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ON-SITE SIDE IMPACT INFLATABLE OCCUPANT PROTECTION INVESTIGATION

CASE NUMBER - IN99-071
LOCATION - ILLINOIS
VEHICLE - 1999 TOYOTA AVALON XLS
CRASH DATE - April, 1999

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The crash investigation process is an inexact science which requires that physical evidence such as skid marks, vehicular damage measurements, and occupant contact points be coupled with the investigator's expert knowledge and experience of vehicle dynamics and occupant kinematics in order to determine the pre-crash, crash, and post-crash movements of involved vehicles and occupants.

Because each crash is a unique sequence of events, generalized conclusions cannot be made concerning the crashworthiness performance of the involved vehicle(s) or their safety systems.

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15. <i>Supplementary Notes</i> On-site side air bag deployment investigation involving a 1999 Toyota Avalon XLS, four-door sedan, with manual safety belts and dual front and front side air bags, which ran-off-road into a fixed object (i.e., culvert)					
16. <i>Abstract</i> This report covers an on-site investigation of a side air bag deployment crash that involved a 1999 Toyota Avalon XLS (case vehicle) which ran-off-road and impacted a fixed object (i.e., a culvert/embankment). This crash is of special interest because the case vehicle was equipped with side impact air bags and the case vehicle's front right passenger (32-year-old male) sustained a serious chest injury in the right side impact, resulting in his death. The case vehicle was traveling east-southeast in the eastbound lane of a two-lane, undivided, county roadway and was negotiating a left-hand curve when the driver lost control and the case vehicle went into a counterclockwise yaw, crossed the westbound lane, and departed the north side of the roadway just prior to impact. The right side of the case vehicle impacted a metal culvert/embankment, causing the case vehicle's right front, side impact air bag to deploy. After the impact the case vehicle continued to rotate counterclockwise and traveled over a gravel drive. The back of the case vehicle impacted the drainage ditch on the east side of the drive where it came to rest. The case vehicle's front right passenger was seated with his seat track located between its middle and rearmost positions and he was restrained by his available, active, three-point, lap-and-shoulder, safety belt system. He sustained, according to his autopsy, serious injuries which included: a laceration of the brachiocephalic (innominate) vein; multiple (unspecified) right rib fractures; and lacerations of his right diaphragm, liver, and mesentery of small bowel. These lesions resulted in 800 milliliters of right hemothorax, 300 milliliters of hemoperitoneum, and 200 milliliters of retroperitoneal hemorrhage. The right hemothorax was attributed to the combination of the rib fractures and the lacerated brachiocephalic vein. The front right passenger's total blood loss was greater than 20% by volume. In addition, he sustained "typical" seat belt restraint injuries to the base of his right neck and to his lower abdomen. This occupant's primary chest injuries were caused by the intruding interior surface of the right front door. The case vehicle's driver (17-year-old male) was seated with his seat track located in its middle position, and the tilt steering wheel was located between its middle and upmost positions. He was restrained by the available, active, three-point, lap-and-shoulder, safety belt system. He sustained unknown head/brain injuries and was hospitalized for an unknown length of time. The driver declined to cooperate in this research.					
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This on-site investigation was brought to NHTSA's attention on April 29, 1999 by the applicable county coroner. This crash involved a 1999 Toyota Avalon XLS (case vehicle) which ran-off-road and impacted a fixed object (i.e., a culvert/embankment). The crash occurred in April, 1999, at 12:16 a.m., in Illinois and was investigated by the applicable State police department. This crash is of special interest because the case vehicle was equipped with side impact air bags and the case vehicle's front right passenger [32-year-old, White (non-Hispanic) male] sustained a serious chest injury in the right side impact, resulting in his death. This contractor inspected the scene and case vehicle on May 5, 1999. The driver of the case vehicle declined to cooperate with this research. This report is based on the Police Crash Report, conversations with the county coroner and the investigating police officer, scene and vehicle inspections, occupant kinematic principles, the front right passenger's autopsy, and this contractor's evaluation of the evidence.

SUMMARY

The case vehicle was traveling east-southeast in the eastbound lane of a two-lane, undivided, county roadway and was negotiating a left-hand curve when the driver lost control and the case vehicle went into a counterclockwise yaw. The case vehicle subsequently crossed the westbound lane while in the yaw and departed the north side of the roadway, facing essentially northward while the vehicle's center of gravity moved primarily in a northeasterly direction just prior to impact. Based on the scene evidence, the case vehicle's driver did not attempt any avoidance maneuvers prior to the crash. The case vehicle deposited 72.2 meters (237 feet) of yaw marks prior to impact. The crash occurred off the roadway on the north roadside; see **CRASH DIAGRAM** below.

