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ON-SITE AIR BAG NON-DEPLOYMENT INVESTIGATION

CASE NUMBER - IN97-016
LOCATION - KENTUCKY
VEHICLE - 1995 CHEVROLET ASTRO CS
CRASH DATE - January, 1997

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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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16. <i>Abstract</i> This report covers an on-site investigation of an air bag non-deployment crash that involved a 1995 Chevrolet Astro (case vehicle) and 1985 Mack dump truck (other vehicle). This crash is of special interest because the case vehicle's driver (34-year-old female) sustained fatal chest injuries and the driver's air bag did not deploy during the case vehicle's narrow, frontal impact. The case vehicle was traveling southeast in the southeastbound lane on a two-lane, undivided, state highway and was negotiating a left-hand curve. The Mack truck was northwestbound in the northwestbound lane of the same state highway and was negotiating a right-hand curve when one or more of right rear tandem wheels went off the northeast shoulder. The Mack truck's driver first steered leftward into the southeastbound lane. Next, the driver of the Mack truck steered back to the right, resulting in a clockwise rotation. The front left corner of the case vehicle impacted the left rear tandem wheels of the Mack truck, causing the case vehicle's left front wheel to be pushed rearward; however, the case vehicle's driver air bag did not deploy as a result of this impact. The Mack truck's left rear tandem wheels and the overhang of the dump truck bed continued along the case vehicle's left side. The case vehicle's driver was seated in a reclined posture with her seat track located between its middle and rearmost positions, and the tilt steering wheel was located in its middle position. The case vehicle's driver, front right passenger, and second seated left passenger were all restrained by their available, active, three-point, lap-and-shoulder, safety belt systems. The driver sustained, according to her autopsy, fatal injuries which included: a total transection of the aorta with associated bilateral hemothoraces, lacerations to her spleen and left lung, a contused pancreas, and a flail chest with multiple left rib fractures. The front right passenger (10-year-old female) was seated in a reclined posture with her seat track located in its rearmost position. She sustained, according to her medical records, a minor abrasion to her left ear. The second seated left passenger (7-year-old male) was seated with his seat track located in its rearmost position. He sustained, according to his medical records, severe skull, brain, chest, and facial injuries which included: a nonanatomic brain injury--with brief unconsciousness and neurologic deficit, bilateral basilar skull fractures, a heart contusion, avulsive lacerations to his left cheek and mouth, a laceration to his upper and lower left eyelids, and other soft tissue injuries.					
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This on-site investigation was brought to NHTSA's attention on April 9, 1997, by an attorney representing the family of the deceased driver in this crash. This crash involved a 1995 Chevrolet Astro minivan (case vehicle) and a 1985 Mack dump truck (other vehicle). The crash occurred in January, 1997, at 2:00 p.m., in Kentucky and was investigated by the applicable county sheriff's department. This crash is of special interest because the case vehicle's driver [34-year-old, White (non-Hispanic) female] sustained fatal chest injuries and the driver's air bag did not deploy during the case vehicle's narrow, frontal impact. This contractor inspected the scene and case vehicle on June 23, 1997. This contractor interviewed the driver's next of kin (i.e., husband) in February, 1998. This report is based on the Police Crash Report, an interview with the husband of the case vehicle's driver, scene and vehicle inspections, police photographs of the Mack truck, occupant kinematic principles, occupant medical records, and this contractor's evaluation of the evidence.

SUMMARY

The case vehicle was traveling southeast in the southeastbound lane on a two-lane, undivided, state highway and was negotiating a left-hand curve [i.e., radius = 139.0 meters (456 feet)], intending to continue traveling eastward. The Mack truck was northwestbound in the northwestbound lane of the same two-lane, undivided, state highway and was negotiating a right-hand curve [i.e., radius = 173.4 meters (569 feet)] when one or more of the right rear tandem wheels went off the northeast shoulder. The Mack truck's driver first steered leftward but overcorrected, causing the Mack truck to travel into the southeastbound lane. Next, while attempting to return to his original travel lane, the driver of the Mack truck steered back to the right, but he overcorrected again, resulting in the Mack truck going into a clockwise rotation; see **CRASH DIAGRAM** below. The case vehicle's driver attempted to avoid the crash by steering partially onto the right shoulder--a distance of 21.9 meters (72 feet) prior to impact. The crash occurred in the southeastbound lane near the southwest shoulder of the roadway.

The case vehicle's front left corner [i.e., a narrow end engagement with 17 centimeters (6.7 inches) of direct damage to the front bumper] was impacted by the left rear tandem wheels of the Mack truck; however, the case vehicle's driver air bag did not deploy as a result of this impact. The Mack truck's left rear tandem wheels continued along the left side of the case vehicle, contacting the left fender and driver's door. Simultaneously, the overhang of the Mack truck's dump truck bed contacted the case vehicle's hood, "A"-pillar, "B"-pillar, "C"-pillar, and "D"-pillar, causing a moderate amount of intrusion [approximately 10-15 centimeters (~3.9-5.9 inches)] along the whole left side greenhouse area. It should be noted that the case vehicle's left front wheel was pushed rearward approximately 12 centimeters (4.7 inches), shortening the wheelbase. As a result of the initial impact, the case vehicle gently veered across the roadway [nearly 30 meters (98.4 feet)], off the northeast shoulder of the road, and continued eastward for a distance of approximately 52.1 meters (171 feet) while traversing a gravel driveway and traveling up the front lawn (+12% grade) of a residence and striking a large tree. Finally, the case vehicle was redirected, approximately 90 degrees clockwise, and traveled down the lawn before coming to final rest heading south-southeastward. After the first impact, the Mack truck continued northwestward approximately 45 meters (147.6 feet) into a guardrail off the northeast

shoulder of the road prior to coming to rest heading north. The Mack truck had its front right corner against the guardrail (at an approximate 60 degree clockwise yaw) and its left rear corner extended over the southeastbound lane's white edge line--effectively blocking the entire roadway. The posted speed limit for the crash site is 89 km.p.h. (55 m.p.h.) with a curve speed advisory sign of 64 km.p.h. (40 m.p.h.). The case vehicle's impact with the tree was also to the front left corner and partially masked the damage caused by the impact with the Mack truck.

The case vehicle's driver [168 centimeters and 68 kilograms (66 inches, 150 pounds)] was restrained by her available, active, three-point, lap-and-shoulder, safety belt system. An inspection of the case vehicle's steering wheel rim showed no visible evidence of deformation; however, post-crash the steering column's shear capsule was completely disengaged from the dash and, according to a police officer at the scene, had pinned the case vehicle's driver against her seat back. Inspection of the driver's seat belt webbing, "D"-ring, and latch plate showed obvious evidence of loading.

