-side of the crash, were far more likely to sustain severe injuries than children seated in the center of the rear row. Arbogast et al (2004) also found a similar trend for FFCRSs; near-sided seating had a significantly higher (8.9 injured children per 1000 crashes) risk of injury when compared to the side that was not struck (2.1 injured children per 1000 crashes). Not surprisingly, given these previous studies, the safest location is the farthest seat from the crash location. In contrast, a trauma center-based study by Charyk Stewart et al (2013) found that the middle rear seating position increased the odds of severe head injury from head contact with the center console due to an absence of an universal anchorage system allowing for greater forward head excursion.

1.1.4.2   Rear Impacts

The injury risk in rear impact crashes is influenced by the deformation of front seat backs. A rear impact scenario that involves an occupied front seat becoming deformed directly in front of the child occupant seated in the rear causes a doubling of risk injury (Jermakian et al. 2008). Viano and Parentau (2008) investigated 19 children occupants in rear impact collisions. Sixty-six percent of the children were in vehicles which had a significant amount of rear intrusion into their seating space, therefore causing the children's heads to move closer to the front seat back. Ten of the 19 children had injuries sustained from head contact with the front seat back.

1.2   Common Injuries

1.2.1 Craniocerebral Injuries

As children grow, the sizes of organs and body regions relative to height change. The most notable is head proportion. The head comprises one fourth of the total stature of a newborn compared to one seventh in an adult attained at the age of 20 (Arbogast et al. 2013). A 5-year-old child's head is 90% the size of an adult head. A significant difference in head size between male and female children is not noticeable until the age of 10 (Arbogast et al 2013). Male children have a 10% larger head volume when compared to female children (Arbogast et al. 2013). The

larger head to torso ratio in newborns and younger children puts them at a higher risk for head injuries.

The importance of craniocerebral injury in younger children involved in motor vehicle collisions is evident when considering how common and highly fatal these injuries are. The high fatality of craniocerebral injuries is in part due to the relative lack of skull rigidity due to its incomplete development. The fontanelles and the sutures of the skull are separated by a narrow region of membrane which allows additional brain growth in childhood. They reach a completely fused state during adulthood (Margulies et al. 2013). Thus, they are virtually the same as adults in terms of synostosis. The immature suture and fontanelles of the child's skull increase the risk for sustaining fatal head injuries (Margulies et al. 2013). In addition, the pediatric brain is softer than the adult brain due to its higher water content (88% versus 78%) and higher proportion of weaker unmyelinated nerve fibers (Margulies et al. 2013).

1.2.2 Neck/Cervical Spine Injuries

Although the frequency of cervical spine injuries is low for pediatric age groups, cervical spine injuries occurring in pediatric MVC occupants can be fatal (Arbogast et al 2013, Rasouli et al 2011, Parent et al 2011). Motor vehicle collisions account for 30% of cervical spine injury admissions (Zuckerbraun et al. 2004). One trauma centre study found that 5% of severely injured pediatric patients had cervical spine injuries (Chan et al. 2013). Sixty to 80% of cervical spine injuries in young children aged less than eight years occur in the higher cervical spine regions (Arbogast et al 2013, Rasouli et al 2011, Hwang et al, 2012, Platzer et al. 2007). This can be attributed to the biomechanical differences in young children compared to older individuals, such as, a larger head to torso ratio, incomplete ossification of vertebra, horizontal orientation of cervical spine facet joints, laxity of the ligaments involved in head and neck support and underdeveloped neck musculature and spinous processes (Ghanem et al 2008, Basu et al 2012 Lustrin et al 2003 Platzer et al. 2007).

Older children sustain injuries more commonly in the lower cervical and thoracic spine region (Hwang et al 2012, Platzer et al. 2007). The most common types of injuries in cervical spine region include fractures, fractures with dislocation, discoligamentary injuries and spinal cord injuries without radiographic abnormalities (SCIWORA) (Pang 2004, Platzer et al. 2007).

The differences in the biomechanical properties of a child's spine compared to that of an adult spine mean that further study between the association of cervical spine injuries and age, gender and types of CRS used can assist in developing the bio-fidelity of pediatric crash dummies and improving the effectiveness of CRSs in injury reduction.

1.3 Rationale

Head injury is the most common fatal injury sustained by pediatric occupants when they are in MVCs. Cervical spine trauma is a less frequent injury encountered under these circumstances, but it must be recognized as a cause of death during the postmortem investigation. Even with the proper use of modern car restraint systems, both of these injuries do occur and cause high mortality and morbidity. No study has determined prevalence and the odds of sustaining head and cervical spine injuries based on a comparison of gender and age populations of children involved in motor vehicle collisions. As stated by Arbogast and Durbin (2013) – "Determination of the prevalence and nature of these injuries, the circumstances under which they occur and the importance of head contact in the causation scenario needs further study." A recent study by Wu et al. (2013) emphasized that, despite the infrequency of cervical spine injuries in children, the mechanical properties of the spine do determine the extent of head excursion thereby influencing the risk of head injury in MVCs. <u>I hypothesize that there is a dependent relationship between head and cervical spine injuries and a higher prevalence and odds for these injuries in younger children involved in motor vehicle collisions.</u>

Specific Questions

1. What is the relationship between head and cervical spine injuries in pediatric motor vehicle occupants involved in collisions?
2. Does gender and age influence the odds of sustaining head and cervical spine injuries in pediatric motor vehicle occupants?
3. Are the odds of sustaining head and cervical spine injuries in pediatric motor vehicle occupants different from pedestrians?

Chapter 2

2 Research Design

2.1 Collection of Data

For this study, deceased victims, ages 12 and under, from motor vehicle –related incidents (n=105) investigated by the Office of the Chief Coroner for Ontario from 2004 to 2009 were reviewed. This review comprised data collection from coroners', police and pathologists' autopsy reports from the Office of the Chief Coroner which, at the time of the study, was located at 200-26 Grenville St, Toronto, Ontario. This study was supported by an AUTO 21 grant (A504-AFC; Principal Investigator – Dr. Andrew Howard). It had Research Ethics Board approval from the Hospital for Sick Children ("Sick Kids" file number 10000-33705). There was a Data Sharing Agreement with Western University Department of Pathology and Laboratory Medicine. The LHSC trauma program data was also obtained to be used for the non-fatal trauma group.

The program used to collect information is called FileMaker (see Appendix A). This was designed by Dr. Andrew Howard's team in Toronto in 2012. Information was entered manually from each victim's file into relevant sections in the FileMaker, e.g. Police Report tab was the entry point for the Police Report information.

2.2 Filemaker

2.2.1 Coroner Investigation Statement

In this section, the following was entered: case number, deceased child's demographic details [Date of Birth (DOB)-converted to age in years and months], investigation details, the collision environment, involvements (other factors contributing to collisions), reports ordered, pathologist's name, medical cause of death and any contributory factors ("due to") to the cause of death, coroner's narrative about the circumstances of the collision, coroner's recommendations, if applicable.