The right side of the case vehicle impacted a metal culvert and the gravel driveway embankment it ran under, causing the case vehicle's right front, side impact air bag to deploy. After the impact the case vehicle continued to rotate counterclockwise an additional 50 degrees and traveled over the 7.9 meter (26 foot) wide gravel drive. The back of the case vehicle impacted the drainage ditch on the east side of the gravel drive and, as a result, it came to rest in the drainage ditch, heading primarily west with its back right bumper corner embedded in the soft dirt and its front end atop the east side of the gravel drive and the culvert.

The 1999 Toyota Avalon XLS was a front wheel drive, four-door sedan (VIN: 4T1BF18B2XU-----). The case vehicle was equipped with anti-lock brakes. Based on the vehicle inspection, the CDCs for the case vehicle were determined to be: **03-RDEW-3 (80)** for the initial impact and **05-BREW-1 (160)** for the second impact. The WinSMASH reconstruction program, barrier algorithm, was used on the case vehicle's highest severity impact. The Total, Longitudinal, and Lateral Delta Vs are, respectively: 45.8 km.p.h. (28.5 m.p.h.), -8.0 km.p.h. (-5.0 m.p.h.), and -45.1 km.p.h. (-28.0 m.p.h.). The case vehicle was towed due to damage.

The case vehicle's initial contact with the culvert/embankment involved the entire right side. Direct damage extended from the front right bumper corner to the back right bumper corner, a

measured distance of 458 centimeters (180.3 inches). Residual maximum crush was measured as 43 centimeters (16.9 inches) and was located 45 centimeters (17.7 inches) forward of C₃. The case vehicle's second impact involved the back right bumper corner. The direct damage started at the back right bumper corner and extended, a measured distance of 72 centimeters (28.3 inches), along the bumper to the left. Maximum crush was measured as 10 centimeters (3.9 inches) at the back right bumper corner. The case vehicle's wheelbase on the case vehicle's right side was shortened 8 centimeters (3.1 inches). Both "A"-pillars and both "B"-pillars were cut, and the roof was peeled back to allow for extrication. The case vehicle's right front and rear doors, right fender, and right quarter panel were directly damaged and crushed inward. There was also direct damage to the back right bumper fascia. The case vehicle's right front tire was deflated. Induced damage occurred to both the right and left headlight and turn signal assemblies as well as both taillight/stop light assemblies. The front bumper fascia was torn away. Remote buckling was found on the roof and left quarter panel as a result of extrication.

The case vehicle's right front, seat-mounted, side impact air bag was located in the outboard side of the front right passenger's seat back. When deployed the uppermost vertical edge of the side air bag measured 18 centimeters (7.1 inches) below the top of the front right seat back. The right side air bag was designed without any tethers or vent ports. The deployed side impact air bag was rectangular with a height of 28.5 centimeters (11.2 inches) and a width of approximately 32.5 centimeters (12.8 inches). There was contact evidence, though not readily apparent, on the interior surface of the side air bag. Furthermore, there was a gray leather transfer and mud on the bag's exterior surface. The case vehicle's driver and front right passenger air bags did not deploy as a result of the right side impact.

Inspection of the case vehicle's interior revealed that the vehicle's center console was cracked and the floor-mounted transmission selector lever was broken away from the console. Furthermore, there was blood evidence around the console. This damage most likely resulted from contact by the case vehicle's driver. In addition, the interior surface of the right front door was deformed and scuffed from contact by the front right passenger. Skin and hair evidence was present along the right side roof rail near the overhead handle. Finally, there was 31 centimeters (12.2 inches) of intrusion to both the right front door panel and sill area as a result of the case vehicle's impact with the culvert/embankment.

Immediately prior to the crash the case vehicle's front right passenger [173 centimeters and 84 kilograms (68 inches, 185 pounds)] was presumably seated in a slightly reclined posture with his back against the seat back and both feet on the floor. In addition, the exact position of his hands is unknown. His seat track was located between its middle and rearmost positions (i.e., two notches rearward from middle), and the seat back was slightly reclined.

The case vehicle's front right passenger was restrained by his available, active, three-point, lap-and-shoulder, safety belt system. Furthermore, based on his autopsy, there was evidence of belt pattern bruising to the base of the front right passenger's neck and on his lower abdomen. The inspection of the front right passenger's seat belt webbing, "D"-ring, and latch plate also showed evidence of loading. Specifically, the safety belt had been cut by rescue personnel, 21 centimeters (8.3 inches) down from the right "D"-ring, the belt was stretched from use, and there

was a 30 centimeter (11.8 inch) area of blue transfers on the webbing from passenger's blue denim jeans.