The case vehicle's driver steered to the right, attempting to avoid the crash while still negotiating the curve left. In addition, as the driver observed the bed of the Mack truck's dump truck sliding clockwise into her travel path, she most likely leaned to the right while still controlling her vehicle. The case vehicle's primary impact with the Mack truck enabled the driver to continue forward and slightly leftward toward the 350 degree Direction of Principal Force. The driver's belt restraint system, while showing evidence of excessive loading, performed as it was designed to do by restraining the driver from contacting the case vehicle's laterally intruding "A"-pillar; however, the restraint system could not prevent the driver from contacting the longitudinally intruding steering wheel and the laterally intruding door panel/arm rest. Because the driver was found, at final rest, restrained and pinned into her seat by the intruding steering column and door panel; this contractor believes that the case vehicle's driver was pushed by the intruding steering wheel back into her seat after impacting the Mack truck. Because of her safety belt use, she was most likely near her pre-crash position just prior to the case vehicle's subsequent off road impact with the large tree. The tree impact had a negligible effect on the driver's posture given that she was pinned by the initial impact.

The case vehicle's driver was transported by ambulance from the scene to the hospital. She sustained fatal chest injuries and was pronounced dead in the emergency room, 55 minutes post-crash. Based on the Autopsy Report, the injuries sustained by the case vehicle's driver included: a total transection of the aorta with associated bilateral hemothoraces (i.e., 1.8 liters), a complex spleen laceration, a superficial laceration to the lower lobe of her left lung, a contused pancreas (i.e., at its tail), and flail chest with multiple left rib fractures (i.e., 2 through 9 laterally, and 3 through 12 posteriorly). The fatal aortic injury to the case vehicle's driver was caused by her contact with the intruding driver's steering column.

The case vehicle was a rear wheel drive, 1995 Chevrolet Astro, three-door minivan (VIN: 1GNDM19W3SB-----). The case vehicle was equipped with four-wheel, anti-lock brakes. The 1985 Mack DM was a rear wheel drive, incomplete vehicle, with dump truck bed (VIN: 1M2B120C7FA-----). The case vehicle was towed from the scene due to damage. The Mack truck was driven from the scene. Based on the case vehicle's inspection, CDCs were determined

to be: **12-FLAE-9 (350)** [maximum crush was 433 centimeters (170.5 inches) down the entire left side from the impact with the dump truck] and **12-FLES-2 (350)** for the tree impact. Based on the police on-scene photographs, the Mack truck's TDCs are estimated as: **11-LBFS-A** for the impact with the case vehicle and **10-FRLE-1** for the guardrail impact. No reconstruction program was used on this crash because the NASS, CDS, WinSMASH protocol requires that the impact configuration (i.e., not sideswipe) and involved vehicles (CDS applicable) be within the scope of the reconstruction program; however, this contractor's visually estimated Delta V for the impact with the Mack truck is low [14-23 km.p.h. (9-14 m.p.h.)]. Likewise, this contractor's visually estimated Delta V for the impact with the tree is between 3 km.p.h. (2 m.p.h.) and 10 km.p.h. (6 m.p.h.).

An inspection of the driver air bag, which was located in the steering wheel hub, revealed that the air bag had not deployed. This contractor believes the case vehicle's driver air bag should have deployed. The case vehicle sustained an initial narrow end engagement and subsequent wheel interaction (i.e., similar to a sideswiping impact that starts on the side but results in pocketing). Based upon our experience in these types of impacts, the air bag usually deploys late during the sequence of the impact. This delayed deployment occurs because of the prolonged change in time (Delta T) relative to the change in speed (magnitude of Delta V—i.e., ramp versus spike). Based upon this contractor's scene and vehicle inspections as well as our previous research experience, a late deployment was expected, but there are two scenarios that come into play both of which involve the fact that the case vehicle traveled an additional 52.1 meters (171 feet) past the point of initial impact and up a steep incline prior . In the first scenario, the additional distance traveled indicates that a significant portion of the case vehicle's pre-impact travel speed remained after the impact, meaning that the Delta V that occurred during the impact with the Mack truck was not that significant. In the second scenario, the additional distance traveled resulted from the driver pressing on the accelerator in response to the crash forces acting upon her, meaning that there most likely was a significant (i.e., threshold level) Delta V during the initial impact phase of the crash sequence. However, the most important fact in determining this contractor's opinion concerned the displacement of the case vehicle's wheelbase [approximately 12 centimeters (4.7 inches)]. In this contractor's opinion, this displacement should have caused a sufficient Delta V to have triggered the air bag's deployment. Unfortunately, there is no resolution available to this contractor because first, at the time of the on-site investigation, to this contractor's knowledge, the agency had no agreement with the manufacturer to access their Event Data Recorders (**EDRs**), and second, it is unknown if this 1995 model year vehicle was so equipped.

The exact posture of the case vehicle's driver, immediately prior to the crash, is unknown, but based on the vehicle inspection, the interview with the husband of the case vehicle's driver, and the driver's attempted avoidance maneuver, she was seated in a reclined posture, leaning to the left, with her back against the seat back, her left foot on the floor, her right foot most likely somewhere between the accelerator and brake pedals, and both hands on the steering wheel. The vehicle inspection showed that her seat track was located between its middle and rearmost positions, her seat back was slightly reclined, and her tilt steering wheel was located in its middle position.

The case vehicle's front right passenger [daughter; 10-year-old, White (non-Hispanic) female; 137 centimeters, 45 kilograms (54 inches, 100 pounds)] was seated in a reclined posture, but the location of her back, arms, hands, and legs is unknown. Her seat track was located in its rearmost position, and the seat back was slightly reclined. The case vehicle's front right passenger was restrained by her available, active, three-point, lap-and-shoulder, safety belt system. She was transported by ambulance to the hospital where she was treated and released. Based on her medical records, she sustained a minor soft tissue injury (i.e., an abrasion to her left ear).

The posture of the second seated left passenger [son; 7-year-old, White (non-Hispanic) male; 127 centimeters, 27 kilograms (50 inches, 60 pounds)] is unknown. His seat track was located in its rearmost position, and seat back was not adjustable. The case vehicle's second seated left passenger was restrained by his available, active, three-point, lap-and-shoulder, safety belt system. This passenger's usage was supported by his medical records which indicated a contusion across his anterior chest from left to right. He was initially transported and stabilized at a local hospital and subsequently airlifted to a trauma center specializing in children where he was hospitalized. Based on his medical records, he sustained severe skull, brain, chest, and facial injuries which included: a nonanatomic brain injury--with brief unconsciousness and neurologic deficit, bilateral basilar skull fractures, a heart contusion, avulsive lacerations to his left cheek and mouth, a laceration to his upper and lower left eyelids, and other soft tissue injuries. These injuries are primarily attributed to the Mack truck's intruding dump truck bed which scraped along the case vehicle at the left side window level. The unrestrained driver of the Mack truck did not sustain any injuries.

