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CASE REPORT

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Neck Injuries Caused by Automatic Two-point Seat Belts: An Analysis of Four Cases

ABSTRACT: Although seat belts significantly reduce the extent and severity of injuries sustained by motor vehicle occupants, seat belts are known to be associated with chest and abdominal trauma. Less commonly understood are severe neck injuries caused by the use of two-point automatic shoulder harnesses without concurrent use of a manual lap belt. Such injuries may include cervical spine fractures, craniocervical dislocations and rarely decapitation. Recognizing patterned injuries caused by seat belts and the ability to correlate autopsy findings with the circumstances surrounding the death will allow for correct interpretation of seat-belt related trauma. The four cases described detail fatal neck injuries as a result of improper seat belt use in which an automatic two-point shoulder harness was used without a manual lap restraint. In two of the cases, the victims were decapitated.

KEYWORDS: forensic science, neck injuries, cervical trauma, spine fractures, decapitation, seat belts, seat belt injuries

Many years of research have shown that seat belts significantly reduce morbidity and mortality among motor vehicle occupants involved in motor vehicle collisions (MVC) (1–6). The engineering and design of safety belts have evolved over time, and currently most motor vehicles are equipped with a combination manual three-point shoulder and lap restraint, in addition to driver and front-seat passenger air bags. Automatic two-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. Chest and abdominal injuries have been clearly associated with automatic two-point shoulder restraints (3,7–10), however, it should be recognized that these type of seat belts also cause neck and cervical spine injuries. Documentation of patterned injuries on the neck and examination of the posterior neck to identify cervical fractures or ligament injuries are necessary to determine the mechanism of the trauma. Furthermore, although rare, it should be understood that automatic two-point shoulder restraints can cause decapitation.

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Case Reports

Case 1

The crash occurred at night on a lighted multilane roadway in a rural Midwest township. Involved in the collision was the case vehicle, a 1991 Eagle Summit, equipped with a manual two-point lap belt and an automatic two-point shoulder restraint. The principal other vehicle (POV) was a 1985 Dodge Caravan. The case vehicle was driven by a 16-year-old male who at the time of the crash was restrained using a two-point automatic shoulder restraint without engagement of the manual lap belt.

The POV was traveling north in the second lane at an estimated speed of 50 mph and the case vehicle was traveling south at an unknown speed. As the case vehicle proceeded south, the driver lost control of the vehicle on the wet pavement. The car rotated in a clockwise direction, crossed over the centerline and entered the northbound lanes. The case vehicle slid laterally into the northbound lanes directly into the path of the POV. The POV struck the case vehicle in the left rear door and quarter panel. This 270° impact (CDC: 09-LZAW-03) crushed the left side of the vehicle causing intrusion into the vehicle to a maximum depth of 14 in. After the initial impact the case vehicle rotated in a counterclockwise direction approximately 180° and came to a final rest position facing in an easterly direction across the second northbound lane.

At impact, the driver of the case vehicle moved to the left with respect to the decelerating vehicle, impacting the left front door with his left side. As the vehicle began to rotate in a counterclockwise direction, the driver continued to load the left front door, at which time the left front door latch mechanism failed allowing the door to open. In response to the centrifugal force, the driver was ejected from the vehicle. Because the driver was wearing only the two-point

FIG. 1—*Decapitation site with adjacent abrasion.*

shoulder harness, his neck and upper torso were anchored by the restraint, as his unrestrained hips and lower extremities continued to move. As the lower portion of the driver's body was ejected through the left front door, his neck and right axilla became further engaged by the shoulder restraint. The continued movement of the driver's body through the open door while his neck was anchored by the shoulder strap caused him to be decapitated. The driver's body was found 43 ft from his vehicle. The driver's head came to rest 55 ft from the vehicle and 12 ft from his body.

