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ON-SITE AIR BAG INVESTIGATION

CASE NUMBER - IN97-021
LOCATION - OKLAHOMA
VEHICLE - 1995 DODGE NEON
CRASH DATE - July, 1997

Submitted:

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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.

Technical Report Documentation Page

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15. *Supplementary Notes* On-site air bag deployment investigation involving a 1995 Dodge Neon, four-door sedan, with manual three-point safety belts and dual front air bags, and a 1994 Dodge Spirit, four-door sedan			
16. *Abstract* This report covers an on-site investigation of an air bag deployment crash that involved a 1995 Dodge Neon (case vehicle) and a 1994 Dodge Spirit (vehicle #2). This crash is of special interest because the case vehicle's, improperly restrained, front right passenger (3-year-old female) sustained a critical spinal cord injury from contacting her deploying front right passenger air bag. The case vehicle was traveling north in the inside northbound lane on a four-lane, undivided, city street (i.e., two northbound and two southbound through lanes). Vehicle #2 had been traveling south in the inside southbound lane of the same four-lane roadway and was turning left turn into a parking lot. The front of the case vehicle impacted the right front side of vehicle #2, causing the case vehicle's driver and front right passenger supplemental restraints (air bags) to deploy. The case vehicle's front right passenger was seated with her seat track located in its middle position. She was restrained by her available, active, three-point, lap-and-shoulder, safety belt system, but she was wearing the shoulder portion behind her back. She sustained, according to her medical records, critical injuries which included: a traumatized spinal cord that resulted in ventilator-dependent quadriplegia, an atlanto-occipital and atlantoaxial dislocations (distractions), a nonanatomic brain injury, a contused spleen, a anterior neck contusion, and severe abrasions across her anterior neck from her left cheek ear to her right shoulder. The driver in the case vehicle (23-year-old female) was seated with seat track located in its center position, and the steering wheel was located in its upmost position. She was not wearing her available, active, three-point, lap-and-shoulder, safety belt system, and sustained, according to her medical records, minor injuries which included: a cervical strain and a forearm abrasion. The case vehicle's back right passenger (1-year-old male) was properly restrained in a child safety seat that was secured by the available, active, three-point, lap-and-shoulder, safety belt system. He did not sustain any injuries as a result of this crash.			
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BACKGROUND

IN97-021

This on-site investigation was brought to NHTSA's attention on July 9, 1997 by a physician at a hospital in Oklahoma. This crash involved a 1995 Dodge Neon (case vehicle) and a 1994 Dodge Spirit (vehicle #2). The crash occurred in July, 1997, at 1:45 p.m., in Oklahoma and was investigated by the applicable city police department. This crash is of special interest because the case vehicle's, improperly restrained, front right passenger [3-year-old, Black (non-Hispanic) female] sustained a critical spinal cord injury (i.e., ventilator-dependent quadriplegia) from contacting her deploying front right passenger air bag. This contractor inspected the scene and vehicles on July 22,1997. This contractor interviewed the driver for the case vehicle in December, 1997. This report is based on the Police Crash Report, interviews with both vehicle drivers and the investigating police officers, scene and vehicle inspections, occupant kinematic principles, occupant medical records, and this contractor's evaluation of the evidence.

SUMMARY

The case vehicle was traveling north in the inside northbound lane on a four-lane, undivided, city street and intended to continue traveling northward (i.e., two northbound and two southbound through lanes). Vehicle #2 had been traveling south in the inside southbound lane of the same four-lane roadway and was turning left turn into a parking lot. The case vehicle's driver attempted to swerve to the right and braked, trying to avoid the crash. The crash occurred in the inside northbound lane within the three-leg junction of the two trafficways (see **CRASH DIAGRAM**).

The front of the case vehicle impacted the right front side of vehicle #2, causing the case vehicle's driver and front right passenger supplemental restraints (air bags) to deploy. The case vehicle rotated approximately 60 degrees clockwise and came to rest straddling the inside northbound lane heading east-northeast. Vehicle #2 was redirected approximately 65 degrees counterclockwise and came to rest heading east-northeast with its front end in the exit lane of the driveway access, against the front bumper of a noncontact pickup truck that was stopped in the parking lot exit lane waiting to make a turn. According to the available information, there was no damage to the pick-up and it subsequently departed the scene prior to the arrival of police. The Police Crash Report did not list this pickup, and its year, make, and model are unknown.

The case vehicle's front right passenger [daughter; 107 centimeters and 16 kilograms (42 inches and 36 pounds)] was improperly restrained (i.e., not in a child safety seat and wearing the torso portion behind her back) by her available, active, three-point, lap-and-shoulder, safety belt system. In addition, the front right safety belt's upper anchorage adjustment was in the full down position. There is no evidence of belt pattern bruising and/or abrasions to the front right passenger's body; however, she sustained a small splenic contusion, which could have resulted from the lap portion of her safety belt if the belt spooled out (no locking clip) during impact. In addition, the inspection of the front right passenger's safety belt webbing, "D"-ring, and latch plate showed no conclusive evidence of loading; although, there were dark fluid blood drops on the webbing as well as an angled crease near where this occupant would have had the belt latched and heavier than normal wear marks on the latch plate.

The case vehicle's driver braked and then tried to steer to the right at the last second, attempting to avoid the crash. As a result of these attempted avoidance maneuvers and the use of the lap portion of her available safety belt, she most likely moved forward, especially her head and upper torso, just prior to impact. Based on the vehicle inspection and occupant kinematic principles, the case vehicle's impact with vehicle #2 enabled the front right passenger to continue forward and slightly leftward towards the 350 degree Direction of Principal Force as the case vehicle decelerated. As this small statured passenger was thrown forward, the belt's inertia system locked-up; although the belt was improperly worn, her safety belt kept the passenger from contacting the dash and windshield but not the deploying air bag. The deploying air bag contacted the front right passenger's neck, chin, and left cheek lifting her head upwards before driving her torso back into her seat back. At final rest the front right passenger was still in her seat, laying to the left with her head on the center console. Immediately following the crash the case vehicle's driver went around to the right front door and removed her 3-year-old daughter from the vehicle and laid her down on the road side grass.

The case vehicle's front right passenger was transported by ambulance to a hospital where she was hospitalized overnight. Subsequently, she was transferred and hospitalized at a children's trauma center. She sustained critical spinal cord injuries including: a traumatized spinal cord that resulted in ventilator-dependent quadriplegia, an atlanto-occipital dislocation (distraction), an atlantoaxial dislocation (distraction), a nonanatomic brain injury, a contused spleen, a anterior neck contusion, and severe abrasions across her anterior neck from her left cheek ear to her right shoulder. According to the front right passenger's initial medical records, the abrasion across her neck is from her seat belt, but based on this contractor's inspection and previous SCI cases, the abrasion pattern and the cervical injuries fit with contact from a deploying air bag.

