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TECHNICAL NOTE

PATHOLOGY AND BIOLOGY

Anthony Sgarlato,[1] *M.D. and Stephen J deRoux,*[1,2] *M.D.*

Motor Vehicle Occupants, Neck Injuries, and Seat Belt Utilization: A 5-Year Study of Fatalities in New York City

ABSTRACT: Despite the implementation of numerous safety devices in automobiles, vehicular occupant fatalities following collisions remain common. We reviewed all fatalities of vehicular occupants in New York City over a 5-year period on whom autopsies were performed (437) to determine the incidence of neck injuries and correlate them with seat belt utilization; 26.5% had neck injuries (mild to severe) and only 10.3% of these occupants were confirmed to be wearing seatbelts. Of those that had documentation of seat belt utilization there were twice as many neck injuries in the unbelted group. We highlight two cases of submarining with severe neck injuries that were related to automatic 2-point shoulder harness restraints without engagement of the lap belt.

KEYWORDS: forensic science, motor vehicle accident, neck injuries, airway injuries, cervical trauma, submarine effect, seat belt injuries

Complex mechanical forces occur in motor vehicle accidents. During deceleration, tremendous forces are rapidly dissipated. Currently available restraint systems significantly reduce the risk of injury, notably during frontal impact; however, improved engineering has not completely eliminated the risk of injury or death. Reduced speed limits, mandated crumple zones, head restraints, airbags, and seat belt utilization all have contributed to lives saved (1). Despite these measures, cervical injuries continue to represent a large number of those fatally injured. A retrospective study of vehicular accidents in the five boroughs of New York City was undertaken to elucidate the incidence and types of cervical injuries sustained in fatal automobile accidents. Seat belt utilization also was evaluated.

Methods and Materials

All deaths of vehicular occupants occurring in New York City from February 1, 1997 to January 31, 2003 were compiled using a computer-based search of the New York City Medical Examiner's Office. Investigative and autopsy reports were reviewed for all cases. Excluded from the study were fatally injured vehicular occupants on whom no autopsy was performed, as were those involved in a motor vehicle accident remote to their time of death but who subsequently died from complications of their injuries. A patient in an ambulance who was restrained on a stretcher at the time of the collision was also excluded. Neck injuries were classified by severity. Three categories were defined based on the most severe injury for each case: mild (abrasions, contusions, and lacerations of soft tissue structures), moderate (injuries to cervical vertebral ligaments or disks, airway fractures, and nondisplaced cervical vertebral fractures), and severe (displaced cervical vertebral injuries, spinal cord injuries, vascular, and/or airway lacerations). Police accident reports and emergency services reports were reviewed to determine if the occupant was wearing a seat belt at the time of impact.

Results

Over the 5-year period of the study there were 468 fatalities involving occupants of motor vehicles in New York City. Autopsies were conducted on 437 of these victims. Of these, 321 had no neck injuries. Of the 116 that had neck injuries 80 (69%) had no documentation of seat belt utilization, 12 (10.3%) were confirmed to be wearing seat belts, and 24 (20.7%) were not belted at the time of impact. Of the 36 cases in which seat belt use was documented there were twice as many injuries (mild to severe) in those who were unbelted (Table 1).

Of the cases reviewed, two unique injuries are highlighted here. Of the eight people that had severe neck injuries and who were confirmed to be belted at the time of impact two (25%) incurred their injuries as a result of utilizing a 2-point automatic seat belt, without the lap portion (third point) being engaged. One was a 23-year-old man who was driving a 1990 Acura Integra at an excessive speed (accident reconstruction estimated a speed of 72 mph in a 30 mph zone) when he lost control and struck a utility pole. Despite the 2-point restraint (Fig. 1), the driver was ejected from the vehicle and his passenger was partially ejected. Both were pronounced dead at the scene. At autopsy the driver was found to have a patterned abrasion of the left neck and upper torso consistent with the shoulder harness (Fig. 2). There was a gaping tracheal laceration (Fig. 3). In addition, there was a displaced fracture of the odontoid process with disarticulation of cervical vertebrae numbers 1 and 2 and transection of the upper cervical spinal cord. The other was a 63-year-old woman who was a front seat passenger in a

[1]New York City Office of Chief Medical Examiner, New York, NY 10016.
[2]Department of Forensic Medicine, New York University, School of Medicine, New York, NY 10016.