CRASH CIRCUMSTANCES



Figure 1: Case vehicle's southeastward travel path in left-hand curve just prior to impact in southeast-bound lane (i.e., orange cone on centerline marks approximate impact area); Note: case vehicle had moved toward right (southwest) shoulder attempting to avoid Mack truck which was in a clockwise yaw (case photo #02)



Figure 2: Mack truck's northwestward travel path after re-entering roadway from right (northeast) shoulder; Note: Mack went into a clockwise yaw, crossed the centerline, and struck the case vehicle in the opposing lane (near orange cone on the centerline) before sliding into the guardrail off the right-hand side of the road near the high-lighted (arrow) orange cone (case photo #10)

The case vehicle was traveling southeast in the southeastbound lane on a two-lane, undivided, state highway and was negotiating a left-hand curve [i.e., radius = 139.0 meters (456 feet)], intending to continue traveling eastward (**Figure 1**). The Mack truck was northwestbound

in the northwestbound lane of the same two-lane, undivided, state highway and was negotiating a right-hand curve [i.e., radius = 173.4 meters (569 feet)] when one or more of the right rear tandem wheels went off the northeast shoulder (**Figure 2** above). The roadway was bituminous, curved left (in the case vehicle's southeastbound direction of travel), and had a 2.8% grade positive to the southeast at the area of initial impact. Ambient conditions were daylight, clear, and a dry pavement. The travel lanes were separated by a double solid yellow centerline, with single solid white edge lines on the southeast and northwest pavement edges. The coefficient of friction was estimated as 0.80 on the relatively new and sharp pavement surface. Visibility was slightly obstructed by the roadway curvature and the leafless trees and limbs (April) in the ravine on the east roadside. There was a series of five warning signs [i.e., Chevron Alignment Signs (W1-8)--Manual on Uniform Traffic Control Devices (MUTCD)] placed along the southwest roadside, with each metal post containing back-to-back signs so both travel directions were alerted to the horizontal alignment change of the roadway. There was also a warning turn sign (W1-2L) with an advisory speed plate (W13-1) of 64 km.p.h. (40 m.p.h.) north of the crash site. The area had a posted speed limit of 89 km.p.h. (55 m.p.h.). The surrounding land use was rural residential.

The Mack truck's driver first steered leftward but overcorrected, causing the Mack truck to travel into the southeastbound lane. Next, while attempting to return to his original travel lane, the driver of the Mack truck steered back to the right, but he overcorrected again, resulting in the Mack truck going into a clockwise rotation (**Figure 2** above). The case vehicle's driver attempted to avoid the crash by steering partially onto the right (southwest) shoulder--a distance of 21.9 meters (72 feet) prior to impact (**Figure 1** above). The crash occurred in the southeastbound lane near the southwest shoulder of the roadway ; see **CRASH DIAGRAM** below.

The case vehicle's front left corner (**Figure 3**) impacted the left rear tandem wheels of the Mack truck (**Figure 4**); however, the case vehicle's driver air bag did not deploy as a result of this impact. The left rear tandem wheels continued along the left side of the case vehicle, contacting the left fender and driver's door. Simultaneously, the left rear overhang of the Mack truck's dump truck bed contacted the case vehicle's hood, "A"-pillar, "B"-pillar, "C"-pillar, and "D"-pillar, causing a moderate amount of



Figure 3: Case vehicle's very narrow front left corner impact; Note: yellow tape on bumper indicates direct damage width from contact with Mack truck's rear tandem wheels and yellow tape on hood shows direct damage width from impact with Mack's dump truck bed (case photo #20)



Figure 4: Mack's left side viewed from left of back showing minimal damage (i.e., scuffing) to left rear tandem wheels and scrapes on the rearward protrusion of the left back corner of the dump truck's bed (case photo #52)

intrusion along the whole left side greenhouse area (Figure 5).

As a result of the initial impact, the case vehicle gently veered (Figure 6) across the roadway [nearly 30 meters (98.4 feet)], off the northeast shoulder of the road (Figure 7), and continued eastward for a distance of approximately 52.1 meters (171 feet) while traversing a gravel driveway (Figure 8 below) and traveling up the front lawn (+12% grade) of a residence and striking a large tree (Figure 9 below). Once again, the case vehicle's driver air bag did not deploy. Finally, the case vehicle was redirected, approximately 90 degrees clockwise, and traveled down the lawn before coming to final rest heading south-southeastward (Figure 10 below).



Figure 5: Overhead left view of case vehicle's left side damage from impact with Mack truck's left rear tandem wheels and left back corner of the bed of the dump truck; Note: absence of left front tire and "A"- through "D"-pillar damage (case photo #25)

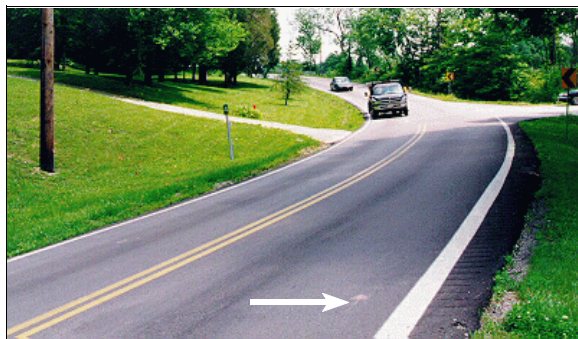


Figure 6: Case vehicle's southeastward path of travel, straddling right edge line, near point of impact; Note: gouge mark on pavement indicates approximate point of impact and case vehicle begins eastward post-impact path of travel across roadway toward mile marker post and gravel driveway (case photo #04)



Figure 7: Case vehicle's eastward, post-impact, path of travel across roadway, right of mile marker post, across gravel driveway, and into a tree before rebounding and coming to rest heading south-southeast near orange cone (case photo #05)

After impact, the Mack truck continued northwestward approximately 45 meters (147.6 feet) into a guardrail off the northeast shoulder of the road prior to coming to rest heading north. The Mack truck had its front right corner against the guardrail (at an approximate 60 degree clockwise yaw) and its left rear corner extended over the southeastbound lane's white edge line--effectively blocking the entire roadway (Figure 11 below). The posted speed limit for the crash site is 89 km.p.h. (55 m.p.h.) with a curve speed advisory sign (i.e., W13-1 in the MUTCD) of 64 km.p.h. (40 m.p.h.). The case vehicle's impact with the tree was also to the front left corner and partially masked the damage caused by the impact with the Mack truck.