The case vehicle was a front wheel drive 1995 Dodge Neon, four-door sedan, (VIN: 1B3ES47C5SD------). The case vehicle was not equipped with anti-lock brakes. Vehicle #2 is a front wheel drive 1994 Dodge Spirit, four-door sedan (VIN: 1B3AA46K7RF------). Both the case vehicle and vehicle #2 were towed due to damage from the scene. Based on the vehicle inspection, the CDC for the case vehicle was determined to be: **12-FDEW-1 (350)** [maximum crush was 33 centimeters (13.0 inches)]. Vehicle #2 was repaired prior to this contractor's on-site visit, but based on the available photographs, the CDC was estimated as: **2-RYEW-2 (60)** [maximum crush was estimated to be 15 centimeters (5.9 inches)]. The WinSMASH reconstruction program, missing vehicle algorithm, was used on the case vehicle's highest severity impact. The Total, Longitudinal, and Lateral Delta V's are, respectively: 28.9 km.p.h. (18.0 m.p.h.), -28.5 km.p.h. (-17.7 m.p.h.), and +5.0 km.p.h. (+3.1 m.p.h).

The case vehicle's driver air bag was located in the steering wheel, and the front right passenger's air bag was located in the top of the instrument panel. An inspection of both air bag module's cover flaps and air bags revealed that the cover flaps opened at the designated tear points, and there was no evidence of damage during the deployment to the air bags or the cover flaps. The driver's air bag was designed with two tethers, each 5 centimeters (2.0 inches), and the front right passenger's air bag was designed with four tethers, each 7.6 centimeters (3.0 inches). The driver's air bag had one vent port, approximately 2.5 centimeters (1.0 inch) in diameter, located at the 12 o'clock position. The deployed driver's air bag was elliptical with a

height of approximately 59 centimeters (23.2 inches) and a width of approximately 62 centimeters (24.4 inches). The front right air bag had one vent port, approximately 5 centimeters (2.0 inches) in diameter, located at the 12 o'clock position. The deployed front right air bag was rectangular with a height of approximately 58 centimeters (22.8 inches) and a width of approximately 49 centimeters (19.3 inches). An inspection of the front right passenger air bag revealed what appeared to be large dark skin transfer to the front left portion of the air bag. The contact mark extended from the upper edge down to the bottom edge of the front portion of the air bag. There was no contact evidence to the top portion of the air bag which would indicate (based on previous SCI air bag cases), that the front right passenger was grossly out-of-position at the time of deployment. An inspection of the driver's air bag revealed skin contact evidence readily apparent on the air bag's fabric at the 9 and 3 o'clock positions. There was no evidence of direct contact to the windshield, sun visor, or header; however, the roof area on the front right side showed blood splatters. According to the investigating officer, the attending physician told him that the front right passenger's injuries were from her head being hung over the torso belt at maximum engagement and were not air bag-related.

The exact posture of the front right passenger immediately prior to the crash is unknown. Just prior to the crash the driver could only recall that the front right passenger was seated upright with her back against the seat back and her legs outstretched in front of her with her feet hanging off the edge of the seat cushion. The case vehicle's driver recalled that the front right seat track was located in the middle position, and the seat back was in the upright position. The vehicle inspection showed that her seat track was located in its rearmost position and the seat back was upright. The distance from the leading edge of the dash to the center of the front right passenger's seat back was 83 centimeters (32.7 inches). This contractor believes that the front right passenger's seat track position had been moved between the time of the crash to the time of this contractor's inspection.

The case vehicle's driver [23-year-old, White (non-Hispanic) female] was seated in an upright posture with her back against the seat back, her left foot on the floor, her right foot on the brake, and both hands on the steering wheel at the 10 and 2 o'clock positions. Her seat track was located in its center position, the seat back was completely upright, and the tilt steering wheel was located in its full-up position. The vehicle inspection showed that her seat track was located in its rearmost position, and the seat back was slightly reclined. Given the driver's height, her seat track had most likely been moved sometime following the crash. The case vehicle's driver ([173 centimeters and 69 kilograms (68 inches, 152 pounds)] indicated that she was restrained by her available, active, three-point, lap-and-shoulder, safety belt system. However, this contractor believes that she was not using her safety belt because an inspection of the driver's seat belt webbing, "D"-ring, and latch plate showed no evidence of loading or separation of the webbing's energy management loop. In addition, there was no evidence of belt pattern bruising and/or abrasions to the driver's body. The case vehicle's driver was transported by ambulance to a hospital. She sustained minor injuries and was treated and released. The injuries sustained by the case vehicle's driver included: a cervical strain and an abrasion to her right distal forearm.

The case vehicle's back right passenger (1-year-old, unknown race or ethnic origin, male) was properly restrained in a child safety seat (unknown make and model, but equipped with a four-

point harness and shield), that was secured by the available, active, three-point, lap-and-shoulder, safety belt system. The case vehicle's back right passenger [97 centimeters and 15 kilograms (38 inches, 32 pounds)] did not sustain any injuries as a result of this crash. However, according to the case vehicle's driver, this occupant was transported by a passerby to the hospital to be with his mother.

CRASH CIRCUMSTANCES

The case vehicle was traveling north in the inside northbound lane on a four-lane, undivided, city street and intended to continue traveling northward (i.e., two northbound and two southbound through lanes). Vehicle #2 had been traveling south in the inside southbound lane of the same four-lane roadway and was turning left turn into a parking lot. Both the case vehicle and vehicle #2 were traveling on a dry, concrete roadway that was straight and level at the area of impact. The width of the travel lanes for both vehicles was 3.2 meters (10.6 feet). The north and southbound lanes were divided by painted, double solid, yellow lines with the lanes divided by a dashed white line. The roadway is bordered by curbs. There were on-colors, pre-timed vertical and horizontal mounted traffic control signals, approximately 100 meters (328 feet) north of the crash site. The estimated coefficient of friction for the roadway is 0.75%. The posted speed limit was 56 km.p.h. (35 m.p.h.). The surrounding area is primarily commercial. The case vehicle's driver attempted to swerve to the right and braked, trying to avoid the crash. The case vehicle continued essentially straight ahead because the case vehicle was not equipped with anti-lock brakes when the driver's braking negated her steering input. The crash occurred in the inside northbound lane (**Figure 1** and **2**) within the three-leg junction of the two trafficways (see **CRASH DIAGRAM**).