Based on the scene evidence, the case vehicle's driver made no known pre-crash avoidance maneuvers. As a result of the vehicle's counterclockwise rotation and independent of the use of his available safety belts, the front right passenger most likely moved slightly to his right and loaded the interior surface of the right front door just prior to impact. The case vehicle's primary impact with the culvert/embankment enabled the case vehicle's front right passenger to continue rightward and slightly upward toward the case vehicle's **80** degree Direction of Principal Force as the case vehicle decelerated. The front right passenger contacted the deployed side air bag with his upper torso and, most likely, the right side roof rail with his head or forehead—note: there were no reported face, head, scalp, or brain injuries in this occupant's autopsy). In addition, this occupant's torso was compressed by the intruding interior surface of the right front door. The door's armrest not only intruded inward but most likely upward into this occupant's torso. After the side impact, the front right passenger moved to his left and slightly forward into his safety belt. As the case vehicle rotated counterclockwise and upwards over the gravel drive and into the drainage ditch on the other side of the driveway, he moved to his right and backward as the vehicle's back right bumper corner embedded in the embankment of the soft earthen ditch. At final rest the front right passenger's head was leaning back over his seat back, and his torso was leaning to the right.

The front right passenger sustained serious injuries and was pronounced dead at the scene; however, he was transported by ambulance to a hospital for autopsy purposes. According to his autopsy the injuries he sustained included: a laceration of the brachiocephalic (innominate) vein; multiple (unspecified) right rib fractures; and lacerations of his right diaphragm, liver, and mesentery of small bowel. These lesions resulted in 800 milliliters of right hemothorax, 300 milliliters of hemoperitoneum, and 200 milliliters of retroperitoneal hemorrhage. The right hemothorax was attributed to the combination of the rib fractures and the lacerated brachiocephalic vein. The front right passenger's total blood loss was greater than 20% by volume. In addition, he sustained "typical" seat belt restraint injuries to the base of his right neck and to his lower abdomen but, according to the coroner, the belt injuries did not contribute to his death. This occupant's primary chest injuries were caused by the intruding interior surface of the right front door.

Presumably, the case vehicle's driver [17-year-old, White (non-Hispanic) male; 175 centimeters and 73 kilograms (69 inches, 160 pounds)] was seated in an upright posture with his back against the seat back, his left foot on the floor, his right foot off the accelerator, and both hands on the steering wheel. His seat track was located in its middle position, the seat back was primarily upright, and the tilt steering wheel was located between its middle and upmost positions.

The case vehicle's driver was restrained by the available, active, three-point, lap-and-shoulder, safety belt system. The inspection of the driver's seat belt webbing, "D"-ring, and latch plate also showed evidence of loading. Specifically, there were heavy friction scrubs on "D"-ring and scrubs and blood stains along the webbing.

The case vehicle's driver was transported by ambulance to the hospital. He sustained unknown head/brain injuries and was hospitalized for an unknown length of time. Because the driver declined to cooperate in this research, the exact injuries he sustained are unknown, but he most likely sustained a traumatic brain injury because he was reportedly in a coma for an unknown period of time.

CRASH CIRCUMSTANCES

The case vehicle was traveling east-southeast in the eastbound lane of a two-lane, undivided, county roadway and was negotiating a left-hand curve (**Figure 1**) when the driver over steered to the left, putting the vehicle into a counterclockwise yaw (**Figure 2**). The case vehicle's driver lost control. According to the investigating police agency, the case vehicle was traveling at a high rate of speed [i.e., 125.5 km.p.h. (78.0 m.p.h.) per police reconstruction]. The case vehicle subsequently crossed the westbound lane while in the yaw (**Figure 3**) and departed the north side of the roadway, facing essentially northward while the vehicle's center of gravity moved primarily in a northeasterly direction just prior to impact (**Figure 4**). Based on the scene evidence, the case vehicle's driver did not attempt any avoidance maneuvers prior to the crash. The case vehicle deposited 72.2 meters (237 feet) of yaw marks prior to impact. The crash occurred off the roadway on the north roadside; see **CRASH DIAGRAM** below.



