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ON-SITE AIR BAG INVESTIGATION

CASE NUMBER - IN97-029
LOCATION - Minnesota
VEHICLE - 1994 DODGE GRAND CARAVAN
CRASH DATE - September 1997

Submitted:

May 7, 1999

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Contract Number: DTNH22-94-D-17058

Prepared for:

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National Highway Traffic Safety Administration
National Center for Statistics and Analysis
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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 1994 Dodge Grand Caravan SE, three-door minivan, with manual safety belts and dual front air bags, and a 1993 Chevrolet T-10, pick-up truck.

16. *Abstract*

This report covers an on-site investigation of an air bag deployment crash that involved a 1994 Dodge Grand Caravan SE (case vehicle) and a 1993 Chevrolet T-10 pickup truck (vehicle #2). This crash is of special interest because the case vehicle's, restrained, front right passenger [11-year-old, White (non-Hispanic) male] sustained fatal brain injuries as a result of impacting the front right passenger air bag. The case vehicle was traveling south, at a low rate of speed, in the outside through lane of a four-lane, divided, interstate trafficway (i.e., the highway had both north and southbound roadways, each with two through lanes). Vehicle #2 was also traveling in the outside through lane of the same, two-lane, southbound roadway and came to a stop due to construction and merging traffic ahead. The crash occurred in the outside lane of the southbound roadway. The front of the case vehicle impacted the back 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 had been seated in a slightly reclined posture with his seat track located between its middle and rearmost positions. However, immediately prior to the crash, he was bending forward in the process of retrieving a tissue out of the glove box underneath the front right seat. He was restrained by his available, active, three-point, lap and shoulder belt and sustained, according to his medical records, fatal injuries which included: a nonanatomic brain injury, herniations of his brain stem (bilateral tonsillar and uncal), a massive right subdural hematoma, massive cerebral edema, diffuse subarachnoid hemorrhage, a contusion to the right lung with a small apical pneumothorax, an abrasion across the forehead, and contusions to his right eye and upper chest. These injuries resulted from his close proximity to the deploying front right air bag. The case vehicle's driver [38-year-old, White (non-Hispanic) female] was seated with her seat track located between its middle and rearmost positions and the tilt steering wheel was located between its middle and upmost positions. She was restrained by her available, active, three-point, lap and shoulder belt, and she sustained, according to her interview, a minor abrasion to her chin. The case vehicle's three other child passengers [10-year-old male--rear left, 3-year-old female--rear center, and 7-year-old male--rear right, all White (non-Hispanic)] were seated, unrestrained in the back bench seat, but only the rear left passenger sustained an injury (i.e., a laceration/abrasion below his left eye).

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BACKGROUND

IN97-029

This on-site investigation was brought to NHTSA's attention on September 15, 1997 by an investigator with NTSB. This crash involved a 1994 Dodge Grand Caravan (case vehicle) and a 1993 Chevrolet T-10 pick-up truck (vehicle #2). The crash occurred in September, 1997, at 3:50 p.m., in Minnesota and was investigated by the Minnesota State Police. This crash is of special interest because the case vehicle's front right passenger [11-year-old, White (non-Hispanic) male] sustained fatal brain injuries from the deploying front right passenger air bag while bending forward to retrieve a tissue from the glove box underneath his seat. This contractor inspected the scene and case vehicle on 18-19 September, 1997. This report is based on the Police Crash Report, interviews with the case vehicle's driver and the investigating officer, scene and vehicle inspections, occupant kinematic principles, occupant medical records, and this contractor's evaluation of the evidence.

SUMMARY

The case vehicle was traveling south in the outside through lane of a four-lane, divided, interstate trafficway and intended to continue traveling south (i.e., the highway had both north and southbound roadways, each with two through lanes). Vehicle #2 was also traveling south in the outside through lane of the same, two-lane roadway and came to a stop due to construction and merging traffic ahead. The case vehicle's driver made no avoidance maneuvers prior to the crash. The crash occurred in the outside lane of the southbound roadway.

The front of the case vehicle impacted the back of vehicle #2, causing the case vehicle's driver and front right passenger supplemental restraints (air bags) to deploy. Both vehicles moved a short distance southward as a result of the impact. The case vehicle came to rest heading south in the outside southbound lane, while the driver of vehicle #2 drove his vehicle to the west shoulder on the south roadway.