Figure 1: On-scene view of case vehicle's northward direction of travel toward impact in three-leg, driveway junction; Note: arrow shows approximate point of impact in inside northbound lane (case photo #02)

Figure 2: On-scene view of case vehicle (left) and vehicle #2 (right) at final rest positions; Note: case rotated approximately 60 degrees clockwise while vehicle #2 was redirected approximately 65 degrees counterclockwise (case photo #51)

Figure 3: Case vehicle's frontal damage with contour gauge present; Note: yellow tape on bumper indicates start of direct damage (case photo #10)

The front of the case vehicle (**Figure 3** and **Figures 4** and **5** below) impacted the right front side of vehicle #2, causing the case vehicle's driver and front right passenger supplemental restraints (air bags) to deploy. The case vehicle

rotated approximately 60 degrees clockwise and came to rest straddling the inside northbound lane heading east-northeast (**Figure 6**). Vehicle #2 was redirected approximately 65 degrees counterclockwise and came to rest heading east-northeast with its front end in the exit lane of the driveway access (**Figure 7**), against the front bumper of a pickup truck (undamaged) that was stopped in the parking lot exit lane waiting to make a turn. According to the available information, there was no damage to the pick-up and it subsequently departed the scene prior to the arrival of police. The Police Crash Report did not list this pickup, and its year, make, and model are unknown.

Figure 4: Case vehicle's frontal deformation viewed along reference line from right with contour gauge present; Note: bumper fascia torn away (case photo #18)

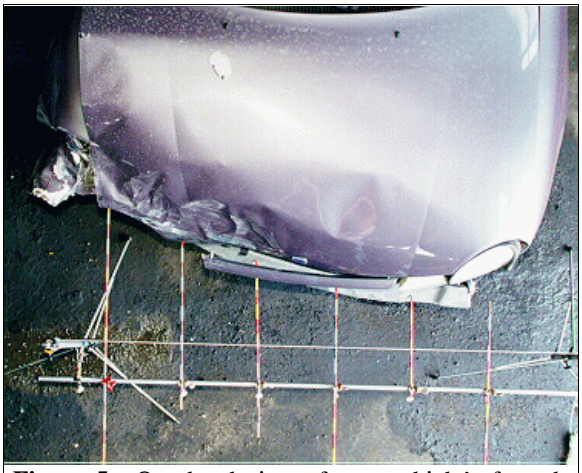


Figure 5: Overhead view of case vehicle's frontal damage/crush measurements (case photo #22)

Figure 6: On-scene view of case vehicle at final rest straddling inside northbound lane; Note: frontal damage, particularly to front right (case photo #53)

Figure 7: On-scene view of vehicle #2 at final rest; Note: direct damage to right fender and right front wheel assembly (case photo #56)

CASE VEHICLE

The case vehicle was a front wheel drive 1995 Dodge Neon, five-passenger, four-door sedan, (VIN: 1B3ES47C5SD------) equipped with power-assisted rack-and-pinion steering, a 2.0L, SOHC SMPFI, I-4 engine, and a three-speed automatic transmission. Braking was achieved by a power-assisted, front disc and rear drum system. The case vehicle was not equipped with the optional anti-lock brakes. The case vehicle's wheel base was 264 centimeters (104.0 inches), and

the odometer reading at inspection was 81,974 kilometers (50,936 miles).

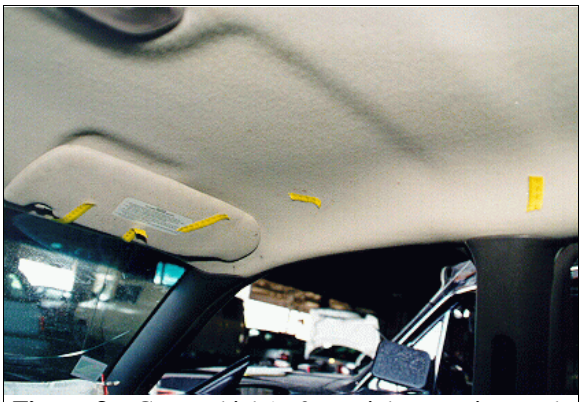


Figure 8: Case vehicle's front right sun visor and roof showing air bag residue on sun visor and blood splatters on roof from front right passenger (case photo #41)

The interior of the case vehicle was equipped with adjustable front bucket seats; integral head restraints; and manual, three-point, lap-and-shoulder, safety belts in the four, outboard seating positions. The vehicle was equipped with rigid plastic knee bolsters for the driver and front right passenger. The back seat was a bench type seat with a manul, two-point, lap belt only in the rear center seating position. The front belt system was equipped with manually operated height adjusters for the "D"-rings. Automatic restraint was provided by a Supplemental Restraint System (SRS) that consisted of frontal air bags for both the driver and front right passenger positions. An examination of the interior revealed evidence of contact (i.e., smeared white powder used to package the air bag) on the front right windshield caused by the air bag during deployment, and air bag exhaust particles were found on the sun visor and roof area above the front right seating position. Also found on the roof above the passenger seating area were two blood splatters from the front right passenger (**Figure 8**). The knee bolsters showed no evidence of contact.

CASE VEHICLE DAMAGE

The initial contact involved the case vehicle's front bumper fascia (**Figures 3** through **6** above) against the right fender and wheel areas of vehicle #2 (**Figure 7** above). The direct contact damage consisted of a lateral abrasive pattern that began 47 centimeters (18.5 inches) left of center and extended 117 centimeters (46.1 inches) to the front right bumper corner. The bumper fascia was consequently torn off during the case vehicle's clockwise rotation to final rest. The residual deformation to the bumper reinforcement bar, was relatively minor. The deformation to C_1 [1 centimeter (0.4 inches)] was minor while deformation at C_6 [33 centimeters (13.0 inches)] was fairly moderate. The damage pattern suggests a angular impact consistent with vehicle #2 turning left across the case vehicle's travel path. The case vehicle's two fenders, hood, and bumper reinforcement bar were shifted slightly to the right (**Figure 5** above). None of the case vehicle's tires were deflated or physically restricted. There was no evidence of intrusion to the case vehicle's interior.

Based on the vehicle inspection, the CDC for the case vehicle was determined to be: **12-FDEW-1 (350)** [maximum crush was 33 centimeters (13.0 inches)]. The WinSMASH reconstruction program, missing vehicle algorithm, was used on the case vehicle's highest severity impact. The Total, Longitudinal, and Lateral Delta V's are, respectively: 28.9 km.p.h. (18.0 m.p.h.), -28.5 km.p.h. (-17.7 m.p.h.), and +5.0 km.p.h. (+3.1 m.p.h). The case vehicle was towed due to damage from the scene.