2.2.2 Pathology Report

This section included the following information about the child: age, sex, and height, and weight, direct quotes from the pathologist's narrative regarding injuries, date of death, date of autopsy, pre-existing medical conditions and therapeutic interventions. It also included a drop down menu for a total of 23 injuries. Each injury was subdivided into body region (e.g. head, face), type of anatomic structure (e.g whole area versus vessels), aspect (right, left), and assigned an injury severity code (each injury section included an AIS code and an AIS description). Ancillary postmortem tests, summary of autopsy findings and the pathologist's determination of the cause of death were also entered.

AIS stands for Abbreviated Injury Scale. For coding, AIS-98 was used (Association for the Advancement of Automotive Medicine 1998). AIS coding categorizes injuries into a specific code (e.g. subdural hematoma tiny; <0.6 cm is classified as 140652.4). The score describes three features of the injury: type, location and severity. Each number sequentially signifies one of these features: 1st-body regions, 2nd-type of anatomical structure, 3rd, 4th- specific anatomical structures, 5th, 6th-level and 7th-severity of the injury (1 minor, 2 moderate, 3 serious, 4 severe, 5 critical, 6 fatal). For example, the code, 140652.4, explains that the injury is located on the head, is a laceration and specifically a subdural hematoma which is severe.

2.2.3 Police Report

From the police report, these data were entered: date of collision, time of collision, location/municipality, position/direction of traffic, collision information such as sequence of crash events, occupant compartment intrusion, position of victim (front middle, front passenger etc.), restraint use, airbag status, reports of other investigative agencies, and follow up, by other agencies.

For the driver, this information was added: age, date of birth, sex, relationship to victim, injuries, level of intoxication, restraint use, and airbag status. These fields were also used for other occupants in the vehicle at the time of the collision.

2.2.4 Accident Diagram

The accident diagram section was available for information regarding the collision delta v (change in velocity), aspect of vehicle struck, vehicle crush, intrusion and location of the vehicles involved in the collision which assisted in the reconstruction of the collision.

2.2.5 Case Vehicle

This section included the case vehicle and any other vehicle involved in the collision (up to 5 vehicles). Each vehicle had the following information entered: vehicle speed, posted speed, make, model, year, VIN (Vehicle Identification Number).

2.3 Odds Ratio and Common Odds

The variables studied were head and neck injuries (coded using AIS) in passengers and pedestrians based on gender and age range (0-3 years; 4-12 years). Head injuries and neck injuries were selected based on the AIS code. AIS codes that start with the number 1 are head injuries, 3 are neck injuries and 6 are spinal injuries. Causes of death that were non-collision related, e.g. asphyxia, pneumonia, were omitted from further analysis. The data were separated into two groups - passengers and pedestrians. Using IBM SPSS, two variables for head and neck injuries, i.e. gender and age, were cross tabulated. The cross tabulation gave the number of head and neck injuries per age group for each gender. Using **Equation 2-1** to calculate the odds ratio (*OR*) of population A (male) compared to population B (females).

Equation 2-1:
$$OR = \frac{n_A / N_A - n_A}{n_B / N_B - n_B}$$

$$N_A = Total\ number\ of\ individuals\ in\ population\ A$$

$$n_A = Total\ number\ of\ cases\ in\ population\ A$$

$$N_B = Total\ number\ of\ individuals\ in\ population\ B$$

$$n_B = Total\ number\ of\ cases\ in\ population\ B$$

The common odds ratio (COR) was then calculated using **Equation 2-2.** This is used to calculate the overall odds of population A compared to population B.

Equation 2-2:
$$COR = \frac{OR_{1N} + OR_{2N}}{OR_{1D} + OR_{2D}}$$

$OR_{1N} = Numerator\ of\ the\ Odds\ Ratio\ of\ Subgroup\ 1$

$OR_{1D} = Denominator\ of\ the\ Odds\ Ratio\ of\ Subgroup\ 1$

$OR_{2N} = Numerator\ of\ the\ Odds\ Ratio\ of\ Subgroup\ 2$

$OR_{2D} = Denominator\ of\ the\ Odds\ Ratio\ of\ Subgroup\ 2$

2.4 Phi Coefficient for Association of Head and Neck Injuries

To test the association between head injuries and neck injuries a phi- 2 X 2 contingency table was used, and the phi coefficient was calculated using this table. The phi coefficient requires two binary variables which in this study were head and neck injuries. Each variable is given a value of present (1) or absent (0). Then the number of each of the four categories is tallied. Using these numbers and the phi coefficient equation:

Equation 2-3:

$$\emptyset = \frac{n_{11}n_{00} - n_{10}n_{01}}{\sqrt{n_{1.}n_{0.}\ n_{.0}n_{.1}}}$$

$n_{11} = Number\ of\ Both\ Variables\ Present$

$n_{00} = Number\ of\ Both\ Variables\ Absent$

$n_{10} = Number\ of\ Only\ Head\ Injuries\ Present$

$n_{01} = Number\ of\ Only\ Neck\ injuries\ Present$

$n_{1.} = Total\ Head\ Injuries\ Present$

$$n_{0.} = Total\ Head\ Injuries\ Absent$$

$$n_{.0} = Total\ Neck\ Injuries\ Absent$$

$$n_{.1} = Total\ Neck\ Injuries\ Present$$

This coefficient ranges between -1 and 1. This indicates the association between the two variables i.e. head and neck injuries. A coefficient of -1 or 1 represents different significance with the latter equaling complete dependence and the former an inverse relationship. A '0' coefficient indicates no relationship. In order to conceptualize the degree of relationship between two variables represented by the phi coefficient it is more meaningful to think in terms of the square of correlation ($\emptyset^2$). Squaring of phi expresses the relationship between two variables more precisely because this value represents the proportion of variance shared (Molto, 1979). Any positive coefficient needs however to be assessed for its strength using the 95% confidence interval particularly given the small sample sizes used in this and most studies.

2.5 95% Confidence Interval for Odds Ratio and Phi Coefficient Correlation

The 95% confidence interval was used in this study to test the statistical significance of the odds ratio and phi coefficient. **Equation 2-4** represents how to calculate the 95% confidence interval (CI) for the odds ratio (OR) or phi coefficient, and **Equation 2-5** is the Standard Error of the Odds Ratio $SE(OR)$. **Equation 2-6** is used to calculate the Standard Error for the phi-coefficient ($SE_\emptyset$). In this equation N is the total number of injuries used in the 2-X-2 phi contingency table. Once the standard errors for both the phi-coefficient and the odds ratio are calculated, they can be inserted into **Equation 2-4** to give the 95% confidence interval for each one.

Equation 2-4: $$95\%CI = e^{\ln(OR\ or\ \emptyset\ )\ \pm[1.96\ \times\ SE(OR\ or\ \emptyset\ )}$$

Equation 2-5: $$SE(OR) = \sqrt{\frac{1}{n_A} + \frac{1}{n_B} + \frac{1}{N_A - n_A} + \frac{1}{N_B - n_B}}$$

Equation 2-6: $$SE_\emptyset = \frac{1}{\sqrt{[N-3]}}$$

2.6 Collaboration within This Study

For this study, the AIS coding of injuries from the pathologists' autopsy report, raw data organization, statistical analysis and the use of statistical techniques were conducted by me. Dr. El Molto directed the use of statistical techniques. Dr.Sarah Richmond and Alice Simneacu in Dr. Andrew Howard's team were involved with the data collection. Dr.Andrew Howard and his team designed and developed the File maker program.