Figure 8: Case vehicle's eastward travel path across gravel driveway where its front left struck a tree before being redirected and coming to rest heading south-southeast near orange cone (case photo #07)



Figure 9: Close-up of yard tree impacted by front left of case vehicle prior to its being redirected south-southeastward to final rest (case photo #08)



Figure 10: On-scene northwestward view of case vehicle's final rest position, heading south-southeastward, after striking and being redirected from tree; Note: case vehicle's left front tire in ditch (case photo #18)

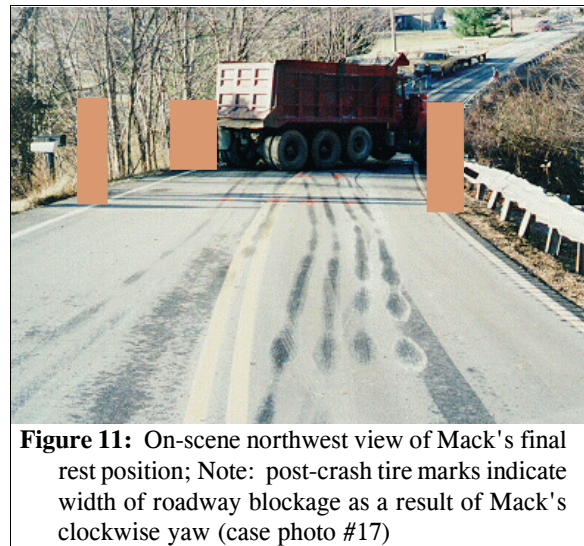


Figure 11: On-scene northwest view of Mack's final rest position; Note: post-crash tire marks indicate width of roadway blockage as a result of Mack's clockwise yaw (case photo #17)

CASE VEHICLE

The 1995 Chevrolet Astro CS was a rear wheel drive, eight-passenger, three-door, 4x2 minivan (VIN: 1GNDM19W3SB-----) equipped with a 4.3L, CPI, V-6 engine and a four-speed automatic transmission with overdrive. Braking was achieved by a power-assisted, four-wheel, anti-lock, front disc/rear drum system. The wheelbase was 282 centimeters (111.0 inches), and the odometer reading at inspection was 59,971 kilometers (37,264 miles).

The interior of the case vehicle had front bucket seats with integral head restraints. The automatic transmission's selection lever was mounted to the steering column's right side. The case vehicle had manual (active), three-point, lap and shoulder belts in the six outboard seat positions. There were manual (active), two-point, lap belts at the two center seat positions of the second and

third bench seats. A rigid plastic knee bolster was present on the driver's side and was slightly deformed by driver contact. There were two, three-passenger bench seats rearward of the front bucket seats. The case vehicle was not equipped with shoulder belt upper anchorage adjusters at the "B"-pillars, "C"-pillars, or "D"-pillars. Automatic restraint was provided by a Supplemental Restraint System (SRS) that consisted of a driver (only) air bag, which did not deploy during the crash sequence. Examination of the case vehicle's interior revealed evidence of driver contact to the left front door panel and its armrest and the instrument panel's lower left side. A possible front right passenger contact was detected just to the right of the center instrument panel's right air vent. The second seat's left side panel revealed occupant contacts to the armrest and the panel immediately below the sill. The glazing along the entire left side of the case vehicle was shattered by the vehicle's impact with the Mack truck. The driver's left hand may have come in contact with the left, interior surface of the windshield.

CASE VEHICLE DAMAGE

The case vehicle's front left corner impacted the left rear tandem wheels of the Mack truck. The front left corner sustained a narrow end engagement with 17 centimeters (6.7 inches) of direct damage width to the front bumper. The maximum crush to the front left bumper corner was 9 centimeters (3.5 inches); however, direct damage extended along the entire left side of the case vehicle for a total distance of 433 centimeters (170.5 inches) and involved the case vehicle's hood, "A"-pillar, "B"-pillar, "C"-pillar, and "D"-pillar. There was approximately 10 to 15 centimeters (3.9 to 5.9 inches) of outside intrusion along the entire left side (sill level and above) of the greenhouse area. The left fender and left front door were impacted by the Mack truck's rearmost, left dual wheel while the hood and upper portions of the pillars were impacted by the left rear corner of the Mack truck's dump truck bed (**Figure 12**). The case vehicle's left front wheel was pushed rearward 12 centimeters (4.7 inches), shortening the wheelbase.

The case vehicle's damaged components included: the front bumper, front splash guard, left front headlamp and turn signal assembly, hood, left fender, windshield, left "A"-pillar, left front door, left front door glazing, left "B"-pillar (**Figure 13**), left second seat window glazing, left quarter panel, left "C"-pillar, left third seat window glazing, left "D"-pillar, and left rear



Figure 12: Case vehicle's left side viewed from left of back showing contact damage to all four pillars from impact with rearward protruding corner of Mack's dump truck bed (case photo #26)



Figure 13: Closer-up view of direct damage to case vehicle's driver door and "A"- and "B"-pillars; Note: intrusion into driver seating area, cut seat belt, and non-deployment of driver's air bag (case photo #38)

window glazing. All of these components were damaged during the vehicle-to-vehicle impact. During the case vehicle's impact with the Mack truck, the Mack truck's left, rearmost, outside wheel rim sliced the case vehicle's left front tire, from the bead to the tread, on the outside sidewall deflating it. That tire separated from the wheel and came to rest in the trafficway's northeast drainage ditch, some 2.4 meters (8 feet) in front of the case vehicle's final rest position (**Figure 10** above). The impact with the tree (**Figures 8 and 9** above) was also to the front left corner of the case vehicle, partially masking the damage caused by contact with the Mack truck. There was lateral intrusion to the case vehicle's driver position, the second seat left position, and the third seat left position from the side panel, "A" through "D" pillars, and the roof side rail.

Based on the case vehicle's inspection, CDCs were determined to be: **12-FLAE-9 (350)** for the impact with the Mack truck and **12-FLES-2 (350)** for the tree impact. No reconstruction program was used on this crash because the NASS, CDS, WinSMASH protocol requires that the impact configuration (i.e., not sideswipe) and involved vehicles (CDS applicable) be within the scope of the reconstruction program; however, this contractor's visually estimated Delta V for the impact with the Mack truck is low [14-23 km.p.h. (9-14 m.p.h.)]. Likewise, this contractor's visually estimated Delta V for the impact with the tree is between 3 km.p.h. (2 m.p.h.) and 10 km.p.h. (6 m.p.h.).

AUTOMATIC RESTRAINT SYSTEM

As previously mentioned, the case vehicle was equipped with a Supplemental Restraint System (SRS) that consisted of a driver air bag. The air bag did not deploy during this crash sequence (**Figure 14**). An inspection of the driver air bag, which was located in the steering wheel hub, revealed that the air bag had not deployed. This contractor believes the case vehicle's driver air bag should have deployed. The case vehicle sustained an initial narrow end engagement and subsequent wheel interaction (i.e., similar to a sideswiping impact that starts on the side but results in pocketing). Based upon our experience in these types of impacts, the air bag usually deploys late during the sequence of the impact. This delayed deployment occurs because of the prolonged change in time (Delta T) relative to the change in speed (magnitude of Delta V—i.e., ramp versus spike). Based upon this contractor's scene and vehicle inspections as well as our previous research experience, a late deployment was expected, but there are two scenarios that come into play both of which involve the fact that the case vehicle traveled an additional 52.1 meters (171 feet) past the point of initial impact and up a steep incline prior . In the first scenario, the additional distance traveled indicates that a significant portion of the case vehicle's pre-impact travel speed remained after the impact, meaning that the Delta V that occurred during the impact with the Mack truck was not that significant. In the second scenario, the additional distance traveled resulted from the driver pressing on the accelerator in response to the crash forces acting