As previously mentioned, the case vehicle was equipped with a SRS that consisted of frontal air bags at the driver and front right passenger positions. The SRS deployed as a result of the case vehicle's frontal impact with the right side of vehicle #2. The front right passenger's air bag was located in the top of the instrument panel. An inspection of the front right passenger air bag module's cover flaps and air bag revealed that the cover flaps opened at the designated tear points (i.e., along the leading and outer edges of the flap), and there was no evidence of damage during the deployment to the air bags or the cover flaps. The module cover consisted of a single forward hinged cover flap. The cover flap opened in an upward direction. The cover flap was made of a vinyl skin over a sheet metal frame/liner which acted as hinge points for the deploying flap. The hinged flap did not contact the windshield. The profile of the case vehicle's instrument panel resulted in a 3 centimeter (1.2 inch) setback of the leading edge of the cover flap from the protruding mid instrument panel. The dimensions for cover flap were 33 centimeters (13 inches) horizontally and 16 centimeters (6.3 inches) vertically.

The front right passenger's air bag was designed with four internal tethers, each 7.6 centimeters (3.0 inches) wide. The top two tethers were interiorly sewn to the passenger's air bag at a point that was approximately 12 centimeters (4.7 inches) below the top horizontal edge of the air bag. The bottom tethers were approximately 12 centimeters (4.7 inches) above the bottom horizontal edge line, and there were 35 centimeters (13.8 inches) separating the two stitched lines. The front right air bag had one vent port, approximately 5 centimeters (2.0 inches) in diameter, located at the 12 o'clock position. The front face of the deployed front right air bag was rectangular with a height of approximately 58 centimeters (22.8 inches) and a width of approximately 49 centimeters (19.3 inches).

Figure 9: Case vehicle's front right air bag with yellow tape outlining skin transfer to air bag from front right passenger's face (case photo #33)

Figure 10: Close-up of skin transfer with blood smear to front of case vehicle's front right air bag (case photo #36)

An inspection of the front right air bag module's cover flap revealed what appeared to be two dark spots (unknown substance, possibly blood splatter) on the cover flap. An inspection of the front right passenger air bag revealed what appeared to be a large dark skin transfer to the front left portion of the air bag (**Figures 9** and **10**). The skin evidence on the front of the air bag ranged from approximately 5 centimeters (2.0 inches) wide at the top to 15 centimeters (5.9 inches) at the middle and 8 centimeters (3.1 inches) at the bottom. The skin evidence started

approximately 3 centimeters (1.2 inches) above the top horizontal edge of the air bag and 15 centimeters (5.9 inches) in from the left edge of the air bag. The skin contact continued down the whole front of the air bag for a distance of 58 centimeters (22.8 inches) and extended 2 centimeters (0.8 inches) into the bottom portion. There was no contact evidence to the top portion of the air bag which would indicate (based on previous SCI air bag cases), that the front right passenger was grossly out-of-position at the time of deployment. There was no evidence of direct contact to the windshield, sun visor, or header; however, the roof area on the front right side showed blood splatters. According to the investigating officer, the attending physician told him that the front right passenger's injuries were from her head being hung over the torso belt at maximum engagement and were not air bag-related.

The case vehicle's driver air bag was located in the steering wheel hub. The module cover consisted of asymmetrical cover flaps with an overall width of 21 centimeters (8.3 inches) at the horizontal seam and vertically 9 centimeters (3.5 inches) for the upper flap and 5 centimeters (2.0 inches) for the lower flap. An inspection of the driver air bag module's cover flaps and air bag revealed that the cover flaps opened at the designated tear points, and there was no evidence of damage during the deployment to the air bags or the cover flaps. The driver's air bag was designed with two tethers, each 5 centimeters (2.0 inches) wide, sewn to the interior center face of the air bag. The driver's air bag had one vent port, approximately 2.5 centimeters (1.0 inch) in diameter, located at the 12 o'clock position. The deployed driver's air bag was elliptical with a height of approximately 59 centimeters (23.2 inches) and a width of approximately 62 centimeters (24.4 inches). An inspection of the driver's air bag revealed visible evidence of direct contact (i.e., skin or cloth transfers) on the air bag (**Figure 11**). The two vertical areas of contact were on the far left and far right sides of the air bag, at the 9 and 3 o'clock positions (**Figure 12**), and measured approximately 16 centimeters (6.3 inches) tall and 12 centimeters (4.7 inches) wide.

Figure 11: Case vehicle's front seating area showing deployed air bags with contact evidence (i.e., skin transfers) highlighted (case photo #26)

Figure 12: Case vehicle's deployed driver air bag showing contact evidence (i.e., skin transfers); Note: steering wheel inverted 180 degrees (case photo #27)

CASE VEHICLE FRONT RIGHT PASSENGER KINEMATICS

The case vehicle's front right passenger [daughter; 107 centimeters and 16 kilograms (42 inches and 36 pounds)] was improperly restrained (i.e., not in a child safety seat and wearing the torso portion behind her back) by her available, active, three-point, lap-and-shoulder, safety belt

system. According to the driver (i.e., mother), only a few blocks prior to the crash, while stopped at a stop sign, the front right passenger attempted to put the shoulder portion behind her, and the driver prevented her from doing so. Apparently the front right passenger was still uncomfortable wearing the shoulder belt since, according to the driver, her daughter had just recently outgrown her child safety seat and was not yet used to wearing it. Sometime between making her daughter wear the seat belt properly and the crash, the front right passenger was able to put the belt behind her back. According to the driver, when she went to remover her daughter from the case vehicle she found her with the shoulder belt behind.

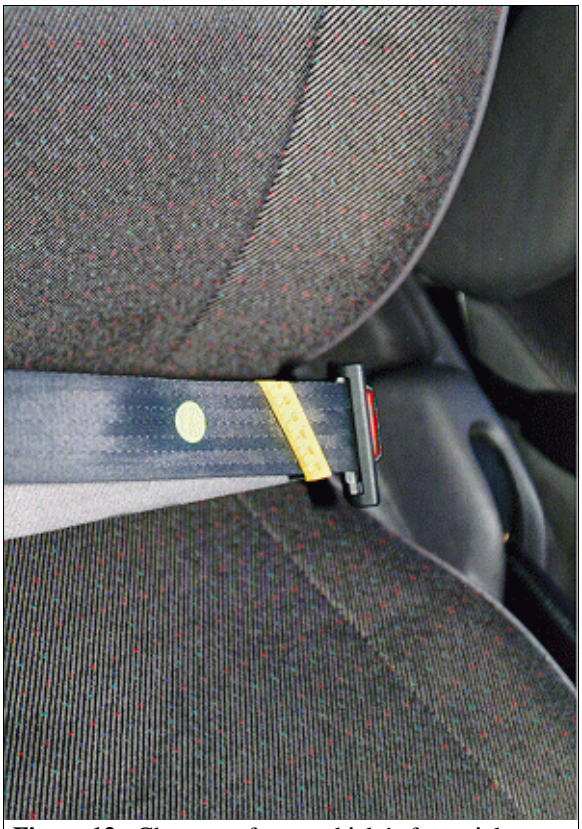


Figure 13: Close-up of case vehicle's front right seat belt webbing showing evidence (i.e., blood drop and angled scrub) of usage (case photo #47)

In addition, the front right safety belt's upper anchorage adjustment was in the full down position. There is no evidence of belt pattern bruising and/or abrasions to the front right passenger's body; however, she sustained a small splenic contusion, which could have resulted from the lap portion of her safety belt if the belt spooled out (no locking clip) during impact. In addition, the inspection of the front right passenger's safety belt webbing, "D"-ring, and latch plate showed no conclusive evidence of loading; although, there were dark fluid blood drops on the webbing as well as an angled crease near where this occupant would have had the belt latched and heavier than normal wear marks on the latch plate (**Figure 13**).