The front right passenger [152 centimeters and 32 kilograms (60 inches, 70 pounds)] was restrained by his available, active, three-point, lap and shoulder belt. However, immediately prior to the crash, he was bending forward in the process of retrieving a tissue out of the glove box underneath the front right seat. As a result his head was directly in front of the right instrument panel and air bag module. The inspection of the front right passenger's seat belt webbing showed blood evidence on the torso portion.

The case vehicle's driver made no pre-crash avoidance maneuvers. As a result and independent of the use of his available safety belts, the front right passenger's body position did not change just prior to impact, and his use of the available seat belt had no injury-prevention role in the crash because of his close proximity to the front right air bag module just prior to the crash. The case vehicle's impact not only deployed the front right passenger air bag, but resulted in the front right passenger moving forward and slightly upward into the excursion area of the deploying air bag. Specifically the front right passenger's forward movement put his head in harms way. In addition, as the air bag deployed, the front right passenger was raising up, looking forward. This fact was determined by finding an imprint of the air bag's fabric on the front right passenger's broken sunglass lens. As the front right passenger was struck by the air bag, he was thrown rearward into his seat back where he came to rest in an upright position.

The front right occupant was transported by helicopter to the hospital. He sustained fatal brain injuries and was pronounced brain dead approximately 51 hours post-crash. Based on the medical records, the front right passenger sustained: a nonanatomic brain injury, herniations of his brain stem (bilateral tonsillar and uncal), a massive right subdural hematoma, massive cerebral edema, diffuse subarachnoid hemorrhage, a contusion to the right lung with a small apical pneumothorax, an abrasion across the forehead, and contusions to his right eye and upper chest. These injuries resulted from his close proximity to the deploying front right air bag.

The case vehicle was a front wheel drive 1994 Dodge Grand Caravan, seven-passenger, three-door, extended minivan (VIN: 1B4GH44R1RX------). The case vehicle was equipped with anti-lock brakes. Vehicle #2 was a four wheel drive 1993 Chevrolet T-10, regular cab, standard bed pickup truck with cap (VIN: not available). The case vehicle was towed due to damage while vehicle #2 was driven from the scene. Based on the vehicle inspection and available photographs, the CDCs were determined to be: **12-FDEW-1 (360)** for the case vehicle [maximum crush was 11 centimeters (4.5 inches)] and **06-BDEW-1 (180)** for vehicle #2 (photographs only, no inspection). The WinSMASH reconstruction program, missing vehicle algorithm was used on the case vehicle's highest severity impact. The Total, Longitudinal, and Lateral Delta Vs are, respectively: 11.9 km.p.h. (7.4 m.p.h.), -11.9 km.p.h. (-7.4 m.p.h.) and 0.0 km.p.h. (0.0 m.p.h.).

The case vehicle's initial contact with vehicle #2 involved the left ¾ of the front end, beginning at the front left bumper corner and extending to the right a measured distance of 132 centimeters (52 inches). The case vehicle's entire front end sustained induced damage for a Field L of 151 centimeters (59.5 inches) with the greatest visible deformation being above bumper. The extended tow hitch/ball attached to vehicle #2's rear penetrated through the case vehicle's plastic bumper fascia, contacting and displacing the bottom half of the case vehicle's radiator rearward 24 centimeters (9.5 inches). Maximum crush to the bumper was only 3 centimeters (1.2 inches).

An inspection of the driver's air bag, which was located in the steering wheel hub, revealed no apparent area of contact. An inspection of the air bag module's cover flap revealed no damage or evidence of direct contact. An inspection of the front right air bag, which was located in the front of the instrument panel, revealed skin evidence on the bottom portion of the air bag. Finally, an inspection of the front right air bag module's cover flap revealed no evidence of contact.

Immediately prior to the crash the front right passenger was seated, leaning forward retrieving a tissue from the glove box underneath his seat. He was retrieving the tissue for his sister who was seated in the rear bench seat. His feet were on the floor and his right hand (most likely) was retrieving the tissue. His seat track was located between its middle and rearmost positions, and the seat back was sightly reclined.

The case vehicle's driver [38-year-old, White (non-Hispanic) female] was seated in an upright posture with her back partially against the seat back, her left foot on the floor, her right foot on the brake, and both hands on the steering wheel. Her seat track was located between its middle and rearmost positions, her seat back was upright, and her tilt steering wheel was located between its middle and upmost positions. The case vehicle's driver [170 centimeters and 54 kilograms (67 inches, 119 pounds)] was also restrained by her available, active, three-point, lap and shoulder belt. The case vehicle's driver was not treated but did sustain an abrasion to her chin and complained of back soreness.