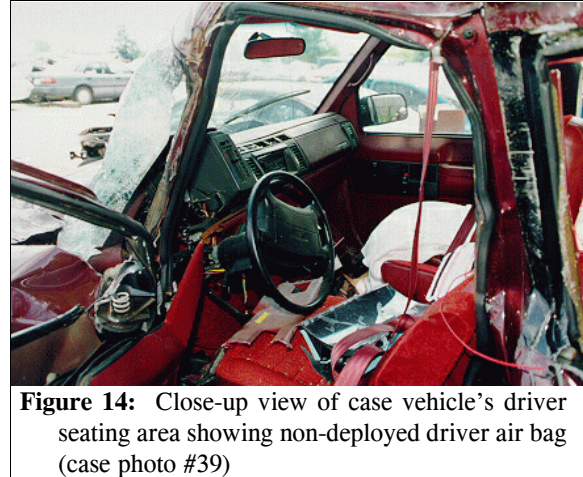


Figure 14: Close-up view of case vehicle's driver seating area showing non-deployed driver air bag (case photo #39)

upon her, meaning that there most likely was a significant (i.e., threshold level) Delta V during the initial impact phase of the crash sequence. However, the most important fact in determining this contractor's opinion concerned the displacement of the case vehicle's wheelbase [approximately 12 centimeters (4.7 inches)]. In this contractor's opinion, this displacement should have caused a sufficient Delta V to have triggered the air bag's deployment. Unfortunately, there is no resolution available to this contractor because first, at the time of the on-site investigation, to this contractor's knowledge, the agency had no agreement with the manufacturer to access their **E**vent **D**ata **R**ecorders (**EDRs**), and second, it is unknown if this 1995 model year vehicle was so equipped.

The driver's air bag was located in the steering wheel rim and the module's cover flaps were in the symmetrical "H"-configuration. The cover flap dimensions were not measured. With no deployment, the air bag's dimensions and the existence and size of tethers and vent ports are unknown. An inspection of the case vehicle's steering wheel rim showed no visible evidence of deformation; however, post-crash the steering column's shear capsule was completely disengaged from the dash and, according to a police officer at the scene, had pinned the case vehicle's driver against her seat back.

CASE VEHICLE DRIVER KINEMATICS

The case vehicle's driver [34-year-old, White (non-Hispanic) female; 168 centimeters and 68 kilograms (66 inches, 150 pounds)] was restrained by her available, active, three-point, lap-and-shoulder, safety belt system. Inspection of the driver's seat belt webbing, "D"-ring, and latch plate showed obvious evidence of loading. The exact posture of the case vehicle's driver, immediately prior to the crash, is unknown, but based on the vehicle inspection, the interview with the husband of the case vehicle's driver, and the driver's attempted avoidance maneuver, she was seated in a reclined posture, leaning to the left, with her back against the seat back, her left foot on the floor, her right foot most likely somewhere between the accelerator and brake pedals, and both hands on the steering wheel. The vehicle inspection showed that her seat track was located between its middle and rearmost positions, her seat back was slightly reclined, and her tilt steering wheel was located in its middle position.

The case vehicle's driver steered to the right, attempting to avoid the crash while still negotiating the curve left. In addition, as the driver observed the bed of the Mack truck's dump truck sliding clockwise into her travel path, she most likely leaned to the right while still controlling her vehicle. The case vehicle's primary impact with the Mack truck enabled the driver to continue forward and slightly leftward toward the 350 degree Direction of Principal Force. The driver's belt restraint system, while showing evidence of excessive loading, performed as it was designed to do by restraining the driver from contacting the case vehicle's laterally

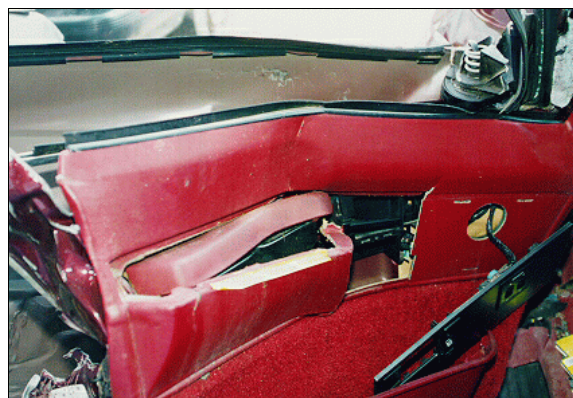


Figure 15: Close-up of interior surface of case vehicle's left front door panel; Note: evidence of driver contact (case photo #42)

intruding “A”-pillar; however, the restraint system could not prevent the driver from contacting the longitudinally intruding steering wheel and the laterally intruding door panel/arm rest (**Figure 15** above). Because the driver was found, at final rest, restrained and pinned into her seat by the intruding steering column and door panel; this contractor believes that the case vehicle’s driver was pushed by the intruding steering wheel back into her seat after impacting the Mack truck. Because of her safety belt use, she was most likely near her pre-crash position just prior to the case vehicle's subsequent off road impact with the large tree. The tree impact had a negligible effect on the driver’s posture given that she was pinned by the initial impact.

CASE VEHICLE DRIVER INJURIES

The case vehicle’s driver was transported by ambulance from the scene to the hospital. She sustained fatal chest injuries and was pronounced dead in the emergency room, 55 minutes post-crash. Based on the Autopsy Report the injuries sustained by the case vehicle's driver included: a total transection of the aorta with associated bilateral hemothoraces (i.e., 1.8 liters), a complex spleen laceration, a superficial laceration to the lower lobe of her left lung, a contused pancreas (i.e., at its tail), and flail chest with multiple left rib fractures (i.e., 2 through 9 laterally, and 3 through 12 posteriorly). The fatal aortic injury to the case vehicle's driver was caused by her contact with the intruding driver's steering column.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1	Transection, total, aorta just distal to left subclavian artery with bilateral hemothoraces ¹	420218.6 ¹ untreatable	Steering wheel hub and/or spokes	Probable	Autopsy
2	Lacerations, superficial, to lower lobe of left lung	441430.3 serious	Steering wheel hub and/or spokes and rim	Probable	Autopsy
3	Flail chest with multiple left rib fractures ²	450260.4 severe	Steering wheel hub and/or spokes and rim	Probable	Autopsy
4	Contusion tail of pancreas	542822.2 moderate	Left door armrest	Probable	Autopsy

¹ Bilateral hemothoraces were present: 800 cc of fluid blood in right pleural cavity and 1,000 cc of fluid and clotted blood in left pleural cavity; thus, the aortic hemorrhage was not confined to the mediastinum.

The following term is defined in DORLAND’S ILLUSTRATED MEDICAL DICTIONARY as follows:

mediastinum (me"de-as"ti'nam): The mass of tissues and organs separating the two pleural sacs, between the sternum anteriorly and the vertebral column posteriorly {i.e., the bodies of the 12 thoracic vertebrae} and from the thoracic inlet superiorly to the diaphragm inferiorly. It contains the heart and its pericardium, the bases of the great vessels {e.g., aorta, aortic arch, vena cava, pulmonary arteries and veins}, the trachea and bronchi, esophagus, thymus, lymph nodes, thoracic duct, phrenic and vagus nerves, and other structures and tissues.