The exact posture of the front right passenger immediately prior to the crash is unknown. Just prior to the crash the driver could only recall that the front right passenger was seated upright with her back against the seat back and her legs outstretched in front of her with her feet hanging off the edge of the seat cushion. The case vehicle's driver recalled that the front right seat track was located in the middle position, and the seat back was in the upright position. The vehicle inspection showed that her seat track was located in its rearmost position and the seat back was upright. The distance from the leading edge of the dash to the center of the front right passenger's seat back was 83 centimeters (32.7 inches). This contractor believes that the front right passenger's seat track position had been moved between the time of the crash to the time of this contractor's inspection.

The case vehicle's driver braked and then tried to steer to the right at the last second, attempting to avoid the crash. As a result of these attempted avoidance maneuver and the use of the lap portion of her available safety belt, she most likely moved forward, especially her head and upper torso, just prior to impact. Based on the vehicle inspection and occupant kinematic

principles, the case vehicle's impact with vehicle #2 enabled the front right passenger to continue forward and slightly leftward towards the 350 degree Direction of Principal Force as the case vehicle decelerated. As this small statured passenger was thrown forward, the belt's inertia system locked-up; although the belt was improperly worn, her safety belt kept the passenger from contacting the dash and windshield but not the deploying air bag. As a result of the belt loading, the passenger's head and upper torso continued forward as her pelvic and lower extremities were restrained by the lap belt. Most likely the passenger's lower torso would have slid forward a short distance with the seat belt having some slack slide through the buckle. The belt loading allowed the passenger's head and upper torso to jackknife over the lap belt. The deploying air bag contacted the front right passenger's neck, chin, and left cheek lifting her head upwards before driving her torso back into her seat back (**Figures 14** and **15**). At final rest the front right passenger was still in her seat, laying to the left with her head on the center console. Immediately following the crash the case vehicle's driver went around to the right front door and removed her 3-year-old daughter from the vehicle and laid her down on the road side grass.

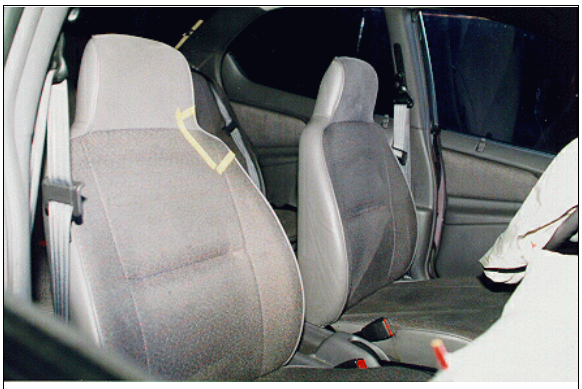


Figure 14: Case vehicle's front bucket seats showing seat back positions; Note: contact to front right seat back (i.e., grease or blood smear) from front right passenger (case photo #45)

Figure 15: Close-up of grease or blood smear to case vehicle's front right seat back from contact by front right passenger (case photo #46)

CASE VEHICLE FRONT RIGHT PASSENGER INJURIES

The case vehicle's front right passenger was transported by ambulance to a hospital where she was hospitalized overnight. Subsequently, she was transferred and hospitalized at a children's trauma center. She sustained critical spinal cord injuries including: a traumatized spinal cord that resulted in ventilator-dependent quadriplegia, an atlanto-occipital dislocation (distraction), an atlantoaxial dislocation (distraction), a nonanatomic brain injury, a contused spleen, a anterior neck contusion, and severe abrasions across her anterior neck from her left cheek ear to her right shoulder. According to the front right passenger's initial medical records, the abrasion across her neck is from her seat belt, but based on this contractor's inspection and previous SCI cases, the abrasion pattern and the cervical injuries fit with contact from a deploying air bag. In addition, see the materials on **SPINAL INJURIES** beginning on page 15.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1	Nonanatomic brain injury, unconscious and unresponsive initially, GCS=3[1], flaccid, no response to painful stimuli	160824.5 critical	Air bag, front right passenger's	Certain	Hospitalization records
2	Injury cervical spine with quadriplegia and dislocations {distractions[2]} between the occipital condyles and C_1 (i.e., atlanto-occipital), 2 cm (0.8 in), and splaying[3] the spinous processes of C_1 or C_2 (i.e., atlantoaxial), 2.5 cm (1.0 in); there were no C_1 or C_2 fractures and insignificant anterior or posterior dislocation	640226.5[4] critical	Air bag, front right passenger's	Certain	Hospitalization records
3	Contusion, small, spleen	544212.2 moderate	Front right safety belt, lap portion	Possible	Hospitalization records
4	Abrasion/friction burn on left cheek	290202.1	Air bag, front right passenger's	Certain	Hospitalization records
5	Abrasion/friction burn on chin	290202.1 minor			
6	Abrasion/friction burn across anterior neck	390202.1 minor	Air bag, front right passenger's	Certain	Hospitalization records
7	Contusion, large, anterior neck	390402.1 minor	Air bag, front right passenger's	Certain	Hospitalization records
8	Abrasion/friction burn on right shoulder – continuation	790202.1 minor	Air bag, front right passenger's	Certain	Hospitalization records

[1] This occupant was apneic and in full (cardiac and respiratory) arrest at scene. She was resuscitated and stabilized by the EMS personnel. Initially her Glasgow Coma Scale (GCS) score was 3, but by the time she had arrived at the initial medical facility, she was awake and could follow simple commands by either closing her eyes and/or protruding her tongue. The GCS score was updated to 6. Throughout the course of her hospitalization she was flaccid with no motor tone, no spontaneous movements of any extremity, and no deep tendon reflexes below her jaw as a result of being quadriplegic from C_2 down. She was ventilator dependent. During her stay at the medical facility that she was transferred to, she was noted to have decreased cranial nerve function, but no specific details were provided.