Chapter 3

3   Project Results

3.1   Office of the Chief Coroner's Data

During the study period of 2004 to 2009, 105 cases were reviewed. These cases comprised 77 occupants, 19 pedestrians and 9 non-collision cases. The latter included one case of homicide, asphyxia, school bus incident, heat stroke and two cases of emergency C-section and three sudden infant deaths. These cases were excluded from the study. Of the 77 occupants there were 12 males, ages 0 to 3 and 27 males ages 4 to 12; 14 females, ages 0 to 3 and 24 females, 4 to 12 years.

3.2   London Health Sciences Centre (LHSC) Trauma Data

During the study period of 2002 to 2011, ten cases of cervical spine-related injury were found. From these cases only 3 were children ages 8 years, 12 years and 15 months old who were occupants in a motor vehicle involved in a collision. The 15-month old child sustained atlanto-occipital dislocation and fracture; the 12 year old child sustained an associated brachial plexus injury; the 8 year old child sustained a C-3 dislocation. The 12- year old was the only patient to be discharged. The 8-year and 15-month old occupants passed away.

3.3   Common Injuries

3.3.1 Craniocerebral Injuries

The fatal head injuries and their sequelae noted on review of the Office of the Chief Coroner records were described as follows in the autopsy reports: skull vault fractures (closed, comminuted, complex and depressed), basal skull fractures, subdural hematoma, subarachnoid hemorrhage, cerebral/cerebellar laceration closed head injury/blunt head trauma, diffuse axonal injury, cerebral edema, brainstem compression, and ischemia.

3.3.2 Cervical Spine Injuries

The following fatal cervical injuries were observed: cord contusions (with or without fracture or dislocation), disc injury (herniation), dislocation without fracture (atlanto-axial, atlanto-occipital, bilateral and unilateral facet joints), and fractures without cord contusion.

3.4 Types of Collisions

The types of collisions for occupants were collected. The most common type of collisions and number of involved occupants are listed in Table 3-1. Fifty (63.9%) of the 77 occupants collected in this study had a known impact location.

Table 3-1: Types of impact locations.

Crash Type	Total	Occupants
Frontal Impact	7	6
Rear Impact	4	4
Side Impacts	30	30
Sideswipe	6	6
Rollover	4	4

3.5 Association of Head and Cervical Spine Injuries Using the Phi-Coefficient

To test the association of head and cervical spine injuries, these injuries were tabulated for 77 individual occupants between the ages of 0 to 12 years. These injuries were coded using the Abbreviated Injury Scale (AIS). Each of the codes used represented a specific injury related to craniocerebral trauma or neck injury. Using a Phi -2 x 2 contingency table, the 77 occupant cases were categorized into the two injury categories, with each of these being split into two sub-categories of absent and present as represented by **Table 3-2**. The phi-coefficient/association was calculated using **Equation 2-3** ($\emptyset = \frac{(13 \times 40) - (20 \times 4)}{\sqrt{(33 \times 44 \times 60 \times 17)}}$).The phi coefficient or correlation ($\emptyset$), which represents the association of head and cervical spine injuries, is $\emptyset = 0.36$. This coefficient

is less than 1 indicating a positive association. Since it is closer to 0 than 1, I interpret this result as indicating fatal head and cervical spine injuries are basically independent. An interesting check of the strength of this association is using the R^2 (0.36^2) which shows a shared coefficient of .13, clearly indicating independence because this value is closer to 0 than 1. To test the precision, reliability and significance of the phi coefficient, the 95% confidence interval was used. This was calculated using **Equation 2-6 and 2-4.** The standard error for the phi coefficient (0.36) was calculated, $SE_\emptyset = \frac{1}{\sqrt{[77-3]}}$, giving a standard error of 0.1162. This value was inserted into **Equation 2-4** which gave the 95% confidence interval of the Fisher transformation. The calculated 95% Confidence Interval $= e^{\ln(0.36)\,\pm[1.96\,\times0.1162]}$, resulted in a lower limit of 0.29 and an upper limit of 0.45.

Table 3-2: **2-by-2 phi-contingency table used to calculate the phi-coefficient for total occupant population.**

Phi-contingency table representing number of head and neck injuries absent and present in a total sample size of N=77 occupants. Individual sample sizes, n=40, 20, 4, 13, were inserted into **Equation 2-3** to calculate the phi coefficient representing association/correlation between head and neck injuries in this sample size.

	Head-Absent	Head-Present	total
Neck-Absent	40	20	60
Neck-Present	4	13	17
total	44	33	77

Table 3-3: 2-by-2 phi-contingency table used to calculate the phi-coefficient for young female occupants.

Phi-contingency table representing number of head and neck injuries absent and present in a total sample size of N=14 young female occupants. Individual sample sizes, n=7, 5, 0, 2, were inserted into **Equation 2-3** to calculate the phi coefficient representing association/correlation between head and neck injuries in this sample size.

	Head-Absent	Head-Present	total
Neck-Absent	7	5	12
Neck-Present	0	2	2
total	7	7	14

Table 3-4: 2-by-2 phi-contingency table used to calculate the phi-coefficient for older male occupants.

Phi-contingency table representing number of head and neck injuries absent and present in a total sample size of N=27 older male occupants. Individual sample sizes, n=16, 6, 0, 5, were inserted into **Equation 2-3** to calculate the phi coefficient representing association/correlation between head and neck injuries in this sample size.

	Head-Absent	Head-Present	total
Neck-Absent	16	6	22
Neck-Present	0	5	5
total	16	11	27

Table 3-5: 2-by-2 phi-contingency table used to calculate the phi-coefficient for older female occupants.

Phi-contingency table representing number of head and neck injuries absent and present in a total sample size of N=24 older female occupants. Individual sample sizes, n=15, 4, 1, 4, were inserted into **Equation 2-3** to calculate the phi coefficient representing association/correlation between head and neck injuries in this sample size.

	Head-Absent	Head-Present	total
Neck-Absent	15	4	19
Neck-Present	1	4	5
total	16	8	24

3.6 Prevalence and Odds of Head and Cervical Spine Injuries in Male and Female Populations

Table 3-6 indicates the total number of young (0-3 years) male children (N=12) and the number of males who sustained head injuries was, n=7 (prevalence = n/N = 7/12 = 58%). Using odds ratio [Equation 2.1] of this specific group sustaining a head injury were $\{\frac{n}{N-n} = \frac{7}{12-7} = 1.4\}$.

The total number of female children in this age group was, N=14. The total number of females in the 0 to 3 year age group that sustained head injuries was, n=7. The odds of sustaining a head injury was $\{\frac{n}{N-n} = \frac{7}{14-7} = 1\}$.