Injuries to the decedent included decapitation at the level of the third cervical intervertebral disc. The line of decapitation was oblique with an upward angle of approximately 45°. The strap muscles, trachea, esophagus, right and left common carotid arteries and the jugular veins were transected with clean edges as if incised. The neck skin immediately inferior to the decapitation site had a patterned injury consisting of a sharply demarcated abrasion and traumatic overstretching injuries indicating that the skin was stretched before the strap lacerated the skin (Fig. 1). Within the abrasion was a 1-cm area of non-abraded, intact skin that resulted from overlapping of the skin as it was pulled and stretched by the strap. Small course black fibers matching the material of the seat belt were recovered from the soft tissues at the decapitation site. The right arm and axilla had abrasions consistent with being caused by the shoulder restraint as it rubbed under the decedent's arm before being ejected from the car. The chest and abdominal organs were without injuries.

Case 2

The collision involved a 1993 Ford Escort Station Wagon equipped with a two-point automatic shoulder restraint and a two-point manual lap belt for each front seat occupant. The driver and front seat passenger were both using automatic two-point shoulder harnesses without the lap portion of the belt.

The crash occurred on a two lane residential roadway with a posted speed limit of 45 mph. The case vehicle was traveling south along the roadway that curved slightly to the left. For unknown reasons, the driver crossed the centerline and entered the northbound lane. He then struck a curb and departed the left side of the road. The vehicle continued across the lawn of a residential house and sideswiped an evergreen tree before crashing through a trimmed hedge. The front of the vehicle struck the corner of a residence causing the vehicle to rotate in a counterclockwise manner approximately 6 ft before coming to rest while still engaged with the house. The distance that the vehicle traveled from the departure point of the roadway to the impact with the residence was 83 ft.

The damage to the front of the vehicle started immediately to the right of the centerline and consisted of crumpling of the hood and intrusion into the front occupant compartment. The 12 o'clock direction of force (CDC: 12-FCEW-3) crushed the front structure of the case vehicle to an approximate depth of 24 in. There was moderate interior intrusion with the instrument panel and dashboard pushed rearward. The impact with the hedgerow failed to produce any significant damage to the vehicle, and the sideswipe contact with the tree was minimal. The change in velocity (ΔV) of the vehicle as it struck the house was estimated to be 30 mph.

Because the vehicle struck the corner of the house in a narrow frontal impact, there was no substantial frame structure to dissipate the crash energy until the crush damage was deep enough to contact the vehicle's engine. This effectively lengthened the crash pulse by approximately 40 ms, from the average of 120 ms to 160 ms. This long crash pulse affected the movement of the occupants inside the vehicle. At impact, as the vehicle began to decelerate, the occupants started to move forward loading the shoulder restraints. When the vehicle crushed against the house deep enough for the structure to contact the front of the engine, there was a rapid increase in the rate of deceleration. With the shoulder restraint completely loaded, the remainder of the collision energy was dissipated by the forward moving occupants.

At the point of impact with the hedgerow, the right front occupant of the vehicle began to move forward with respect to the principal direction of force. Because she was protected only by the automatic two-point shoulder restraint, her torso initially anchored against the shoulder restraint and her pelvis and lower extremities continued to move forward. The forward movement continued until her knees contacted and then became anchored by the glove compartment. When the vehicle contacted the corner of the house, the shoulder restraint raised up across her chest and then across her neck with the strap, being held at that level by her chin. When the vehicle reached maximum engagement with the house, the glove compartment door failed allowing the decedent's lower extremities and pelvis to underride or "submarine" beneath the right side of the dashboard. At this moment, the shoulder restraint would have been above her right shoulder and tightly anchored against her neck. As the victim submarined under the right side of the dashboard, the edge of the shoulder restraint cut into the decedent's neck causing a near complete decapitation. It should be noted that the driver of this vehicle was also killed. He too was wearing only the automatic two-point shoulder restraint and at autopsy the cause of death was determined to be lacerations of the heart and liver.

The near complete decapitation was associated with lacerations of the anterior neck muscles and transection of the trachea, esophagus, right and left common carotid arteries, jugular veins, cervical spine at the atlanto-axial membrane and cervical spinal cord. The skin at the back of the neck was intact and served to keep the head attached to the body. The angle of injury was upward at approximately 45°. Patterned injuries consisting of a broad abrasion and traumatic overstretching injuries were on the skin adjacent to the decapitation site (Fig. 2). The abrasion was confined to the front and left side of the neck.