[2] The following term is defined in DORLAND'S ILLUSTRATED MEDICAL DICTIONARY as follows:
distraction (dis-trak'shen): a form of dislocation in which the joint surfaces have been separated without rupture of their binding ligaments and without displacement.
For this occupant this word was used to mean a longitudinal (i.e., along the spinal cord) dislocation between the cited structures.

[3] According to the RANDOM HOUSE WEBSTER'S UNABRIDGED DICTIONARY, this term is defined as follows:
splay (spl): *v.t.* – 1. to spread, expand, or extend. 2. to form with an oblique angle; make slanting; bevel. 4. to disjoin; dislocate. *v.i.* – 5. to have an oblique or slanting direction. 6. to spread or flare. *adj.* – 8. spread out; wide and flat; turned outward. 10. oblique or awry.

[4] The choice of injury code is difficult because the NASS CDS Injury Coding manual presumes that one knows whether the spinal cord lesion is either a contusion or a laceration (i.e., no option for unknown is provided). In the absence of protocol, this contractor chooses to assume the lesion was a contusion.

The case vehicle's driver [23-year-old, White (non-Hispanic) female] was seated in an upright posture with her back against the seat back, her left foot on the floor, her right foot on the brake, and both hands on the steering wheel at the 10 and 2 o'clock positions. Her seat track was located in its center position, the seat back was completely upright, and the tilt steering wheel was located in its full-up position. The vehicle inspection showed that her seat track was located in its rearmost position, and the seat back was slightly reclined. Given the driver's height, her seat track had most likely been moved sometime following the crash. The case vehicle's driver ([173 centimeters and 69 kilograms (68 inches, 152 pounds)] indicated that she was restrained by her available, active, three-point, lap-and-shoulder, safety belt system. However, this contractor believes that she was not using her safety belt because an inspection of the driver's seat belt webbing, "D"-ring, and latch plate showed no evidence of loading or separation of the webbing's energy management loop. In addition, there was no evidence of belt pattern bruising and/or abrasions to the driver's body.

The case vehicle's driver braked (with lock-up) and then tried to steer to the right at the last second, attempting to avoid the crash. As a result of these attempted avoidance maneuvers and the nonuse of her available safety belt, she most likely moved forward just prior to impact. Based on the vehicle inspection and occupant kinematic principles, the case vehicle's impact with vehicle #2 enabled the driver to continue forward, upwards, and slightly leftward towards the 350 degree Direction of Principal Force as the case vehicle decelerated. The deploying air bag most likely contacted the driver's chest and right upper extremity before driving her torso back into her seat back. There was no evidence of compression of the energy absorbing shear capsules in the base of the steering column. The case vehicle's driver cannot recall her exact final rest position, most likely because her focus was on her daughter (i.e., front right passenger). At final rest she was essentially in her pre-crash posture.

CASE VEHICLE DRIVER INJURIES

The case vehicle's driver was transported by ambulance to a hospital, primarily to accompany the front right passenger (i.e., daughter). She sustained minor injuries and was treated and released; her medical evaluation began approximately one hour after her daughter was seen. The injuries sustained by the case vehicle's driver included: a cervical strain and an abrasion to her right distal forearm.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1	Strain, cervical	640278.1 minor	Other noncontact injury source	Possible	Emergency room records
2	Abrasion right distal forearm	790202.1 minor	Air bag, driver's	Probable	Emergency room records

The case vehicle's back right passenger (1-year-old, unknown race or ethnic origin, male) was properly restrained in a child safety seat (unknown make and model, but equipped with a four-point harness and shield), that was secured by the available, active, three-point, lap-and-shoulder, safety belt system. The case vehicle's back right passenger [97 centimeters and 15 kilograms (38 inches, 32 pounds)] did not sustain any injuries as a result of this crash. However, according to the case vehicle's driver, this occupant was transported by a passerby to the hospital to be with his mother. The back right passenger's movement at impact was minimized due to the proper use of his available restraints.