Calculation of odds ratio (OR) (**Equation 2-1**) was the method used to statistically compare head and cervical spine injuries in these young and old male and female pediatric populations.

The common odds ratio (COR) was then determined using **Equation 2-2**. This is used to calculate the overall odds of population A compared to population B. For example, the common odds ratio of head injuries in population A (males) compared to population B (females) is, $COR = \frac{7+50}{5+51}$, 1.02. A common odds ratio of 1 indicates that there is no significance at the 5% level; however, a common odds ratio above 2 indicates a significant difference. The COR relates the age-specific proportional prevalence in two populations, A and B, as a single figure (Klaus et al. 2009). Clearly, these results show statistically there is no difference between the sexes, although the odds were slightly higher in the males.

Table 3-6: Head Injuries of Young and Old Male Populations Compared to Female Populations.

N=Total Number of Children by Age and Gender, n= Total Number of Injured Cases. Head injuries of young males (n=7) compared to young females (n=7) is 1.4 (CI 0.296-6.6221) times more likely to sustain a head injury. Head injuries in the older age group (male n=10 and female n=9) have an OR of 0.98 (CI 0.314-3.0567) indicating similar odds of sustaining craniocerebral trauma. Common odds representing the overall comparison of male to females is 1.02 (CI 0.41-2.52). This again shows an insignificant result.

Head Injuries Young and Old Male By Female

	Population A			*Population B*			*A:B OR*	*95% CI*
Age-Years	Male			Female				
	n	N	P%	n	N	P%		
0-3	7	12	58	7	14	50	1.4	0.296-6.6221
4-12	10	27	37	9	24	38	0.98	0.314-3.0567
Total	**17**	**39**		**16**	**38**		**1.02 CO**	**0.41-2.52**

Table 3-7: Neck Injuries of Young and Old Males Compared to Female Populations.

N=Total Number of Children by Age and Gender, n= Total Number of Injured Cases. Neck injuries of young males (n=1) compared to young females (n=2) was 0.55 (CI 0.043-6.89) times less likely to sustain a neck injury. In the older age group (male n=6 and female n=6) males have a 0.86 (CI 0.235-3.13) odds of sustaining a neck injury relative to females. Common odds ratio representing the overall comparison of male to females is 0.67 (CI 0.15-2.93).

Neck Injuries Young and Old Male By Female

	Population A			*Population B*			*A:B OR*	*95% CI*
Age-Years	Male			Female				
	n	N	P%	n	N	P%		
0-3	1	12	8	2	14	14	0.55	0.043-6.89
4-12	6	27	22	6	24	25	0.86	0.235-3.13

Total	**7**	**39**	**8**	**38**	**0.67 CO**	**0.15-2.93**

Table 3-8: Head Injuries of Young Males Compared to Older Males.

N=Total Number of Children by Age and Gender, n= Total Number of Injured Cases. Younger males (n=7) had a 2.38 (CI 0.594-9.54) odds of sustaining a head injury compared to older males (n=10).

Head Injuries in Young Males Compared to Older Males

	Population A			*Population B*			*A:B OR*	*95% CI*
Age-Years	0-3			4-12				
	n	N	P%	n	N	P%		
Male	7	12	58	10	27	37	2.38	0.594-9.54

Table 3-9: Head Injuries of Young Females Compared to Older Females.

N=Total Number of Children by Age and Gender, n= Total Number of Injured Cases. Younger females (n=7) had a 1.67 (CI 0.44-6.33) odds of sustaining a head injury compared to older females (n=9).

Head Injuries in Young Females Compared to Older Females

	Population A			*Population B*			*A:B OR*	*95% CI*
Age-Years	0-3			4-12				
	n	N	P%	n	N	P%		
Female	7	14	50	9	24	38	1.67	0.44-6.33

Table 3-10: Neck Injuries of Young Males Compared to Older Males.

N=Total Number of Children by Age and Gender, n= Total Number of Injured Cases. Younger males (n=1) had a 0.216 (CI 0.0237-1.963) odds of sustaining a neck injury compared to older males (n=8).

Neck Injuries in Young Males Compared to Older Males

	Population A			*Population B*			*A:B OR*	*95% CI*
Age-Years	0-3			4-12				
	n	N	P%	n	N	P%		
Male	1	12	8	8	27	30	0.216	0.0237-1.963

Table 3-11: Neck Injuries of Young Females Compared to Older Females.

N=Total Number of Children by Age and Gender, n= Total Number of Injured Cases. Younger females (n=2) had a 0.333 (CI 0.06-1.863) odds of sustaining a neck injury compared to older females (n=8).

Neck Injuries in Young Females Compared to Older Females

	Population A			*Population B*			*A:B OR*	*95% CI*
Age-Years	0-3			4-12				
	n	N	P%	n	N	P%		
Female	2	14	14	8	24	33	0.333	0.06-1.863

Table 3-12: Head Injuries of Young and Old Occupants Compared to Pedestrians.

N=Total Number of Children by Age and Gender, n= Total Number of Injured Cases. Prevalence, odds ratios, common odds ratios and 95%confidence intervals of head injuries in young (0-3 years of age) and old (4-12 years of age) age groups of population A (pedestrians= "No MV") compared to population B (occupants in Motor Vehicle).

Head Injuries Young and Old with and without Motor Vehicles

	Population A			*Population B*			*A:B OR*	*95% CI*
Age-Years	No MV			Motor Vehicle				
	n	N	P%	n	N	P%		
0-3	2	2	100	14	26	54	NA	NA
4-12	12	17	71	19	51	37	4.04	1.23 -13.26

Total	14	19	33	77	NA Common Odds

Table 3-13: Neck Injuries of Young and Old Occupants Compared to Pedestrians.

N=Total Number of Children by Age and Gender, n= Total Number of Injured Cases. Prevalence, odds ratios, common odds ratios and 95% confidence intervals of neck injuries in young (0-3 years of age) and old (4-12 years of age) age groups of population A (pedestrians= "No MV") compared to population B (occupants in "Motor Vehicles").

Neck Injuries Young and Old with and without Motor Vehicles

	Population A			Population B			A:B OR	95% CI
Age-Years	No MV			Motor Vehicle				
	n	N	P%	n	N	P%		
0-3	0	2	0	3	26	12	0	0
4-12	3	17	18	16	51	31	0.47	0.118-1.86

Total	3	19	19	77	NA Common Odds

Chapter 4

4 Discussion

The leading cause of death of children in the age group of 1-14 years is unintentional injury (CDCP WIS 2009). Motor vehicle collisions (MVCs) make up 63% of all unintentional injury deaths, and traumatic brain injury is the most common cause of death in these cases (CDCP WIS 2009.). Pediatric spinal cord injury is rare (2.7% to 9% of all injuries) but has a high morbidity and mortality (Ramrattan et al, 2012; Li et al, 2011).

In this study, the first objective was determining the relationship of head and cervical spine injuries in a population of pediatric motor vehicle occupants. The second objective focused on a comparative analysis of whether gender and age increase or decrease the odds of sustaining head and cervical spine injuries. The final objective was to do a comparative analysis of the passenger (within a motor vehicle) and pedestrian (outside a motor vehicle) populations and the likelihood of these children sustaining head and cervical spine injuries using the odds ratio.