Figure 1: Case vehicle's east-southeasterly travel path in left-hand curve; Note: arrow marks location of impact (case photo #01)



Figure 2: Coroner's photo of case vehicle's yaw marks starting in easterly lane leading into impact with culvert/embankment (case photo #44)



Figure 3: Coroner's photo of case vehicle's travel path in yaw across centerline leading into impact with culvert/embankment (case photo #45)



Figure 4: Coroner's photo of case vehicle's travel path onto north roadside leading into impact with culvert/embankment (case photo #46)

The county road was curved to the left for eastbound traffic and level (i.e., actual slope was 0.4%, positive to the east) at the area of impact. According to the police reconstruction, the roadway's radius of curvature was 415.8 meters (1,364.1 feet). The pavement was bituminous, and the width of the easterly travel lane was 3.2 meters (10.4 feet). The shoulders were not improved (i.e., gravel), and there was a 0.9 meter (3 foot) wide gravel shoulder adjacent to the grassy roadside. Pavement markings consisted of a double solid yellow centerline for both the east and westbound traffic. In addition, solid white edge lines were present. The estimated coefficient of friction was 0.71. There were no visible traffic controls in the immediate area of the crash. The statutory speed limit was 89 km.p.h. (55 m.p.h.). No regulatory speed limit sign was posted near the crash site. At the time of the crash the light condition was dark, the atmospheric condition was clear, and the road pavement was dry. Traffic density at the time of the crash is unknown, and the site of the crash was rural agricultural.



Figure 5: Case vehicle's right side damage from impact with culvert/embankment; Note: stringline adjusted for protruding door (case photo #22)



Figure 6: Culvert's embankment on north roadside that was impacted by case vehicle; Note: case vehicle came to rest on other (east) side of gravel drive (case photo #05)



Figure 7: Coroner's photo, looking northeastward, showing culvert/embankment impacted by case vehicle; Note: disruption of embankment that occurred during crash (case photo #48)

The right side (**Figure 5**) of the case vehicle impacted a metal culvert and the gravel driveway embankment (**Figures 6 and 7**) it ran under, causing the case vehicle's right front, side impact air bag to deploy. At impact the case vehicle was facing north-northeastward (25 degrees) with its front end angled downward. After the impact the case vehicle continued to rotate counterclockwise an additional 50 degrees and traveled over the 7.9 meter (26 foot) wide gravel drive. The back of the case vehicle impacted the drainage ditch on the east side of the gravel drive and, as a result, it came to rest in the drainage ditch, heading primarily west (**Figure 8** below) with its back right bumper corner embedded in the soft dirt (**Figure 9** below) and its front end atop the east side of the gravel drive and the culvert (**Figure 10** below).



Figure 8: On-scene eastward view of case vehicle's final rest in drainage ditch on eastern side of gravel access road; arrow marks culvert's location (case photo #53)



Figure 9: Northeastward view of case vehicle's final rest position in drainage ditch (case photo #07)

CASE VEHICLE

The 1999 Toyota Avalon XLS was a front wheel drive, five-passenger, four-door sedan (VIN: 4T1BF18B2XU-----) equipped with a 3.0L, V-6 engine and a four-speed automatic transmission. Braking was achieved by a power-assisted, front and rear disc, four-wheel, anti-lock system. The case vehicle's wheelbase was 272 centimeters (107.1 inches), and the odometer reading at inspection is unknown because the case vehicle was equipped with an electronic odometer.



Figure 10: On-scene southward view of case vehicle at final rest, heading west, on north roadside; Note: extensive damage to right side of vehicle (case photo #54)

Inspection of the vehicle's interior revealed adjustable front bucket seats with adjustable head restraints; a non-adjustable back bench seat with separate back cushions and integral head restraints for the back outboard seating positions; and continuous loop, three-point, lap-and-shoulder, safety belt systems at the front and back outboard positions and at the back center position. The front seat belt systems were equipped with manually operated, upper anchorage adjusters for the "D"-rings. Both the driver and front right passenger had their upper anchorage adjusters located in the upmost positions. The vehicle was equipped with knee bolsters for both the driver and front right passenger, neither of which were deformed. Automatic restraint was provided by a Supplemental Restraint System (SRS) that consisted of a frontal air bag for the driver and front right passenger seating positions. In addition, the vehicle was equipped with front, seat back-mounted, side impact air bags. Neither frontal air bag deployed as a result of the case vehicle's right side impact with the culvert/embankment. However, the right front, seat back-mounted, side air bag deployed as a result of the case vehicle's right side impact.

CASE VEHICLE DAMAGE

The case vehicle's initial contact with the culvert/embankment involved the entire right side (Figure 5 above, Figure 10 and Figure 11 below). Direct damage extended from the front right

bumper corner to the back right bumper corner, a measured distance of 458 centimeters (180.3 inches). Residual maximum crush was measured as 43 centimeters (16.9 inches) and was located approximately 5 centimeters (2.0 inches) above the bottom of the sill and 45 centimeters (17.7 inches) forward of C₃. The case vehicle's second impact involved the back right bumper corner. The direct damage started at the back right bumper corner and extended, a measured distance of 72 centimeters (28.3 inches), along the bumper to the left. Maximum crush was measured as 10 centimeters (3.9 inches) at the back right bumper corner. The distance of the direct contact damage forward along the right quarter panel was masked from the case vehicle's initial impact.