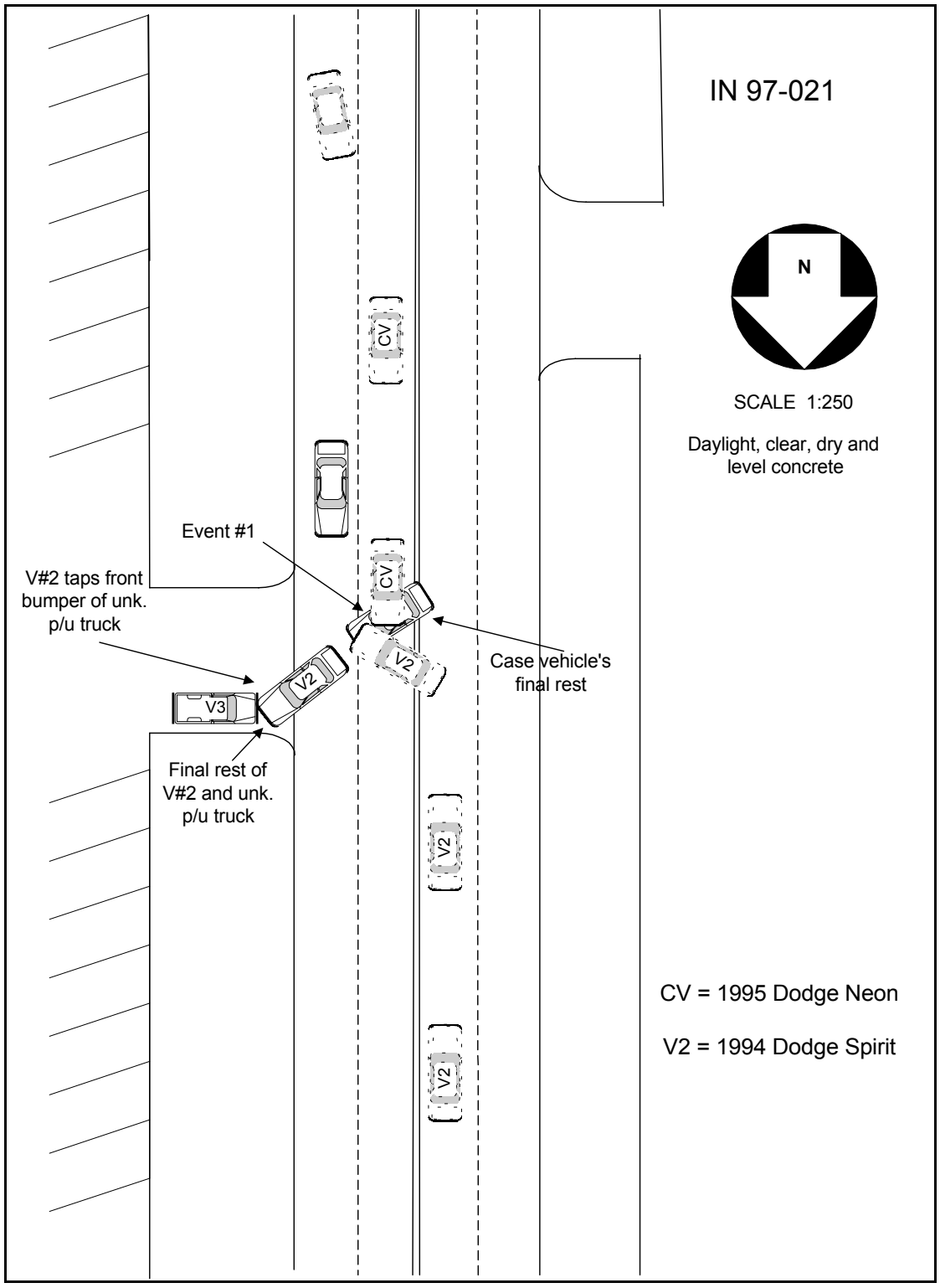
VEHICLE #2

Vehicle #2 is a front wheel drive 1994 Dodge Spirit, five-passenger, four-door sedan (VIN: 1B3AA46K7RF------) equipped with a 2.5L, SOHC TBI, L-4 engine and a three-speed automatic transmission. Four wheel anti-lock brakes are an option for this model, but it is unknown if vehicle #2 was so equipped. Vehicle #2's wheel base was 264 centimeters (104.0 inches), and the odometer reading is unknown because vehicle #2 had been repaired and no inspection occurred.

Based on the VIN and on-scene photographs, the front seat was equipped with a split bench with separate back cushions and adjustable head restraints. The front outboard seats were equipped with automatic, two-point, motorized belts and a manual, two-point, lap belt. The rear seat was a bench type seat without head restraints. The rear outboard seats were equipped with manual, three-point, lap-and-shoulder, safety belts, and there was a manual, two-point, lap belt in the rear center seat position.

Based on the on-scene photographs, the direct damage extended from just behind the right front bumper corner to the middle of the right front door. The right front tire is bent inwards towards the top with damage to the associated wheel assembly components. The front right turn signal glass is broken out, most likely from this vehicle's minor front impact with the unknown pick-up truck in the driveway exit.

Vehicle #2 was repaired prior to this contractor's on-site visit, but based on the available police photographs, the CDC was estimated as: **2-RYEW-2 (60)** [maximum crush was estimated to be 15 centimeters (5.9 inches)]. The WinSMASH reconstruction program, missing vehicle algorithm, was used on vehicle #2's highest severity impact. The Total, Longitudinal, and Lateral Delta V's are, respectively: 24.8 km.p.h. (15.4 m.p.h.), -12.4 km.p.h. (-7.7 m.p.h.), and -21.4 km.p.h. (-13.3 m.p.h). Vehicle #2 was towed due to damage from the scene.


IN 97-021
N
SCALE 1:250
Daylight, clear, dry and level concrete
Event #1
V#2 taps front bumper of unk. p/u truck
Case vehicle's final rest
Final rest of V#2 and unk. p/u truck
CV
V2
V3
CV = 1995 Dodge Neon
V2 = 1994 Dodge Spirit

This following material on ***spinal injuries*** was taken from the chapter entitled: "Spine," written by Anderson, Paul B., M.D., Harborview Medical Center, from the book ORTHOPAEDIC TRAUMA PROTOCOLS, edited by Hansen, Jr., Sigvard T., M.D.; and Swiontkowski, Marc F., M.D.; Raven Press, Ltd., New York, 1993.

SKELETALLY IMMATURE PATIENTS: Factors that contribute to the difficulty of evaluating a child's spine are incomplete ossification of the vertebrae, the presence of multiple growth centers, and physiologic hypermobility of the spine. Most pediatric cervical injuries occur in the upper cervical spine between the occiput and C_3, because the ratio of mass between the head and the body is disproportionate and the muscles and ligaments supporting the cervical spine are weak. Ligament injuries, particularly atlanto-occipital dislocations, are common. Spinal cord injuries may be present in children who exhibit no radiographic abnormalities. This phenomenon occurs in cord-traction injuries and is due to greater elasticity in the spinal column than in the spinal cord. Also, injuries at the junction of cartilaginous and bony end plates are not easily identified on radiographs. Children with spinal tenderness or questionable radiographic findings are treated by immobilization until their symptoms resolve or until experienced physicians can review the radiographs.

(p. 197)

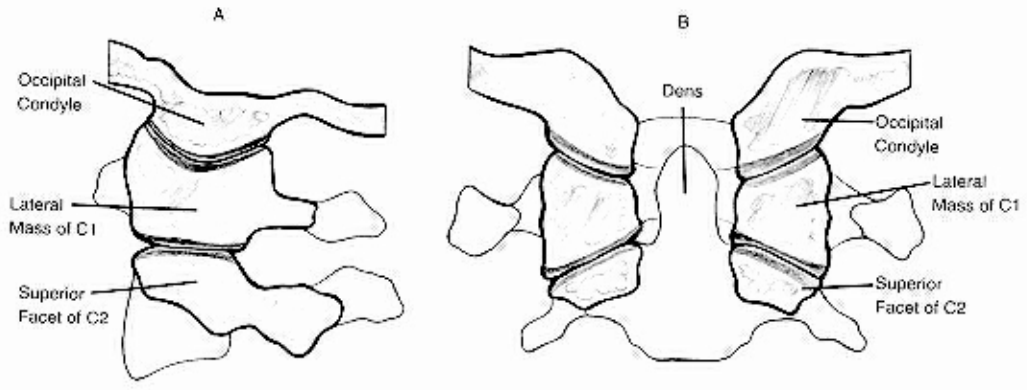


Figure 16: A - Lateral view of craniocervical articulation.
B - Anteroposterior view of bony anatomy of craniocervical articulation

ANATOMIC CONSIDERATIONS: The skull is affixed to the cervical spine at the occipitocervical articulation, which includes the atlanto-occipital and atlantoaxial joints. The strong ligament and bony structures allow a wide range of motion yet are rarely injured. The convex-shaped occipital condyles project downward from the occiput and articulate with corresponding concavities in the lateral masses of the atlas (C_1--**Figure 16**). The principal ligament structures that limit motion in the occipitocervical articulation are the alar ligaments and the tectorial

membrane (**Figure 17** and **Figure 18** below). The alar ligaments attach on the tip of the dens and extend to the medial aspect of the occipital condyles. The tectorial membrane is the uppermost extension of the posterior longitudinal ligament and attaches to the anterior aspect of the foramen magnum. These ligaments span from the occiput to C_2 without attaching directly to C_1, which acts merely as a bushing. *(p. 198)*