Recent studies point to a lack of information on whether there is an interdependent mechanistic relationship between the cervical spine and head in terms of injury causation in pediatric motor vehicle occupants (Arbogast et al. 2013; Wu et al. 2013). This pilot study provides statistical analysis on the association between fatal head injuries and cervical spine injuries. In addition, this study is the first to provide information about variables such as age and gender on the odds of sustaining head and cervical spine injuries in pediatric motor vehicle occupants involved in MVCs.

4.1 What is the relationship between head and cervical spine injuries in pediatric motor vehicle occupants involved in collisions?

The results for the phi coefficient correlating head and cervical spine injuries in young females, older males and females in this study were, 0.41 ($R^2 = 0.17$) (CI=0.23-0.74), 0.58 ($R^2 = 0.33$)

(CI=0.39-0.87) and 0.51 ($R^2 = 0.26$) (CI=0.33-0.78) respectively. Though the coefficients are highest for the older two cohorts than the younger females, the confidence intervals do not result in significant results. In part this can be explained by the large ranges. These ranges are large because their confidence intervals cover a range from 0 to 1 for a measurement which is within the range from 0 to 1. The sample size for young males was too small to calculate a phi coefficient.

The phi coefficient correlating the total number of head and cervical spine injuries is 0.36. This translates into a small and insignificant R^2 value of .13 as shown by Molto (1979). This number represents a statistically insignificant and an independent association between head and cervical spine injuries. According to this correlation, head and cervical spine injuries could have occurred relatively independent from one another in the population of pediatric MVC occupants studied. The confidence interval, 0.29 to 0.45 for the phi coefficient is low, and the calculated phi coefficient fits in this range. This signifies that the analytical findings are reliable, precise and valid. But the phi confidence interval of .29 to .45 is also insignificant. Thus these results contrast with the assumption that there is a dependent relationship between spine and head excursion when efforts in improving the biofidelity of spinal movement in pediatric anthropometric dummies are discussed (Wu et al 2013). Again I emphasize the small sample size used here.

There is a lack of information correlating the relationship of head and cervical spine injuries in children involved in MVCs. Wu et al. (2013) have stressed the need for research in pediatric spine anatomy and movement and its association with head injuries. The mechanical properties and development of the cervical spine affect head excursion of child occupants during motor vehicle collisions and the risk of subsequent head injury. More focus on epidemiological and injury causation analyses of pediatric head and cervical spine injuries in MVCs, in particular, the importance of head trauma in association with cervical spine injuries, and vice versa has been encouraged (Arbogast et al. 2013).

4.2 Does gender and age influence the odds of sustaining head and cervical spine injuries in pediatric motor vehicle occupants?

To determine whether gender and age influence the odds of sustaining head and neck injuries, the present study compared a population of 39 male and 38 female occupants who were subdivided into young (0 to 3 years old) and older (4 to 12 years of age) children for comparison. Age and gender were chosen as variables because they determine the developmental stages of head, neck and body as a whole and the consequent injury biomechanics (Arbogast et al. 2013).

In addition, Table 3-6 indicates that younger males had a higher odds (1.4 times) of sustaining a head injury compared to females; however, the older age group showed no sex difference (OR=0.98). The confidence interval for the younger age group had a larger range when compared to the older age group. These findings support recent studies which have described the higher odds and prevalence of sustaining head injuries in a younger male population. The higher male odds can be attributed to developmental changes that occur in this group (Pang, 2004). Female maturation happens earlier than male development. Female children tend to have stronger bones (vertebrae, skull), ligaments and muscles (Arbogast et al. 2013; Pang, 2004). Young females are better structured to withstand the high forces generated in MVCs (Pang, 2004). Table 3-6 indicates that in the older male and female populations, the odds of sustaining head injuries is similar (OR=0.98) consistent with a similar stage of development in these groups. A similar prevalence (37% for males vs 38% for females) was also observed again supporting the aforementioned. In contrast to the wide variability of the odds of sustaining head injuries, there was less variability in the confidence interval (0.314 to 3.057) in the older males and females. Though these findings are statistically insignificant, they still show a trend to higher odds in males in the younger age group. As the sample is small, this could be a confounding variable. The higher odds of male injury support recent studies that anatomical factors play a role.

In contrast, Table 3-7 shows a different trend in the odds ratio for neck injuries in the younger (0.55) and older (0.86) male populations. They had less odds of sustaining neck injuries compared to females. The male population had a slightly lower prevalence and a wider range in the confidence interval. These observations do parallel the findings of Arbogast et al (2013) which indicated that fatal cervical spine injuries were increased in females. These authors stated that development of deeper facet joints, stronger cervical ligaments, larger spinous processes and larger vertebrae allowed younger females a larger range of motion and helical axial rotation for the cervical spine when compared to older females and younger males and could predispose to injury (Arbogast et al 2013, Greaves et al. 2009). The high number of side impacts (30) and sideswipes (6) in our study were notable and may also have been a factor. These types of impacts result in a higher risk of injury and death in pediatric occupants of MVCs (Arbogast et al. 2013).

Tables 3-8 and 3-9 indicate the specific influence of age within each gender population. For both genders, head injuries had higher odds of occurring in the younger populations, 2.38 in males and 1.67 in females. Although none of these findings are statistically significant because of their confidence intervals, the observed pattern follows that of recent studies, which indicate that young age groups are predisposed to higher odds of fatal head injuries (Ghanem et al. 2008; Pang, 2004).

In contrast, as shown by Tables 3-10 and 3-11, neck injuries for younger populations in both genders compared to older age groups have considerably lower odds of occurring and a very low variability based on their respective confidence intervals. The low variability of neck injuries for both sexes is an accurate reflection of our findings in these groups. Future studies to further increase our knowledge about neck injury causation in motor vehicle collisions will help improve the bio-fidelity of pediatric crash test dummies and restraint system designs that provide greater protection for neck injuries.

4.3   Are the odds sustaining head and cervical spine injuries in pediatric motor vehicle occupants different from pedestrians?

Seventy-seven passengers and 19 pedestrians were compared to determine the odds of head and cervical spine injuries within these populations. The pedestrian group acted as a control group. Children struck by vehicles have no limitations on head movement until their heads hit the vehicle or road surface. However, pediatric passengers, particularly the younger age group, are more likely to have limitations of head movement because of restraint systems. A comparison of age groups (0 to 3 years and 4 to 12 years) of passengers and pedestrians provided not only the odds of sustaining head and cervical spine injuries in these respective groups but also the influence that age had on sustaining these injuries.

Table 3-12 indicates a higher prevalence of head injuries among both younger and older pedestrians compared to the passenger population. The odds of sustaining a head injury among the 4-12 year old pedestrian population were 4.04 times more likely. These odds are statistically significant because the 95% confidence interval did not include 1 (95% CI=1.23-13.26). The odds and prevalence of sustaining head injuries in pedestrians compared to passengers in this study supports the results by Arbogast et al. (2013). This study found that head injuries were common in both passengers and pedestrians.