Figure 11: Case vehicle's right side damage viewed from right of back (case photo #17)

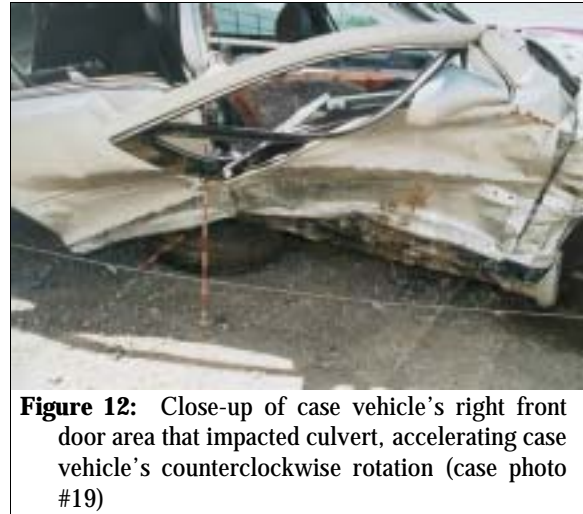


Figure 12: Close-up of case vehicle's right front door area that impacted culvert, accelerating case vehicle's counterclockwise rotation (case photo #19)

The case vehicle's wheelbase on the case vehicle's right side was shortened 8 centimeters (3.1 inches). Both "A"-pillars and both "B"-pillars were cut, and the roof was peeled back to allow for extrication. The windshield was folded over the front hood. The case vehicle's right front and rear doors, right fender, and right quarter panel were directly damaged and crushed inward. The right quarter panel sustained only minor damage. This damage pattern indicates that the brunt of the impact with the metal culvert and embankment occurred primarily into the passenger seating area on right side (**Figure 12**). There was also direct damage to the back right bumper fascia. The case vehicle's right front tire was deflated but not physically restricted from the impact. The right rear tire was completely torn off as the vehicle's undercarriage bottomed out against the embankment supporting the gravel driveway. Induced damage occurred to both the right and left headlight and turn signal assemblies as well as both taillight/stop light assemblies. The front bumper fascia was torn away. Remote buckling was found on the roof and left quarter panel as a result of extrication.

Inspection of the case vehicle's interior revealed that the vehicle's center console was cracked and the floor-mounted transmission selector lever was broken away from the console.

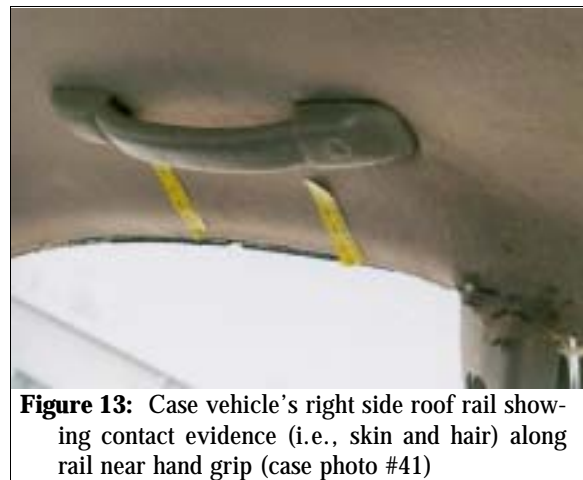


Figure 13: Case vehicle's right side roof rail showing contact evidence (i.e., skin and hair) along rail near hand grip (case photo #41)

Furthermore, there was blood evidence around the console. This damage most likely resulted from contact by the case vehicle's driver. In addition, the interior surface of the right front door was deformed and scuffed from contact by the front right passenger. Skin and hair evidence was present along the right side roof rail near the overhead handle (**Figure 13** above). The case vehicle sustained integrity loss to the windshield and both right side door glazings. Only the vehicle's backlite, both left side door window glazings, and motorized moon roof remained intact. Finally, the case vehicle's interior revealed severe intrusion to the entire right side of the passenger compartment. Of greatest importance was the 31 centimeters (12.2 inches) of intrusion to both the right front door panel (**Figure 14**) and sill area as a result of the case vehicle's impact with the culvert/embankment. Furthermore, the right "B"-pillar also intruded into the front right passenger's seating area significantly decreasing the seating space. In addition, the front right seat cushion and seat back folded inward, further collapsing the front right passenger's seating space. The adjustable head restraint attached to the front right passenger's seat back was knocked off. The back right seat cushion also sustained significant intrusion. The center instrument panel was folded upward from the right side door intrusion (**Figure 15**). The energy absorbing steering column showed no visible evidence of compression.