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TABLE 1—*Case by severity and seat belt utilization.*

	Cases	Belted	Unbelted
Mild	9	3	6
Moderate	4	1	3
Severe	23	8	15
Total	36	12	24

FIG. 1—*1990 Acura Integra showing drivers side after the collision. The 2-point restraint is intact. The lap belt is not engaged.*

FIG. 2—*Driver of the Acura Integra showing the patterned abrasion extending across the left side of his neck and diagonally across the upper torso. Scale is in inches.*

1991 Toyota Camry LE that rear-ended a stationary city bus. Upon extrication from the vehicle she was in cardiac arrest. She was noted to have subcutaneous emphysema and a right chest needle decompression was performed. On arrival at the emergency room, bilateral chest tubes were inserted. However, resuscitation efforts were not successful and she was declared dead shortly after arrival at the hospital. At autopsy she was found to have a patterned abrasion of the anterior and right neck, consistent with being caused by the 2-point shoulder harness restraint. Her larynx was transected just above the cricoid cartilage. The body and superior horns of the thyroid cartilage were fractured. There was a fracture of cervical vertebra number 2 with separation of the dens from the body. In addition, she incurred numerous rib, sternal, pelvic, and long bone fractures.

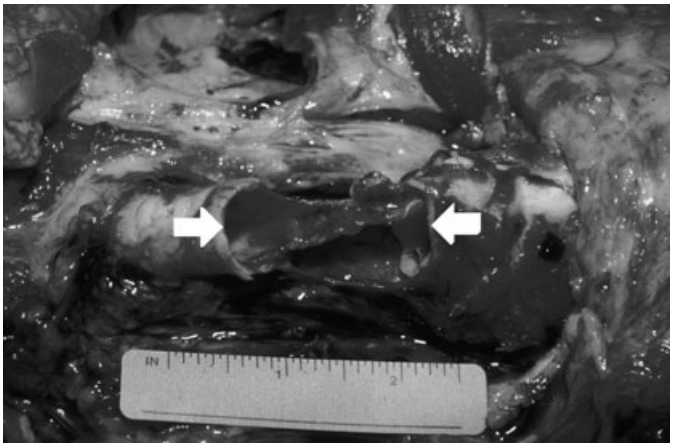

FIG. 3—*Autopsy neck dissection showing the lacerated trachea and associated neck hemorrhage. The ends of the lacerated trachea are highlighted by the arrows. Scale in inches.*

Discussion

Traffic accidents are the most common cause of cervical injuries (2–6). Of the 437 fatalities reported here due to motor vehicle collisions 26.5% had injuries to the neck (mild to severe). Bucholz et al. (7) found that 20% of automobile occupants who die in traffic accidents sustain cervical spine injury. Alker et al. (8) demonstrated cervical injuries in 21% of people dying in traffic accidents which included occupants of vehicles and pedestrians. In a study by Tonge et al. (9), of 453 fatalities of vehicular occupants, 18% had a neck injury (4.6% larynx and neck structures and 13.4% cervical spinal fractures and dislocations).

Seat belts were introduced in the 1950s. The first mandatory seatbelt law was enacted in 1984 in New York State. Since their introduction, the general use of safety belts has steadily increased. There are three types of seat belts in general use, the lap belt (2-point restraint) which normally prevents ejection, the shoulder harness (2-point restraint), and the combined shoulder harness lap belt (3-point restraint). The 3-point restraint is more effective than the 2-point restraining device in reducing occupant injury (10). The 3-point restraint is considered to fit correctly when the lap portion of the belt rides low over the hips, and the diagonal portion crosses the shoulder and is centered over the sternum. Seat belts have three main beneficial effects: they prevent ejection from the vehicle, they allow the occupant to decelerate with the car during the period of rapid deceleration following impact, and they prevent the second impact of the victim with the interior of the vehicle. However, secondary injuries may occur from forward trunk motion and compression against the safety restraints, thus exposing the occupant to additional injury.