Table 3-13 shows the prevalence of neck injuries among pedestrians and passengers. Younger and older passengers had a higher prevalence of neck injuries (18% and 31%, respectively) when compared to similar age groups of pedestrians. The odds ratio of the young pedestrians compared to the young passengers was zero and not interpretable because the sample size was small (0/2). This likely reflects the development of these children and their inability to walk and run into traffic. An odds ratio of 0.47 was calculated for the 4-12 year group. The odds of sustaining neck injuries among pedestrians compared to passengers was 0.47 times less likely; however, these findings are not statistically significant because the 95% confidence interval (0.118-1.86) includes 1.

The pedestrians in our study had a higher prevalence of sustaining head injuries in both younger and older children. A statistically significant odds ratio of 4.04 for head injuries among pedestrians compared to occupants can be attributed to direct head contact by pedestrians with the hood or front grill of the impacting vehicle. The lower prevalence of head injuries in passengers was likely due to the reduction of head contact, by various CRSs, an observation made by others (Arbogast et al.2013). Although the neck injury analyses are not statistically significant, they do indicate a trend. The higher prevalence and odds of sustaining neck injuries among passengers may be related to the design of CRSs. These restraint systems do reduce head contact. The findings in the present study imply that, although CRSs limit the movement of the child's torso, the neck is relatively free to move (Arbogast et al 2013). Neck excursion during a MVC coupled with relatively large head of a child causes exponential torque forces on the proportionally small neck (Arbogast et al 2013). In addition, the kinematics (range of motion) of the cervical spine in young children has a large effect on injury risk and prevalence (Greaves et al. 2009).

4.4 Conclusion

The present study was limited by the retrospective database available for this project. Information about variable controls such as vehicle collision details, seating position of infant and type of restraint was lacking. This was likely a reflection of the multi-source input by the various medicolegal death team investigators - coroners, pathologists, police - involved. A future strategy to ensure a more complete database would be use of an uniform questionnaire template by medicolegal death investigators, such as appended as **Appendix B**. In the interim, because no single database in Canada provides the sufficient sample size quantity and quality of data to address all research issues in child passenger safety, reviews and statistical analyses of current databases in other provinces could determine whether the trends and associations seen in this study are replicated in other jurisdictions.

In conclusion, the findings of this study indicated passengers compared to pedestrians had a higher chance of sustaining neck injuries but significantly lower odds of sustaining head injuries. Among motor vehicle occupants, younger males had higher odds of head injuries but lower odds of neck injuries when compared to the female population. In addition, the younger populations for both genders had a higher odds of head injuries and lower odds of neck injuries. This may be indicative of a relatively independent relationship between head and cervical spine injuries as observed in this study. The results of this study can further add to the current epidemiological information on the association of fatal head and cervical spine injuries in children. This study emphasizes that postmortem investigations of these deaths must consider neck injuries as a significant contributing factor in children dying in motor vehicle collisions. Appreciation of the association between head and cervical spine injuries provides a broader understanding of their relationship in the context of the design of child restraint use and systems, development of crash test dummies with better bio-fidelity and acquisition of more complete and uniform prospective databases with the use of a standardized investigative questionnaire by coroner's and medical examiner's offices.

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Appendix A: Filemaker Database

File components:

Tab 1

Coroner investigation statement

- Case number (number)
- Subject personal details (date) (DOB-converted to age in years and months)
- Investigation details (text)
- Environment (drop down)
    - Primary (text)
    - Secondary (text)
    - Tertiary (text)
- Involvement (other factors involved with the accident; alcohol, drugs) (text)
- Reports ordered (text)
- Pathologist name (text)
- Medical cause of death (text)
- Due to – cause of death (text)
- Coroners narrative about the situation (text)
- Coroners recommendations (text)

Tab 2

Pathology report

- Age (number)
- Sex (text)
- Height (text)
- Weight (text)
- Direct quotes (text)
- Date of death (date)
- Date of autopsy (date)
- Direct quotes (text)
- Preexisting conditions (text)

Injury 1: (choice of yes or no)

Yes   No

(if yes)

- Body region (drop down)

  - Head

  - Face

  - Neck

  - Thorax

  - Abdomen

  - Spine

  - Upper Extremity

  - Lower Extremity

  - Unknown

- Type of anatomic structure (drop down)

  - Whole area

  - Vessels

  - Nerves

  - Organs

  - Skeletal

  - Head

  - Skin

-                           Nature: (text)

-                           Aspect: (drop down)

  - 1. Right

  - 2.Left

- 3.Bilateral

- 4. Central

- 5. Anterior

- 6. Posterior

- 7. Superior

- 8. Inferior

- 9. Unknown

- 0. Whole region

- Severity code: (drop down)

    - 1. Minor

    - 2. Moderate

    - 3. Serious

    - 4. Severe

    - 5. Critical

    - 6. Maximum

    - 7. Injured Unknown Severity

- Ancillary tests (text)

- Summary (text)

- Cause of death (text)

- Therapeutic Interventions (text)

AIS Code (small text box)

AIS Description (medium text box)

ISS Code: (small text box)

Tab 3

Police report

- Date of collision (date)
- Time of collision (text)
- Location/municipality (text)
- Position/direction of traffic (text)
- Collision information; sequence of events (text)
- Occupant compartment intrusion (text)
- Position of seat of victim (drop down) (front middle, front passenger, back seat right, back seat left, back seat middle, third row right, third row middle, third row left)
- Restraint use (text)
- Airbag: (radio buttons, ability to choose more than 1)

-       -present

-       -absent

-       -deployed

-       -non-deployed

-       - unknown

- Reports of other investigative agencies (text)
- Other agency follow up

DRIVER TAB TABLE

Driver

Age: (number)

DOB: (date)

Sex: (Drop Down)

     -male

-female

Relationship to victim: (drop down)

-mother

-father

-grandparent

-other relative

-not related

Intoxicated: (Drop Down)

-yes

-no

-unknown

Injured: (drop down)

-K – Fatal

-A – Severe

-B – Moderate

-C – Mild

-0 – None (this is a zero not the letter O)

Restraint: (drop down)

-yes

-no

-unknown

Airbag: (radio buttons, ability to choose more than 1)

-present

-absent

-deployed

- non-deployed

- unknown

Other Occupant 1:

Age: (number)

DOB: (date)

Sex: (Drop Down)

-male

-female

Seat Position: Text box – small

Injured: (drop down)

-K – Fatal

-A – Severe

-B – Moderate

-C – Mild

-0 – None (this is a zero not the letter O)

Restraint: (drop down)

-yes

-no

-unknown

Airbag: (drop down)

-present

-absent

-deployed

- non-deployed

-unknown

Other Occupant 2:

Age: (number)

DOB: (date)

Sex: (Drop Down)

-male

-female

Seat Position: Text box – medium

Injured: (drop down)

-K – Fatal

-A – Severe

-B – Moderate

-C – Mild

-0 – None (this is a zero not the letter O)