Based on the vehicle inspection, the CDCs for the case vehicle were determined to be: **03-RDEW-3 (80)** for the initial impact and **05-BREW-1 (160)** for the second impact. The WinSMASH reconstruction program, barrier algorithm, was used on the case vehicle's highest severity impact. The Total, Longitudinal, and Lateral Delta Vs are, respectively: 45.8 km.p.h. (28.5 m.p.h.), -8.0 km.p.h. (-5.0 m.p.h.), and -45.1 km.p.h. (-28.0 m.p.h.). The case vehicle was towed due to damage.



Figure 14: Vertical view of case vehicle's front right seating area showing no obvious contact evidence to right instrument panel or greenhouse area and significant intrusion to seating area from interior surface of right front door (case photo #34)



Figure 15: Case vehicle's front seating area showing non-deployed driver and front right passenger air bags and distortion and damage to instrument panel from right side intrusions (case photo #33)

The case vehicle was equipped with a Supplemental Restraint System (SRS) that contained frontal air bags at the driver and front right passenger positions. In addition, the vehicle was equipped with front, seat back-mounted, side impact air bags. The case vehicle's driver and front right passenger air bags did not deploy as a result of the right side impact (**Figure 15** above). The right front passenger's seat back-mounted, side air bag deployed as a result of the case vehicle's right side impact with the culvert/embankment (**Figure 16**).



Figure 16: Case vehicle's front seating area showing deployed right front side impact air bag and contact evidence on front right safety belt's webbing (case photo #25)



Figure 17: Case vehicle's deployed right front side impact air bag viewed through windshield; Note: intrusion to front right seat and seating area from right front door's interior surface (case photo #35)

The case vehicle's right front, seat-mounted, side impact air bag was located in the outboard side of the front right passenger's seat back (**Figure 17**). When deployed the uppermost vertical edge of the side air bag measured 18 centimeters (7.1 inches) below the top of the front right seat back. The single chambered right side air bag was designed without any tethers or vent ports. The deployed side impact air bag was rectangular with a height of 28.5 centimeters (11.2 inches) and a width of approximately 32.5 centimeters (12.8 inches). There was contact evidence, though not readily apparent, on the interior surface of the side air bag (**Figures 17 and 18**). This



Figure 18: Close-up of interior surface of case vehicle's right front side impact air bag showing unknown fluid dot to right of tape on bag's fabric (case photo #37)

contractor identified a yellowish dot (unknown substance), minimal evidence of mud splattered, and what appeared to be a spot of some type of body fluid on the upper portion (**Figure 18** above and **Figure 19**). Furthermore, there was a half-moon-shaped gray leather transfer and mud on the bag's exterior surface. There was no apparent evidence of damage to the air bag shell.

CASE VEHICLE FRONT RIGHT PASSENGER KINEMATICS

Immediately prior to the crash the case vehicle's front right passenger [32-year-old, White (Non-Hispanic) male; 173 centimeters and 84 kilograms (68 inches, 185 pounds)] was presumably seated in a slightly reclined posture with his back against the seat back and both feet on the floor. In addition, the exact position of his hands is unknown. His seat track was located between its middle and rearmost positions (i.e., two notches rearward from middle), and the seat back was slightly reclined. According to his autopsy, his blood alcohol concentration was 290 mg/dl (i.e., .290).



Figure 19: Case vehicle's deployed right front side impact air bag and front right safety belt's webbing showing stretching and blue transfers (case photo #36)

The case vehicle's front right passenger was restrained by his available, active, three-point, lap-and-shoulder, safety belt system. Furthermore, based on his autopsy, there was evidence of belt pattern bruising to the base of the front right passenger's neck and on his lower abdomen. The inspection of the front right passenger's seat belt webbing, "D"-ring, and latch plate also showed evidence of loading. Specifically, the safety belt had been cut by rescue personnel, 21 centimeters (8.3 inches) down from the right "D"-ring, the belt was significantly stretched from use, and there was a 30 centimeter (11.8 inch) area of blue transfers on the webbing from passenger's blue denim jeans (**Figure 19**).