² The multiple rib fractures involved ribs 2 through 9 laterally, and 3 through 12, posteriorly.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
5	Laceration, complex ³ , spleen	544228.5 critical	Left door armrest	Probable	Autopsy
6	Contusion over left mandible	290402.1 minor	Left window sill	Possible	Autopsy
7	Abrasion left mandible in area of contusion	290202.1 minor	Left window sill	Possible	Autopsy
8	Contusions periumbilicus and mid-left abdomen	590402.1 minor	Steering wheel hub and/or spokes	Probable	Autopsy
9	Contusion left upper abdomen, 14 cm (5.5 in) left of midline	590402.1 minor	Safety belt, torso portion	Probable	Autopsy
10	Contusions from left elbow down to left forearm and wrist	790402.1 minor	Left side interior surface excluding hardware and/or armrest	Probable	Autopsy
11	Lacerations, superficial, left medial wrist and proximal left little finger	790602.1 minor	Noncontact: flying glass	Probable	Autopsy
12	Contusions anterior thighs, bilaterally	890402.1 minor	Steering wheel rim	Probable	Autopsy
13	Contusion right medial knee	890402.1 minor	Steering column	Probable	Autopsy
14	Contusion mid-anterior right lower leg	890402.1 minor	Left instrument panel and below	Probable	Autopsy

CASE VEHICLE FRONT RIGHT PASSENGER KINEMATICS

The case vehicle's front right passenger [daughter; 10-year-old, White (non-Hispanic) female; 137 centimeters, 45 kilograms (54 inches, 100 pounds)] was seated in a reclined posture, but the location of her back, arms, hands, and legs is unknown. Her seat track was located in its rearmost position, and the seat back was slightly reclined. The case vehicle's front right passenger was restrained by her available, active, three-point, lap-and-shoulder, safety belt system. Inspection of her seat belt webbing, "D"-ring, and latch plate did not provide evidence of loading.

The case vehicle's driver steered to the right, attempting to avoid the crash while still negotiating the curve left. As a result of the attempted avoidance maneuver and the use of her

³ According to the autopsy, the spleen was totally macerated and could not be further identified. The following term is defined in DORLAND'S ILLUSTRATED MEDICAL DICTIONARY as follows:
macerate (mas'er-at): to soften by wetting or soaking.

available safety belts, the front right passenger most likely moved slightly to her left just prior to impact. The case vehicle's primary impact with the Mack truck enabled the front right passenger to continue forward and slightly leftward toward the 350 degree Direction of Principal Force. Although the front right passenger's belt restraint system did not showed evidence of loading, it performed as designed by restraining the front right passenger from any significant contact with the case vehicle's instrument panel and any contact with the windshield. The only contact may have been scratching of the instrument panel's midline--near the second from the right air vent (**Figure 16**). She rebounded rearward into her seat back as the case vehicle traveled across the roadway, onto a steeply sloped residential lawn and its gravel driveway. Because of her safety belt use, she was most likely near her pre-crash position just prior to the case vehicle's subsequent off road impact with the large tree. The tree impact and subsequent clockwise redirection likely caused the front right passenger to move forward and leftward toward the center instrument panel, but there is no evidence of any contacting. This passenger reportedly exited the case vehicle under her own power.



Figure 16: Case vehicle's front right seating position showing right sun visor and "A"-pillar, windshield, and center and right instrument panels; Note: yellow tape highlights possible contact area on right instrument panel (case photo #46)

CASE VEHICLE FRONT RIGHT PASSENGER INJURIES

She was transported by ambulance to the hospital where she was treated and released. Based on her medical records, she sustained a minor soft tissue injury (i.e., an abrasion to her left ear).

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1	Abrasion left ear	290202.1 minor	Noncontact: flying glass	Possible	Emergency room records

CASE VEHICLE SECOND SEAT LEFT PASSENGER KINEMATICS

The posture of the second seated left passenger [son; 7-year-old, White (non-Hispanic) male; 127 centimeters, 27 kilograms (50 inches, 60 pounds)] is unknown. His seat track was located in its rearmost position, and seat back was not adjustable. The case vehicle's second seated left

passenger was restrained by his available, active, three-point, lap-and-shoulder, safety belt system. Inspection of his seat belt webbing showed slight stretching, but the “D”-ring and latch plate did not evidence much loading. This passenger's usage was supported by his medical records which indicated a contusion across his anterior chest from left to right.

The case vehicle's driver steered to the right, attempting to avoid the crash while still negotiating the curve left. As a result of the attempted avoidance maneuver and the use of his available safety belts, the second seated left passenger most likely moved slightly to the left just prior to impact. The case vehicle's primary impact with the Mack truck enabled the second seated left passenger to continue forward and slightly leftward toward the 350 degree Direction of Principal Force. The second seated left passenger's belt restraint system showed evidence of loading and performed as designed by restraining this passenger from contacting the case vehicle's laterally intruding “B”-pillar; however, the restraint system could not prevent this occupant from contacting the laterally intruding side panel/arm rest and window sill (**Figure 17**). He rebounded rearward and rightward toward the center of the second seating position's seat back only to move back to his left as the case vehicle traveled across the roadway, onto a steeply sloped residential lawn and its gravel driveway. Because of his safety belt use, he was most likely near his pre-crash position just prior to the case vehicle's subsequent off road impact with the large tree. The tree impact and subsequent clockwise redirection likely caused this passenger to move forward and leftward, likely coming to rest against the left side panel. According to an interview with his father, this passenger was removed from the vehicle with some assistance.



Figure 17: Case vehicle's second seating area showing occupant contact evidence to left side panel and intrusion into second row bench seat, causing serious injuries to second seated left passenger (case photo #47)

CASE VEHICLE SECOND SEAT LEFT PASSENGER INJURIES

He was initially transported and stabilized at a local hospital and subsequently airlifted to a trauma center specializing in children where he was hospitalized. Based on his medical records, he sustained severe skull, brain, chest, and facial injuries which included: a nonanatomic brain injury--with brief unconsciousness and neurologic deficit, bilateral basilar skull fractures, a heart contusion, avulsive lacerations to his left cheek and mouth, a laceration to his upper and lower left eyelids, and other soft tissue injuries. These injuries are primarily attributed to the Mack truck's intruding dump truck bed which scraped along the case vehicle at the left side window level.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1	Nonanatomic brain injury with prior brief unconsciousness ⁴ , unequal pupils ⁴ , and appropriate response, but only (and always) to painful stimuli	160608.3 serious	Left side of other vehicle's dump truck bed	Probable	Hospitalization records
2	Contusion heart {cardiac} with septal dyskinesias ⁵	441002.3 serious	Safety belt torso portion	Probable	Hospitalization records
3	Fracture, bi-basilar ⁶ , at junction of occipital and mastoid portions of temporal bones, extending into the temporal bone on the right	150206.4 severe	Left side of other vehicle's dump truck bed	Probable	Hospitalization records
4	Avulsion laceration, gaping, 23 cm (9.1 in), left cheek	290804.2 moderate	Left side of other vehicle's dump truck bed	Probable	Hospitalization records
5	Contusion {hematoma} over left and right eyes	297402.1 minor	Left side of other vehicle's dump truck bed	Probable	Hospitalization records
6	Avulsive laceration, 3-4 cm (1.2-1.6 in), left corner of mouth involving upper and lower borders of lips	290802.1 minor	Left side of other vehicle's dump truck bed	Probable	Hospitalization records
7	Laceration left eyelid, upper and lower lids	290602.1 minor	Noncontact: flying glass	Probable	Hospitalization records
8	Abrasions {road rash} left cheek	290202.1 minor	Left side of other vehicle's dump truck bed	Probable	Hospitalization records