Restraint: (drop down)

-yes

-no

-unknown

Airbag: (drop down)

-present

-absent

-deployed

- non-deployed

-unknown

Other Occupant 3:

Age: (number)

DOB: (date)

Sex: (Drop Down)

-male

-female

Seat Position: Text box – medium

Injured: (drop down)

-K – Fatal

-A – Severe

-B – Moderate

-C – Mild

-0 – None (this is a zero not the letter O)

Restraint: (drop down)

-yes

-no

-unknown

Airbag: (drop down)

-present

-absent

-deployed

- non-deployed

-unknown

(Subsequent) Police report tab

Impact_Location

01-Within intersection

02-Thru lane

03-Left turn lane

04-Right turn lane

05-Right turn channel

06-Two-way left turn lane

07-Passing lane

08-Left shoulder

09-Right shoulder

10-Not on roadway-left side

11-Not on roadway-right side

12-Off highway

99-Other

Accident_Location Text:

01-Non intersection

02-Intersection related

03-At intersection

04-At/near private drive

05-At railway crossing

06-Underpass or tunnel

07-Overpass or bridge

08-Off highway-trail

09-Off highway-Frozen lake or river

10-Off highway-Parking lot

98-Other

99-Off highway-other

Environment_Condition

    01-Clear

    02-Rain

    03-Snow

    04-Freezing rain

    05-Drifting snow

    06-Strong wind

    07-Fog, mist, smoke, dust

    99-Other

Light Text Indexed, Allow user to override validation, Value List (Custom Values):

    01-Daylight

    02-Daylight, artificial

    03-Dawn

    04-Dawn, artificial

    05-Dusk

    06-Dusk, artificial

    07-Dark

    08-Dark, artificial

    99-Other

Light

    01-Daylight

    02-Daylight, artificial

03-Dawn

04-Dawn, artificial

05-Dusk

06-Dusk, artificial

07-Dark

08-Dark, artificial

99-Other

Traffic_control

01-Traffic signal

02-Stop sign

03-Yield sign

04-Ped. crossover

05-Police control

06-School guard

07-School bus

08-Traffic gate

09-Traffic controller

10-No control

99-Other

Traffic_Control_Condition

01-Functioning

02-Not functioning

03-Obscured

04-Missing/damaged

Road_Character

01-Undivided-one-way

02-Undivided-two-way

03-Divided with restraining barrier

04-Divided-no barrier

05-Ramp

06-Collector lane

07-Express lane

08-Transfer lane

Vehicle_Type

01-Automobile, station wagon

02-Motorcycle

03-Moped

04-Passenger van

05-Pick-up truck

06-Delivery van

07-Tow truck

08-Truck-open

09-Truck-closed

10-Truck-tank

11-Truck-dump

12-Truck-car carrier

13-Truck-tractor

14-Municipal transit bus

15-Intercity bus

16-Bus (other)

17-School bus

18-School van

19-Other school vehicle/bus

20-Motor home

21-Off-road-2 wheels

22-Off-road-3 wheels

23-Off-road-4 wheels

24-Off-road-other

25-Motorized snow vehicle

26-Farm tractor

27-Other farm vehicle

28-Construction equipment

29-Railway train

30-Street car

31-Snow plow

32-Ambulance

33- Fire vehicle

34-Police vehicle

35-Other emergency vehicle

36-Bicycle

00-Unknown

98-Truck-other

99-Other

Vehicle_Condition

01-No apparent defect

99-Defect

Apparent_Driver_Action

01-Driving properly

02-Following too close

03-Exceeding speed limit

04-Speed too fast for condition

05-Speed too slow

06-Improper turn

07-Disobey traffic control

08-Failed to yield right of way

09-Improper passing

10-Lost control

11-Wrong way on a one-way road

12-Improper lane change

99-Other

Driver_Pedestrian_Condition

01-Normal

02-Had been drinking

03-Ability impaired, alcohol (over .08)

04-Ability impaired, alcohol

05-Ability impaired, drugs

06-Fatigue

07-Medical or physical disability

08-Inattentive

00-Unknown

99-Other

Pedestrian_Action

01-Crossing with right of way

02-Crossing without right of way

03-Crossing-no traffic control

04-Crossing ped crossover

05-Crossing marked crosswalk without right of way

06-Walking on roadway with traffic

07-Walking on roadway against traffic

08-On sidewalk or shoulder

09-Playing or working on highway

10-Coming from behind parked vehicle or object

11-Running onto roadway

12-Person getting on/off school bus

13-Person getting on/off vehicle

14-Pushing/working on vehicle

99-Other

Initial_Direction_Travel

01-North

02-South

03-East

04-West

Initial_Impact_Type

01-Approaching

02-Angle

03-Rear end

04-Sideswipe

05-Turning movement

06-SMV unattended vehicle

07-SMV other

99-Other

Vehicle_Manoeuver

01-Going ahead

02-Slowing or stopping

03-Overtaking

04-Turning left

05-Turning right

06-Making "U" turn

07-Changing lanes

08-Merging

09-Reversing

10-Stopped

11-Parked

12-Disabled

13-Pulling away from shoulder or curb

14-Pulling into shoulder or toward curb

00-Unknown

Location_Vehicle_Damage

01-Right front corner

02-Right front

03-Right centre

04-Right rear

05-Right rear corner

06-Back centre

07-Left rear corner

08-Left rear

09-Left centre

10-Left front

11-Left front corner

12-Front centre

13-Front complete

14-Right side complete

15-Back complete

16-Left side complete

17-Top

18-Undercarriage

19-No contact

00-Unknown

Injury_Fatal_Accident

01-Involved driver/passenger

02-Investigating officer

03-Witness

Safety_Equipment_Used

1-Lap and shoulder belt

2-Lap belt only

3-Lap belt only of combined assembly

4-Child safety seat used incorrectly

5-Child safety seat used correctly

6-Air bag deployed

7-Other passive restraint device

8-Helmet

9-Equipment not used but available

10-No equipment available

00-Use unknown

99-Other safety equipment used

Ejection

     1-Yes

     2-Partial

     3-No

Position_In_Car

     1-Driver

     2-Front middle

     3-Front passenger

     4-Middle left passenger

     5-MIddle middle passenger

     6-Middle right passenger

     7-Rear middle passenger

     8-1-Left Hanger-on

     8-2-Left-front Hanger-on

     8-3-Right-front Hanger-on

     8-4-Right Hanger-on

     9-Pedestrian

     10-Sitting on lap

Injuries_New

     0-None

     1-Minimal

     2-Minor

3-Major

4-Fatal

Sequence_Events Text

01-Within intersection

02-Thru lane

03-Left turn lane

04-Right turn lane

05-Right turn channel

06-Two-way left turn lane

07-Passing lane

08-Left shoulder

09-Right shoulder

10-Not on roadway-left side

11-Not on roadway-right side

12-Off highway

99-Other

Impact Location

01 Within intersection

02 Thru lane

03 Left turn lane

04 Right turn lane

05 Right turn channel

06 Two way left turn lane

07 Passing lane

08 Left shoulder

09 Right shoulder

10 Not on roadway – left side

11 Not on roadway – right side

12 Off highway

99 Other

Vehicle Damage

01 None

02 Light

03 Moderate

04 Severe

05 Demolished

Other agency follow-up

ACCIDENT DIAGRAM TAB

Delta V _____ km/h (small text box)