Based on the scene evidence, the case vehicle's driver made no known pre-crash avoidance maneuvers. As a result of the vehicle's counterclockwise rotation and independent of the use of his available safety belts, the front right passenger most likely moved slightly to his right and loaded the interior surface of the right front door just prior to impact. The case vehicle's primary impact with the culvert/embankment enabled the case vehicle's front right passenger to continue rightward and slightly upward toward the case vehicle's 80 degree Direction of Principal Force as the case vehicle decelerated. The front right passenger contacted the deployed side air bag with his upper torso and, most likely, the right side roof rail with his head or forehead—note: there were no reported face, head, scalp, or brain injuries in this occupant's autopsy). In addition, this occupant's torso was compressed by the intruding interior surface of the right front door (**Figures 14** and **17** above). The door's armrest not only intruded inward but most likely upward into this occupant's torso (**Figures 14** and **15** above). After the side impact, the front right passenger moved to his left and slightly forward into his safety belt. As the case vehicle rotated counterclockwise and upwards over the gravel drive and into the drainage ditch on the other side of the driveway, he moved to his right and backward as the vehicle's back right bumper corner

embedded in the embankment of the soft earthen ditch. At final rest the front right passenger’s head was leaning back over his seat back, and his torso was leaning to the right (i.e., sanitized portion of **Figure 10** above shows occupant at final rest).

CASE VEHICLE FRONT RIGHT PASSENGER INJURIES

The front right passenger sustained serious injuries and was pronounced dead at the scene; however, he was transported by ambulance to a hospital for autopsy purposes. According to his autopsy the injuries he sustained included: a laceration of the brachiocephalic (innominate) vein—see **Figure 20** in the section below entitled: **SELECTED ANATOMICAL FIGURES**; multiple (unspecified) right rib fractures; and lacerations of his right diaphragm, liver, and mesentery of small bowel—see **Figure 21** in the section below entitled: **SELECTED ANATOMICAL FIGURES**. These lesions resulted in 800 milliliters of right hemothorax, 300 milliliters of hemoperitoneum, and 200 milliliters of retroperitoneal hemorrhage. The right hemothorax was attributed to the combination of the rib fractures and the lacerated brachiocephalic vein. The front right passenger’s total blood loss was greater than 20% by volume. In addition, he sustained “typical” seat belt restraint injuries to the base of his right neck and to his lower abdomen but, according to the coroner, the belt injuries did not contribute to his death. This occupant’s primary chest injuries were caused by the intruding interior surface of the right front door.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1	Laceration {tear} brachiocephalic (innominate) vein ¹ , not specified as to right or left [Aspect = Central]	420606.4 ² severe	Right side interior surface, excluding hardware and/or armrest	Probable	Autopsy
2	Fractures, multiple, right ribs—not further specified, with 800 ml of right hemothorax	450222.3 serious	Right side interior hardware and/or armrest	Certain	Autopsy
3	Laceration, diaphragm, right leaflet, not further specified	440604.3 serious	Right side interior hardware and/or armrest	Certain	Autopsy
4	Lacerations ³ , multiple, liver, not further specified	541820.2m oderate	Right side interior hardware and/or armrest	Certain	Autopsy
5	Lacerations ³ , multiple, mesentery of small bowel	542020.2 moderate	Right side interior hardware and/or armrest	Certain	Autopsy

¹ The right and left brachiocephalic veins merge to form the superior vena cava, which drains into the right atrium of the heart.

² According to the autopsy report the blood loss was approximately 20% by volume. Based on this occupant’s reported weight, his reported blood loss was greater than 20% by volume.

³ According to this occupant’s autopsy there was 300 ml of hemoperitoneum.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
6	Hemorrhage, retroperitoneum	543800.3 serious	Right side interior hardware and/or armrest	Probable	Autopsy
7	Contusion base of right neck	390402.1 minor	Torso portion of safety belt system	Certain	Autopsy
8	Contusion lower abdomen, not further specified	590402.1 minor	Lap portion of safety belt system	Certain	Autopsy

CASE VEHICLE DRIVER KINEMATICS

Presumably, the case vehicle's driver [17-year-old, White (non-Hispanic) male; 175 centimeters and 73 kilograms (69 inches, 160 pounds)] was seated in an upright posture with his back against the seat back, his left foot on the floor, his right foot off the accelerator, and both hands on the steering wheel. His seat track was located in its middle position, the seat back was primarily upright, and the tilt steering wheel was located between its middle and upmost positions.

The case vehicle's driver was restrained by the available, active, three-point, lap-and-shoulder, safety belt system. The inspection of the driver's seat belt webbing, "D"-ring, and latch plate also showed evidence of loading. Specifically, there were heavy friction scrubs on "D"-ring as well as significant stretching and blood stains along the webbing.