The overall observed shoulder belt use in 2007 was 82%, compared to 71% in 2000, 69% in 1998, 61% in 1996, and 58% in 1994 (1). The use of the seat belt has resulted in marked reduction in mortality and morbidity in motor vehicle accidents. Three-point safety belts reduce the risk of fatal injury to front seat passengers by 45% and the risk of moderate to critical injury by 50% (1). Of significance in our review of neck injuries in New York City was the low number of cases, 36 out of 116 (31%), in which the documentation of the use of restraining devices was accomplished. However, of those that had documentation there were twice as many neck injuries sustained in those who were not belted.

In 1956, Kulowski and Rost (11) described an intra-abdominal injury due to impingement by a lap belt. The "seat belt syndrome"

later termed by Garrett and Braunstein (12) described lap belt injuries of the lower torso, including pelvic and lumbar spinal fractures and intra-abdominal injuries complicating deceleration of the victim's trunk by the harness. The "cervical seat belt syndrome" refers to injuries of the neck resulting from the diagonal shoulder sash of a 2- or 3-point restraint device. Taylor et al. suggested that diagonal neck bruising should arouse suspicion of cervical spinal trauma related to utilization of a seat belt (13). The two cases of severe neck injury highlighted above had patterned abrasions of the neck consistent with being caused by the shoulder harness thus supporting a statement by Huelke (14) that "when associated with neck trauma, shoulder belts invariably leave an abrasion along the side of the neck."

Neck injuries directly resulting from seat belts, both the shoulder harness 2-point (15–21) and the 3-point (13,16,22–29), have been reported. With the former restraints, the injuries run the spectrum from laryngeal contusions to decapitation and with the 3-point restraints, from minor laryngeal lacerations and contusions to cervical vertebral dislocation. In addition, asphyxiation resulting from shoulder harness 2- and 3-point seat belts has been reported (29–31). The risk of submarining (the occupant slides under the belt) is much lower in car occupants wearing 3-point restraints than in those wearing shoulder belts only when involved in head-on collisions. Saldeen (15) reported three individuals who were wearing only a diagonal belt (2-point restraint) at the time of impact. They exhibited severe neck injuries, including decapitation, that were attributed to the sharp edge of the belt when they slipped (submarined) out of their restraints while being ejected. Skold and Voigt (16) described eight cases of submarining in individuals wearing the 2-point diagonal restraint. They also described a case of submarining in a person wearing a 3-point restraint. Spitz et al. (21) described four cases of fatal neck injury from 2-point restraints, still a rare occurrence. Our retrospective review of autopsies on 437 fatally injured motor vehicle occupants identified two cases (0.46%) of severe neck injury associated with patterned abrasions of the neck consistent with submarining under automatic 2-point restraints. Both demonstrated airway lacerations and cervical vertebral fractures. In one case the cervical spinal cord was transected.

Automatic 2-point restraints were introduced in an attempt to increase compliance with seat belt requirements. However, to be effective, the lap portion must be engaged to convert it to a 3-point restraint system. Automatic 2-point shoulder restraints are no longer manufactured. However, because they were widely used in the recent past, millions of motor vehicles are still equipped with this type of seat belt (21). Owners of these vehicles are at risk of injury if the lap belt is not secured and they should be educated about the dangers and how to prevent serious injury from inappropriate use.

Serious or fatal injuries to car drivers and passengers occur most frequently in head-on collisions. Safety devices in automobiles are integral to the prevention of serious injury and death when used as designed. There are several mechanisms that may result in neck trauma to occupants in motor vehicle collisions. There can be direct trauma to neck structures due to impact with the automobile interior or restraint devices. The anterior location of the larynx and trachea predispose them to injury in this manner. With the head and neck in the hyperextended position a compression fracture of the thyroid, cricoid, or tracheal cartilages may result following impact against the dashboard or steering wheel (2,3,32). In addition, hyperextension, hyperflexion, and torque of the neck during rapid deceleration may result in cervical spinal injuries. In addition, all types of seat belts are capable of producing injury, each with its own constellation of clinical and autopsy findings. However, few investigators would challenge the protective benefits of seatbelts in frontal collisions, their reduction in impact severity and diminution of the degree of injury. Despite reviewing all available data, only a minority of our cases had documentation of seat belt utilization. Routine reporting of safety device implementation in accident assessment must be emphasized to validate their effectiveness.

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Additional information and reprint requests:
Stephen deRoux, M.D.
Office of the Chief Medical Examiner of the City of New York
520 First Avenue
New York, NY 10016
E-mail: sderoux@ocme.nyc.gov