The case vehicle's three other child passengers [10-year-old male--rear left, 3-year-old female--rear center, and 7-year-old male--rear right, all White (non-Hispanic)] were in the rear bench seat. They were seated in an upright posture with their backs against the seat back, and their feet hanging down. The exact positions of their arms and hands is unknown. The case vehicle's center bench seat had been removed to make room for trip supplies (i.e., beverage cooler, etc.). All three back-seated children were unrestrained immediately prior to the crash. At impact, these three passengers were thrown forward onto the floor of the case vehicle. Only the 10-year-old rear left passenger sustained an injury (i.e., a laceration/abrasion below his left eye) from contacting a cooler in the vehicle. The rear left passenger was transported by ambulance to the hospital where he was treated and released.

CRASH CIRCUMSTANCES

Figure 1: Case vehicle and vehicle #2's southbound travel path in outside lane just prior to impact and final rest (case photo #03)

Both vehicles were traveling south in the outside through lane on a four-lane, divided, interstate trafficway (i.e., the highway had both north and southbound roadways, each with two through lanes). The southbound roadway was concrete, dry, straight, and level at the area of impact. The north and south roadways were divided by an unprotected grassy median approximately 15 meters (49 feet) wide, bordered by 2 meter (6.6 feet) bituminous shoulders with a solid white fog lines along each road edge. The trafficway's travel lanes were divided by dashed white lines. The southbound outside lane was 3.6 meters (12 feet) wide, with a 3 meter (9.8 foot) bituminous shoulder on the west side of the roadway (**Figure 1**). The area was primarily undeveloped with some commercial areas at the exits. The legal speed limit was 113 km.p.h. (70 m.p.h.).

The case vehicle was traveling in the outside southbound through lane at a low rate of speed because of merging traffic and road construction ahead. The case vehicle intended to continue southward. Vehicle #2 had come to a stop due to merging traffic and road construction ahead. The case vehicle's driver was distracted by her 3-year-old daughter in the rear bench seat and turned around to assess the situation and didn't observe vehicle #2 come to a stop in front. When she turned back around she had no time to react. The case vehicle's driver made no avoidance maneuvers prior to the crash. The crash occurred in the outside lane of the southbound roadway.

The front of the case vehicle (**Figures 2** and **3**) impacted the back of vehicle #2 (**Figure 4**), causing the case vehicle's driver and front right passenger supplemental restraints (air bags) to deploy. Both vehicles moved a short distance southward as a result of the impact. The case vehicle came to rest heading south in the outside southbound lane. Vehicle #2 was knocked forward, but the driver of vehicle #2 drove his vehicle onto the west shoulder on the south roadway prior to coming to rest heading south. The case vehicle was towed from the scene due to damage, while vehicle #2 was driven away.

Figure 2: On-scene view of case vehicle's frontal damage; Note: hole punched through front bumper by vehicle #2's trailer hitch (case photo #68)

Figure 3: Case vehicle's damaged front viewed from right of center; Note: vertical yellow tape indicates start of direct damage and yellow line shows hole punched in front bumper (case photo #13)

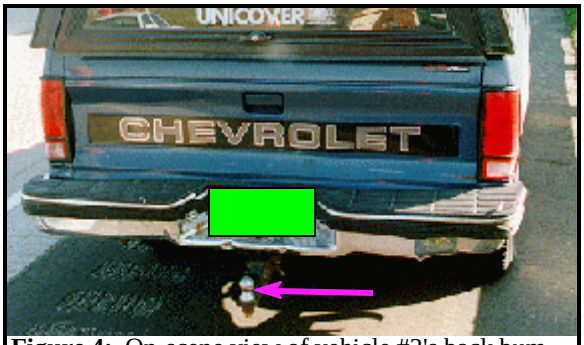


Figure 4: On-scene view of vehicle #2's back bumper showing minimal damage; Note: extended "tow ball" trailer hitch (case photo #61)

CASE VEHICLE

The case vehicle was a front wheel drive 1994 Dodge Grand Caravan SE, seven-passenger, three-door, extended minivan (VIN: 1B4GH44R1RX------) equipped with a 3.3L, SMPI, V-6 engine, power-assisted rack-and-pinion steering, and a four-speed automatic transmission. Braking was achieved by a hydraulic, power-assisted, front disc and rear drum, four wheel anti-lock braking system. The case vehicle's wheel base was 303 centimeters (119.3 inches), and the odometer reading at inspection was 86,954 kilometers (54,031 miles). The case vehicle was bought used and had been driven approximately 21,726 kilometers (13,500 miles) the twelve months prior to the crash.