⁴ The Glasgow Coma Scale was reported as 7, at the scene by the Emergency Medical Advanced Life Support team, and as 9 in the Emergency Department. This patient's pupils were reported as unequal at the scene by the EMS and in the emergency department of the "transferred to" facility. In addition, the patient's left pupil reacted adversely (i.e., down-going) at the "transferred to" facility, and it was considered a direct traumatic "mydriasis". The patient was given mannitol (i.e., as a precaution against cerebral edema) and sent for a head CAT scan.

The following terms are defined in DORLAND'S ILLUSTRATED MEDICAL DICTIONARY as follows:

mydriasis (mi-dri'a-sis): morbid dilation of the pupil.

morbid (mor'bid): pertaining to, affected with, or inducing disease; diseased.

⁵ The following terms are defined in DORLAND'S ILLUSTRATED MEDICAL DICTIONARY as follows:

dyskinesia (dis'ki-ne'zha): distortion or impairment of voluntary movement, as in tic, spasm, or myoclonus.

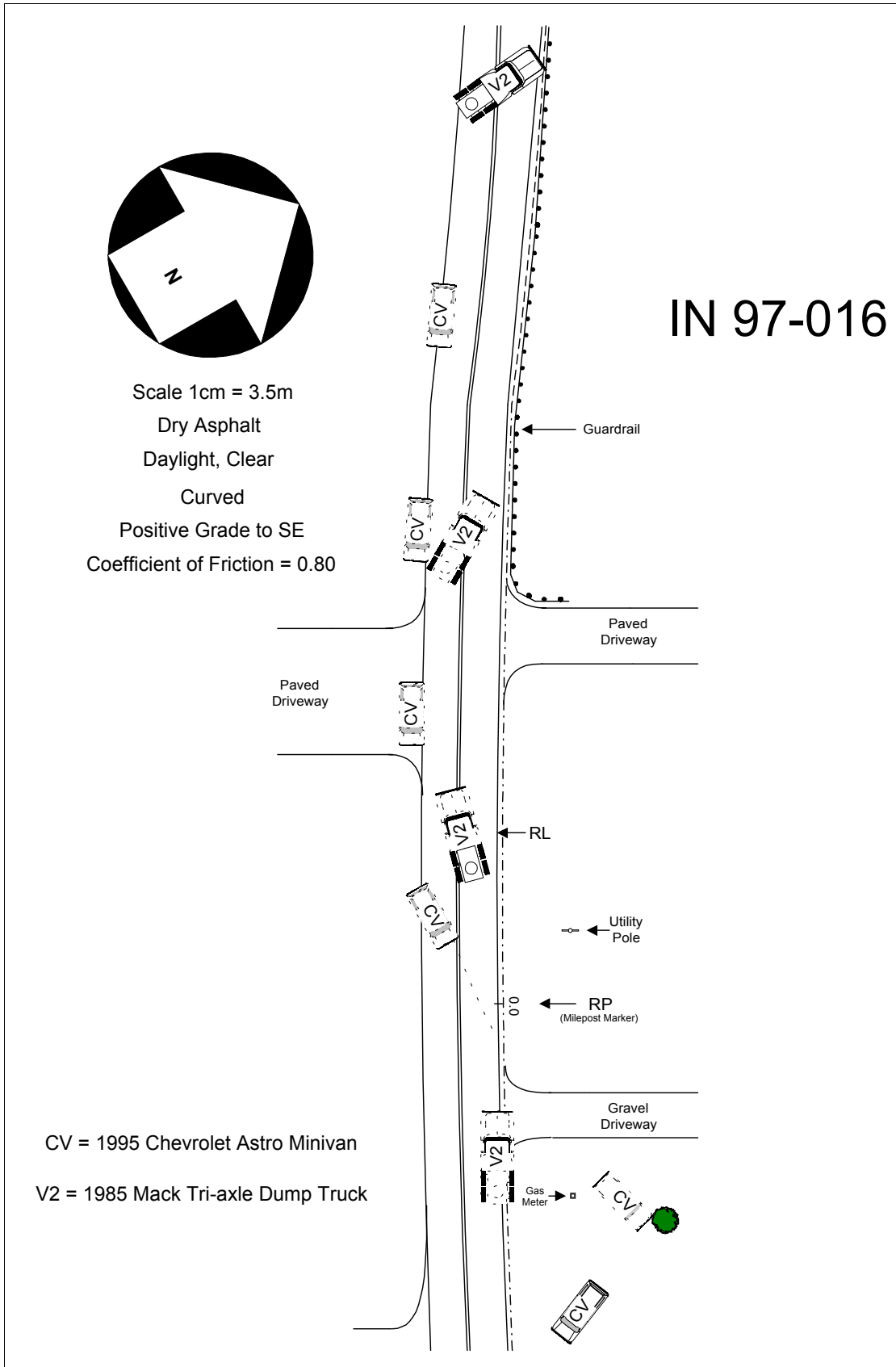
myoclonus (mi'ok'lo-nas): shocklike contractions of a portion of a muscle, an entire muscle, or a group of muscles, restricted to one area of the body or appearing synchronously or asynchronously in several areas. It may be part of a disease process (e.g., epileptic or post-anoxic myoclonus) or be a normal physiologic response (e.g., nocturnal myoclonus).

⁶ At the initial medical facility this patient was diagnosed with a C₁ fracture (component not further specified) and dislocation (i.e., increased atlantoaxial separation). A head CAT scan at the "transferred to" facility found no fractures or dislocation, but diagnosed instead, a bi-basilar skull fracture involving both the right and left posterior cranial fossa and possibly the right middle cranial fossa. In addition, the presence of cerebrospinal fluid leakage was suspected but never confirmed.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
9	Contusion across anterior chest from left to right	490492.1 minor	Safety belt torso portion	Certain	Hospitalization records
10	Contusion left shoulder/humerus area	790402.1 minor	Left side interior surface, excluding hardware and/or armrest	Probable	Hospitalization records

OTHER VEHICLE

The 1985 Mack DM series was a rear wheel drive, incomplete, tri-axle vehicle with an offset conventional cab (VIN: 1M2B120C7FA-----) and a dump truck body. This vehicle was not inspected but, based upon police on-scene photographs, two TDCs were estimated as: **11-LBFS-A** for the impact with the case vehicle and **10-FRLE-1** for the guardrail impact. No reconstruction program was used on this crash because the WinSMASH protocol requires that the impact configurations and vehicle types be within the program's scope. Damage to the Mack truck (**Figure 4** above) was limited to the rearmost, outside, left tire with scrapes and slashes on the sidewall and scratching along the bottom, left rear corner of the bed of the dump truck. The Mack truck was driven from the scene. The unrestrained driver of the Mack truck did not sustain any injuries.