Case 3

The case vehicle was a 1991 Ford Escort 4-door station wagon equipped with a two-point automatic shoulder restraint and a

FIG. 2—*Near decapitation with adjacent abrasion and overstretching injuries.*

FIG. 3—*Right front seat occupant "submarined" beneath the dashboard.*

two-point manual lap belt for each front occupant. In the car were the driver and a right front seat passenger. It was determined that at the time of the collision both occupants were using the automatic two-point shoulder harnesses without the manual lap belt.

The case vehicle was traveling in a northerly direction at an estimated speed of 45 mph. As the vehicle approached an intersection, the driver veered to the left in an attempt to avoid a collision with the other vehicle. This caused her to lose control of the vehicle, depart the roadway and collide with a tree.

Direct damage to the front of the case vehicle was located primarily in the midline. The 12 o'clock direction of force (CDC: 12-FCEN-2) crushed the frontal structures of the vehicle resulting in an estimated 10 in. of intrusion. The estimated ΔV for the impact was 15–18 mph, which was consistent with the severity of frontal damage sustained by the case vehicle.

Based on the on-scene investigation, it was apparent that the driver had applied the brakes prior to impacting the tree. This pre-impact braking caused the right front occupant to move forward in response to the vehicle's deceleration. As her chest loaded the shoulder restraint it became anchored, however, without a lap belt her pelvis and lower extremities continued to move forward. The victim's knees impacted the glove compartment and with continued forward movement, her right tibia and fibula fractured; this allowed her torso to "submarine" beneath the right side of the dashboard. The decedent was pronounced dead at the scene found slumped partially beneath the dashboard (Fig. 3). Upon arrival of rescue personnel, the driver of the vehicle was in stable condition.

From the injuries present on the decedent's torso, it appeared that she was wearing the shoulder restraint above the left breast. As she submarined forward, the shoulder restraint moved upward and impacted the front of her neck causing it to hyperextend.

At autopsy, the decedent had dashboard injuries on both knees and the right tibia and fibula had compound fractures. An abrasion was on the neck starting beneath the right ear and extending 3 cm left of the midline (Fig. 4). The trachea was transected through the cricoid cartilage and the second cervical vertebra had a dislocated fracture through the vertebral body at the base of the odontoid process. The carotid arteries and jugular veins were intact. The spleen and right lobe of the liver had superficial capsular lacerations.

FIG. 4—*Abrasion band on the neck caused by the shoulder harness of a two-point automatic seat belt.*

Case 4

The collision occurred on a rural state roadway. Involved in the crash was the case vehicle, a 1989 Toyota Camry LE equipped with a two-point automatic shoulder restraint and a two-point manual lap belt for each front passenger. The passenger was restrained with a two-point shoulder harness, and was not wearing the manual lap belt.

The case vehicle was traveling in a northerly direction in the right lane. For unclear reasons, the driver veered off the right side of the roadway, and at this point was traveling at a police estimated speed of 65–70 mph. As the driver steered back to the left in an attempt to re-enter the roadway, the vehicle rotated in a counterclockwise direction and slid laterally leading with the right side. The right side tires dug into the soft ground that bordered the east shoulder, and the vehicle overturned several times leading with the right side.

As the vehicle overturned, the right front occupant, who was protected only by the two-point shoulder restraint, was ejected from the vehicle as it rolled. As she was being ejected, the shoulder restraint engaged against her neck causing the fatal injuries. She was pronounced dead at the scene upon arrival of paramedics.

Autopsy demonstrated a gaping laceration across the anterior surface of the neck, with extension into the soft tissue and musculature at the base of the tongue. The laceration had a patterned

abrasion along its inferior margin consistent with being caused by the shoulder strap as it engaged and tightened in front of her neck. The thyroid cartilage was fractured and the neck had a craniocervical dislocation causing laceration of the brainstem at the pontomedullary junction. The diaphragmatic surface of the spleen had a 2.5-cm superficial laceration and the right and left sacroiliac joints and the pubic symphysis were dislocated.