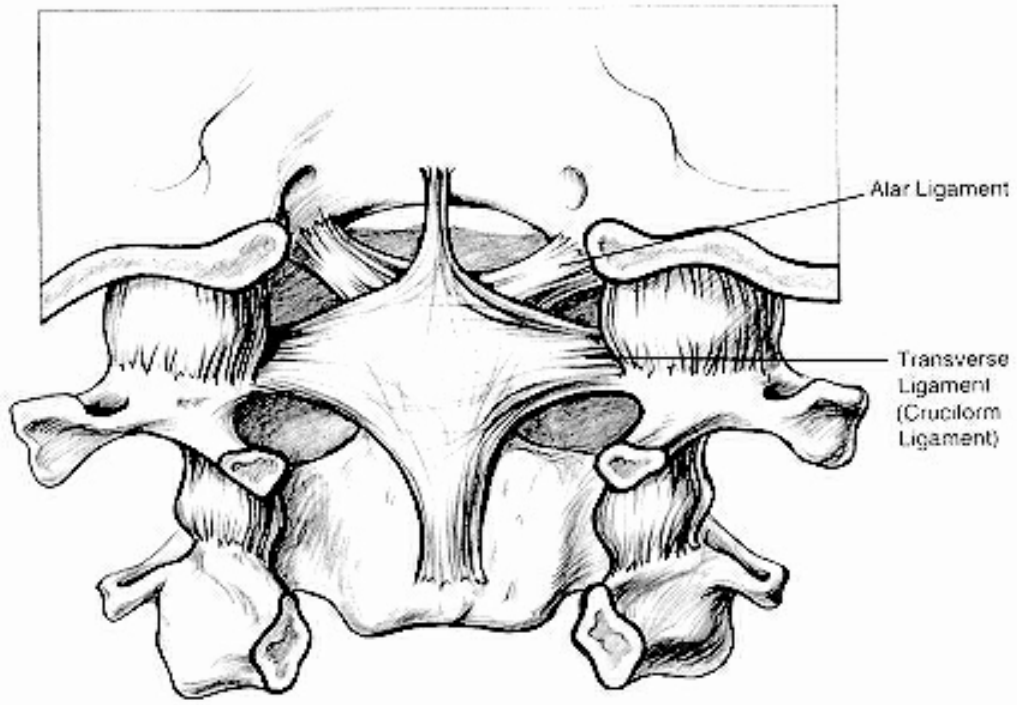


Figure 17: Posterior view of ligamentous anatomy of the craniocervical articulation

CLASSIFICATION: ATLANTO-OCCIPITAL DISLOCATIONS: Patients rarely survive atlanto-occipital dislocations because of brainstem and the spinal cord damage. These injuries, which can range from mild instability to complete dislocation with marked vertical distraction, are often initially missed. Atlanto-occipital dislocations are classified by the direction of displacement: anterior, vertical, or posterior. Pathologically, all the major restraining and alar ligaments and the tectorial membrane are ruptured regardless of the direction of displacement. All injuries are unstable and require posterior occipitocervical fusion. *(p. 200)*

ASSESSMENT: SPECIAL STUDIES: Computerized tomography is invaluable for evaluating the integrity of the occipitocervical articulation. Sagittal reconstructions in the plane of the facet articulation document alignment of these joints. Joint diastasis greater than 2 mm is indicative of

ligament disruption and a highly unstable spinal column. Occipital condylar fractures frequently occur in patients with atlanto-occipital dislocations. *(p. 201)*

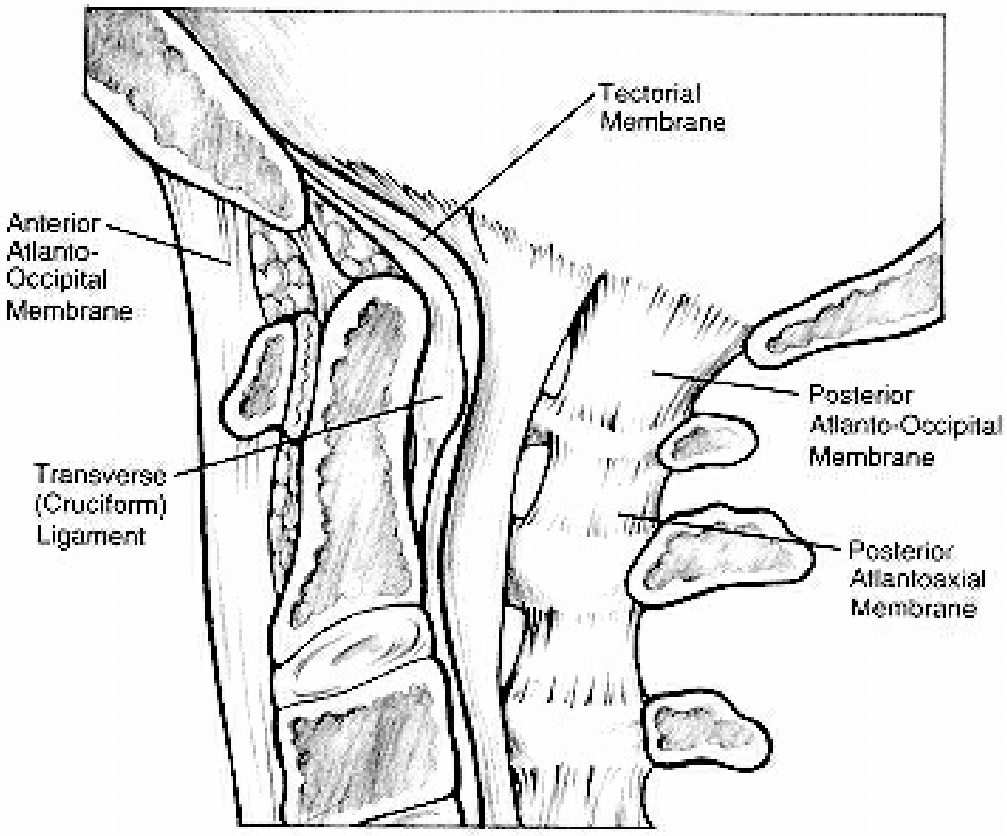


Figure 18: Lateral view of ligamentous anatomy of craniocervical articulation

DEFINITIVE MANAGEMENT: ATLANTO-OCCIPITAL DISLOCATIONS: All patients with occipitocervical dislocations require posterior fusion of the occiput to C_2. This injury warrants an aggressive surgical approach because the healing potential of ligament injuries is poor and the consequences of loss of reduction are catastrophic. Posterior fusion is accomplished by Bohlman's technique, in which autologous iliac bone grafts are wired to the occiput, C_1, and C_2. Postoperatively the patient is immobilized in a halo brace for 12 weeks or until bone union is demonstrated on flexion-extension radiographs. *(p. 201)*