Based on the scene evidence, the case vehicle's driver made no known pre-crash avoidance maneuvers. As a result of the vehicle's counterclockwise rotation and independent of the use of his available safety belts, the driver most likely moved slightly to his right and may have loaded the vehicle's center console just prior to impact. The case vehicle's primary impact with the culvert/embankment enabled the case vehicle's driver to continue rightward and slightly upward toward the case vehicle's **80** degree Direction of Principal Force as the case vehicle decelerated. The driver loaded the lap portion his safety belts and most likely slipped out from underneath the shoulder belt portion. In addition, the driver contacted the center console cracking the console and knocking the transmission selector lever off the console. After the side impact, the driver moved to his left and slightly forward while continuing to load the lap portion of his safety belt. Without any medical information, the driver's exact movements are unclear, but the driver may also have contacted the center instrument panel with his head/face and the steering wheel rim with his back. As the case vehicle rotated counterclockwise and upwards over the gravel drive and into the drainage ditch on the other side of the driveway, he moved to his right and backward as the vehicle's back right bumper corner embedded in the embankment of the soft earthen ditch. According to the police investigators, at final rest he was leaning to the right over the center console.

The case vehicle's driver was transported by ambulance to the hospital. He sustained unknown head/brain injuries and was hospitalized for an unknown length of time. Because the driver declined to cooperate in this research, the exact injuries he sustained are unknown, but he most likely sustained a traumatic brain injury because he was reportedly in a coma for an unknown period of time.

SELECTED ANATOMICAL DIAGRAMS

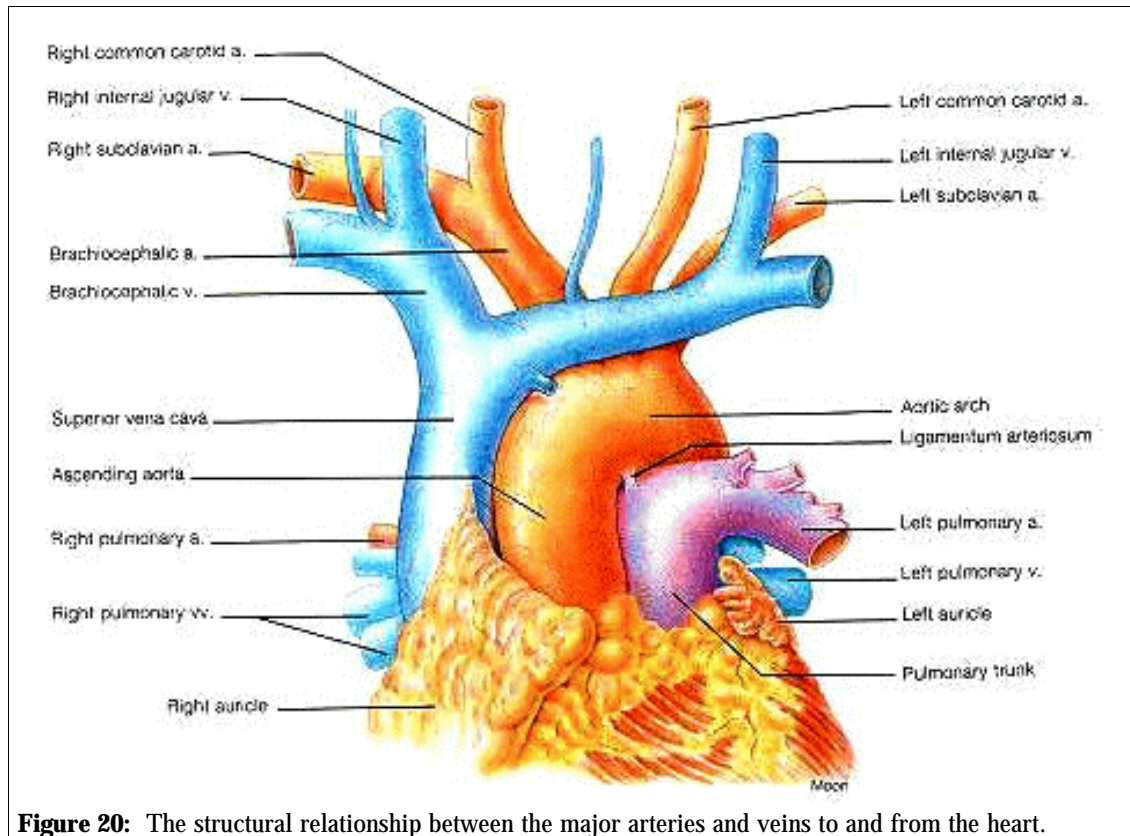


Figure 20: The structural relationship between the major arteries and veins to and from the heart.