The following material is taken from the book: FORENSIC PATHOLOGY by Dominick J. DiMaio and Vincent J.M. DiMaio, CRC Press, Ann Arbor, 1993; Chapter Five: Blunt Trauma Injuries of the Trunk and Extremities, *The Aorta*, pages 113-116.

The heart is suspended in the pericardial sac by the aorta, pulmonary artery, and superior vena cava. Any force that violently compresses the anterior chest and forces the heart downward may exert sufficient traction on the aorta to tear it transversely. The superior vena cava and the pulmonary artery are rarely torn. Aortic lacerations are most commonly seen in automobile accidents, less commonly in falls. In automobile accidents, the victim, usually the driver sustains the injury when the chest forcibly strikes the steering wheels, and the front seat passenger when the chest strikes the dashboard. Aortic lacerations may also occur in side impact crashes.

Bursting rupture of the ascending portion and arch of the aorta occur when a violent force compresses the heart and intrapericardial portion of the ascending aorta, producing a sudden rise in intracardiac and intraluminal pressure which results in a transverse tear of the aorta immediately above the cusps of the aortic valve. This usually involves only a portion of the aorta's circumference. Death rapidly ensues from severe hemorrhage. These injuries are associated with fractures of the upper ribs and sternum.

Most traumatic injuries of the aorta involve the descending portion just distal to the origin of the left subclavian artery. The arch of the aorta is anchored by the great vessels arising from the aortic arch, that is, the right innominate⁷, left common carotid, and subclavian arteries, and the ligamentum arteriosum⁸ (which connects the left pulmonary artery to the arch of the aorta). Partial or complete lacerations of the descending aorta occur at almost precisely the same location: immediately distal to the left subclavian artery, at the junction of the aortic arch and the descending aorta. The precise mechanism of this injury is not known. The relatively constant location of aortic lacerations, the relative fixation of the descending aorta just below the aortic isthmus⁹, the relative fixation of the aortic arch by the vessels, and the constant association of the aortic laceration with deceleration injuries¹⁰, such as automobile collisions, suggest that the abrupt deceleration of the body and resulting forceful compression of the anterior chest and underlying mediastinal

⁷ Also called the brachiocephalic artery.

⁸ The following term is defined in DORLAND'S ILLUSTRATED MEDICAL DICTIONARY as follows:
ligamenta arterio/sum -- a short, thick, strong fibromuscular cord extending from the pulmonary artery to the arch of the aorta; it is the remains of the ductus arteriosus. Called also *ligament of Botallo*.

⁹ The following terms are defined in DORLAND'S ILLUSTRATED MEDICAL DICTIONARY as follows:
isthmus (is/mas) -- a narrow connection between two larger bodies or parts; a general term for such a connecting structure or region. *isthmus of aorta* -- a narrow portion of the aorta, especially noticeable in the fetus, at the point where the ductus arteriosus is attached.

¹⁰ The following term is defined in DORLAND'S ILLUSTRATED MEDICAL DICTIONARY as follows:
deceleration injury -- an injury sustained by sudden deceleration in the movement of the body, as in a motor vehicle accident; the brain is especially liable to such trauma.

structures causes the heart and great vessels to be jerked away from the posterior chest wall to which the thoracic aorta is attached. This traction on the ligament ductus arteriosus and descending aorta at its point of fixation is sufficient to lacerate the aorta immediately below the origin of the left subclavian artery.

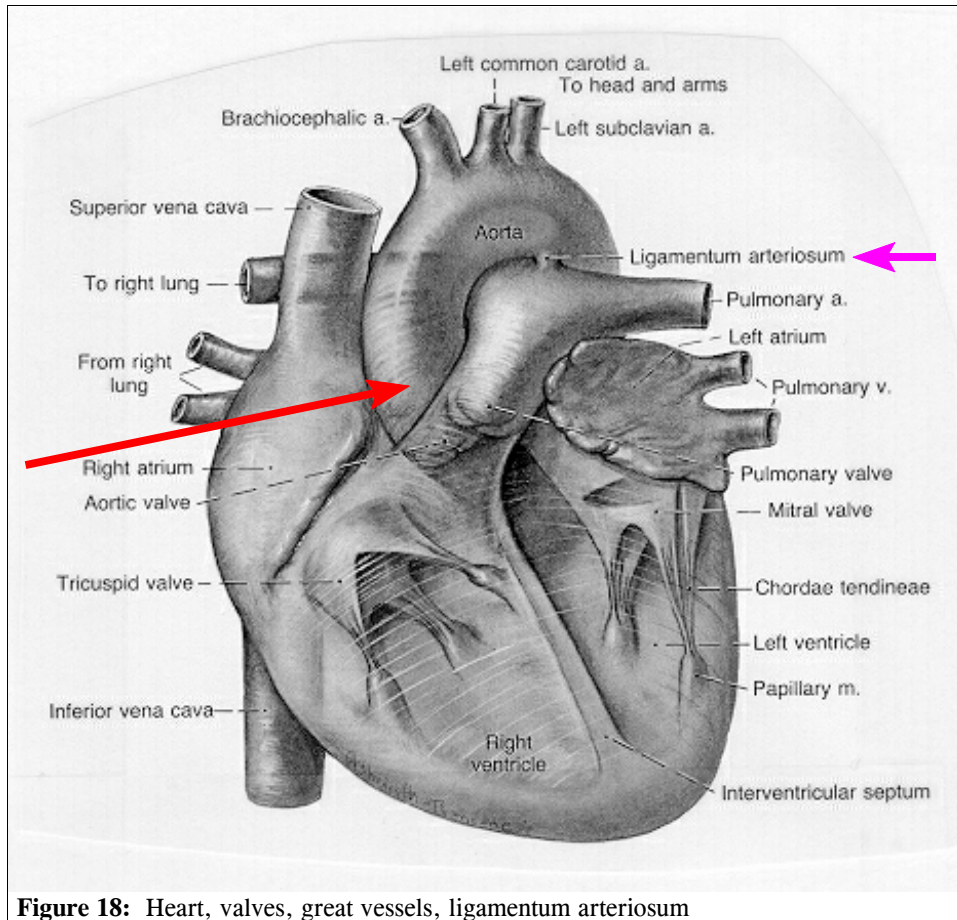


Figure 18: Heart, valves, great vessels, ligamentum arteriosum