Discussion

The use of safety belts by automobile occupants was initially suggested by Straith in the 1930's (11). Several studies in the following years convincingly showed that restraining devices were highly effective in reducing injuries and fatalities associated with a MVC. The idea that seat belts may themselves be responsible for injuries first came to light in 1956, when Kulowski reported a case in which the injury sustained by a motor vehicle occupant was attributed to the restraining device (12). In the past 45 years, numerous articles have described injuries associated with properly and improperly worn seat belts (3–5,7–21).

Over the years, automobile manufacturers and mechanical engineers have developed different types of seat belt systems designed to maximize usage and decrease injury (22). One way to accomplish this goal was to passively increase seat belt usage by motor vehicle occupants. To this end, one popular design consisted of a four-point seat belt system, incorporating an automatic two-point shoulder strap and a separate manual two-point lap belt (23). This restraint system and other automatic systems of similar design were widely implemented in 1987 secondary to federal mandate that called for passive restraints in all passenger vehicles. Since that time more than 27 million cars have been equipped with this type of restraint system (8,23–25). Approximately 10 million such cars are estimated to currently be in use throughout the United States (8).

The automatic two-point shoulder restraint was designed to increase usage and decrease head and facial injuries, however, shortly after this seat belt design was implemented, a pattern of injuries emerged (3). Motor vehicle occupants restrained with improperly worn seat belts may sustain a variety of injuries (26). A recent paper by Rivera et al. noted that use of an automatic two-point shoulder belt without concurrent use of a manual lap belt was associated with a significant increase in thoracic and abdominal injuries (8). Specific injuries associated with shoulder harnesses included rib, sternal and clavicular fractures, thoracic and lumbar spine fractures, spinal cord injuries, and lacerations of the diaphragm, liver, spleen, kidney, heart and lungs (7,8,13–15,17–19). The majority of literature dealing with seat belt injuries describe intra-abdominal trauma, most commonly lacerations of the liver and spleen (9,10). Neck injuries caused by two-point automatic shoulder belts are less common than thoracic and abdominal trauma, however, several reports have described cervical spine fractures, carotid artery injuries and tracheal transaction (13,15,20,23,24). Yarbrough et al. described a case in which a motor vehicle occupant submarined under the shoulder restraint and sustained a fracture of the second cervical vertebra. The front impact collision and lack of a properly secured lap restraint allowed the victim's body to be propelled forward while her neck became anchored by the shoulder harness (18).

Seat belt associated neck injuries typically involve one of the following mechanisms. During a front impact collision, the neck is injured as the body "submarines" forward and underneath the shoulder harness causing the head and neck to hyperextend while being anchored against the strap of the shoulder restraint. In both front and side impact collisions, the neck may become snared by the shoulder restraint as the victim is ejected through the side door of the vehicle (8,13–17).

Decapitation associated with seat belts is extremely rare and a search of the English literature revealed one case report by Saldeen in 1967 that described two cases of decapitation caused by a shoulder harness. In both cases, the occupants were ejected from the vehicle (13). The two seat belt associated decapitation deaths described in this report are the only other known cases in the English literature.

From the physical evidence and kinematic data associated with our cases as well as other studies, decapitation most likely results when: (1) the shoulder harness anchors the neck as the victim is ejected from the vehicle; or (2) when the victim "submarines" forward and downward along the crash vector, with the head and neck becoming fixed against the diagonal shoulder restraint. As the shoulder restraint engages the neck, continued movement of the victim causes the harness to tighten as it abrades and stretches the anterior surface of the neck. As the body continues to submarine forward or as the body is ejected, the neck skin and soft tissue may be lacerated as the shoulder harness becomes anchored under the chin. The location and direction of the abrasion and the location of the overstretching injuries indicates that the direction of the force imparted by the shoulder harness is from inferior to superior leading up to the level of the laceration. Recognition of these patterned injuries will help reconstruct the scene and allow correct interpretation of the injury mechanism.

Conclusion

Restraining devices, including automatic shoulder harnesses' reduce morbidity and mortality associated with MVC, however, the use of an automatic two-point shoulder harness without concurrent use of a lap belt may be associated with severe neck trauma including cervical spine fractures and rarely decapitation.

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