Aspect _____ (small text box)

Crush _____ cm (small text box)

Intrusion _____ cm (small text box)

Location_____ (small text box)

CASE VEHICLE TAB TABLE

Tab 1 Case Vehicle
- o Case vehicle Speed
- o Posted speed limit
- o make
- o model
- o year
- o VIN

Tab 2 Vehicle 2
- o Vehicle Speed
- o Posted speed limit
- o make
- o model
- o year
- o VIN

Tab 3 Vehicle 3
- o Vehicle speed
- o Posted speed limit
- o make
- o model
- o year
- o VIN

Tab 4 Vehicle 4
- o Vehicle speed
- o Posted speed limit
- o make
- o model
- o year
- o VIN

Tab 5 Vehicle 5

- o Vehicle speed
- o Posted speed limit
- o make
- o model
- o year
- o VIN
- o
- o

Appendix B: Child Fatality-Study Motor Vehicle Collisions

Child Fatality Study - Motor Vehicle Collisions

Decedent Details

Sex: ○ Female   ○ Male

Age   _____

Date of death (yyyy-mm-dd)_____   Height (cm)   _____

Head circumference (cm)_____   Weight (kg)   _____

☐ Death at the scene

☐ Death upon admission to hospital (i.e., in Emergency Department)

☐ Death in hospital after treatment

Decedent Injuries

Medical cause of death (MCOD):

_____

Indicate all areas of injury (MCOD)	Yes	No	Describe (Physical and **radiographic** findings)
o Craniocerebral trauma	☐	☐	_____
o C-Spine trauma	☐	☐	_____
o Thoracic trauma	☐	☐	_____
o Abdominal trauma	☐	☐	_____
o Pelvic trauma	☐	☐	_____
o Extremity trauma	☐	☐	_____
Other	☐	☐	_____

All Other Injuries

Summary of all injuries observed (Include both physical and **radiographic** findings)

Craniocerebral:_____

_____

C-Spine_____

_____

Thoracic_____

_____

Abdominal _____

_____

Pelvic _____

_____

Extremity_____

_____

Other_____

_____

_____

○   Occupant   ○   Pedestrian

1

Child Fatality Study - Motor Vehicle Collisions

Vehicle Information

1. Restraint (tick off all that apply) (include photo of seat if possible)

	Rear-facing infant seat		Lap belt only
	Forward-facing infant seat		Lap and shoulder belt
	Rear-facing child safety seat		Restraint available but not used
	Forward-facing child safety seat		No equipment available
	Booster seat		Unknown

2. Position of child in vehicle (include photo of seat if possible)

	Driver		Front middle		Front right
	Backseat left		Backseat middle		Backseat right
	3rd row left		3rd row middle		3rd row right
	Bed of pick up		Trunk		Other:

Decedent's Vehicle Type

	Automobile		Railway Train	Specify model/make/year:
	Passenger Van		Tractor Trailer	
	SUV		Pick Up Truck	
	School Bus		Other:	

Vehicle 2 Type (i.e., type of vehicle which collided with decedent's vehicle)

	Automobile		Railway Train	Specify model/make/year:
	Passenger Van		Tractor Trailer	
	SUV		Pick Up Truck	
	School Bus		Other:	

Coroner's narrative on preventability:

_____
_____
_____
_____
_____

Collision reconstruction done?   ○ Yes   (if yes, please include) ○ No

Collision sequence of events:

_____
_____
_____
_____
_____
_____
_____

2

Curriculum Vitae

PERSONAL INFORMATION:

Name   Shayan Shekari

EDUCATION:

2012-09 -   Masters of Science

                              Western University, London ON

                              Field/Discipline: Pathology

                              Thesis title: ASSOCIATION OF HEAD AND CERVICAL   SPINE
INJURIES IN PEDIATRIC OCCUPANTS INVOLVED IN MOTOR
VEHICLE COLLISIONS

                              Thesis advisor: Michael Shkrum, MD

2008-09 – 2012-05   Bachelor of Sciences

                              University of Toronto, Scarborough ON

                              Field/Discipline: Biology

LAB EXPERIENCE

2011-2012	Undergraduate Research Assistant – Adenosine effect on discontinuous breathing in cane toads.

-Injection of Adenosine into Cane Toads

-Capture and Stitch on Live Cane Toads

-Recording and Analysis of Breath Data

DISTINCTIONS, HONOURS, FELLOWSHIPS, SCHOLARSHIPS:

2010-2011	Dean's Honours List, B.Sc
	University of Toronto, Scarborough ON
2011-2012	Dean's Honours List, B.Sc
	University of Toronto, Scarborough ON

VOLUNTEERING AND OTHER PROFESSIONAL WORK EXPERIENCE:

2012-09 -	Masters of Science
	Western University, London ON
	Field/Discipline: Pathology
	Thesis title: **Association of Head and Cervical Spine Injuries in Pediatrics Involved in Motor Vehicle Occupants**

Thesis advisor: Michael Shkrum, MD

2011-09 – 2012-08	Volunteer, Mackenzie Health
	Markham ON
2011-09 – 2012-08	Volunteer, Mackenzie Health Information Desk
	Markham ON
2011-03 – 2012-03	Volunteer, Brain Day
	Scarborough ON
2011-05 – 2011-08	Undergraduate Research Assistant
	Supervisor: Dr. Stephen Reid
	Department of Biological Sciences
	University of Toronto, Scarborough ON

ARTICLES PUBLISHED AND IN PREPARATION

The American Journal of Forensic Medicine and Pathology or Journal of Forensic Sciences
Shekari S, Shkrum MJ, Howard A. Association of Head and Cervical Spine Injuries. Western University, London ON.

In Preparation

Comparative Biochemistry and Physiology Part C: Pharmacology, Toxicology and Endocrinology

Shekari S, Reid SG, Peters A. The Adrenergic Stress Response in Cane Toads. Comparative Biochemistry and Physiology Part C: Pharmacology, Toxicology and Endocrinology, University of Toronto, Scarborough ON.

In Preparation

ABSTRACTS and PROFESSIONAL PRESENTATIONS:

Annual Pathology Day Presentation

Shekari S, Shkrum MJ, Howard A. Association of Head and Cervical Spine Injuries. Presented at the Annual Pathology Research Day, Western University, London ON. April 2013-April 2014.

Department of Pathology Journal Club Seminars

Shekari S, Shkrum MJ, Howard A. Association of Head and Cervical Spine Injuries. Presented at the Annual Pathology Research Day, Western University, London ON.

September 2013 – September 2014.

2014 Annual AUTO21 Conference

Shekari S, Shkrum MJ, Howard A. Association of Head and Cervical Spine Injuries.

Presented at the 2014 Annual AUTO21 conference, Niagara Falls, ON. May 2014.