The interior of the case vehicle was equipped with adjustable front bucket seats with integral head restraints, three-point, lap and shoulder safety belts, in the six outboard seat positions, and a lap belt in the rear center seat position. The vehicle was equipped with rigid knee bolsters for both the driver and front right passenger, neither of which were deformed from contact. The center bench seat had been removed to allow for more interior room during the family's trip. The rear seat was a three seat bench and was not equipped with head restraints. The front belt systems came equipped with manually operated height adjusters for the "D"-rings and buckle webbing assembly energy management loops. Automatic restraint

was provided by a Supplemental Restraint System (SRS) that consisted of frontal air bags for the driver and front right passenger positions.

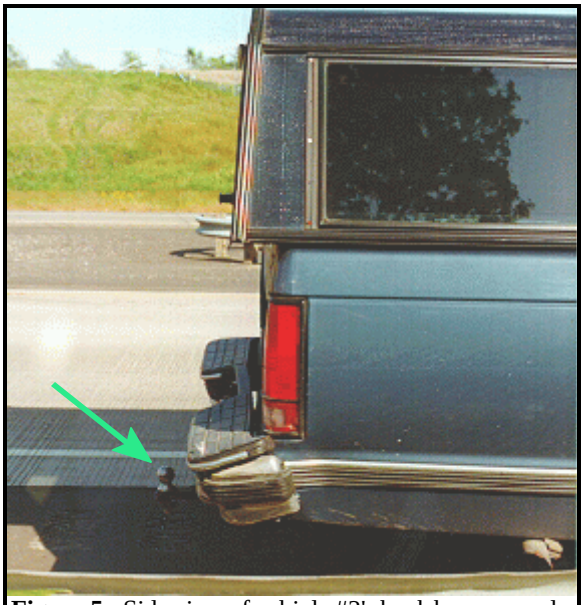


Figure 5: Side view of vehicle #2's back bumper and extended trailer hitch; Note: bumper rotated downward and of truck bed's cap displaced rearward (case photo #63)

CASE VEHICLE DAMAGE

The case vehicle's initial contact with vehicle #2 involved the left ¾ of the front end (**Figure 3**), beginning at the front left bumper corner and extending to the right a measured distance of 132 centimeters (52.0 inches). The direct contact damage extended 55 centimeters (21.7 inches) to the right of center. The case vehicle's entire front end, from bumper corner to bumper corner, sustained induced damage for a Field L of 151 centimeters (59.4 inches) with the greatest visible deformation being above bumper. The front bumper fascia, grille, and radiator were crushed rearward. The extended tow hitch/ball attached to vehicle #2's rear (**Figure 5**) penetrated through the case vehicle's plastic bumper fascia at a point approximately 40 centimeters to the left of center, and was 5 centimeters (2.0 inches) in diameter (**Figures 6** and **7**). The extended hitch/ball contacted and displaced the bottom half of the case vehicle's radiator rearward. The residual crush to the radiator was measured at 24 centimeters (9.4 inches).

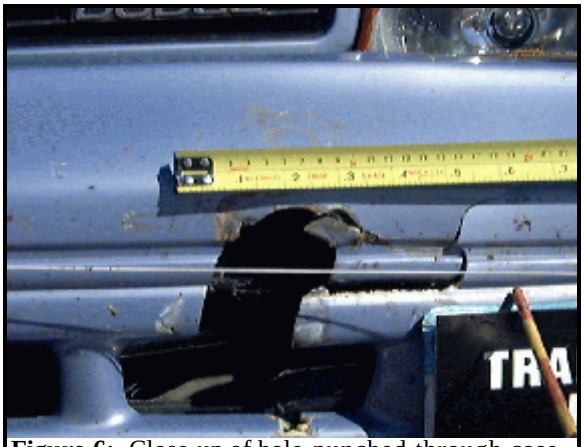


Figure 6: Close-up of hole punched through case vehicle's front bumper cover by extended trailer hitch attached to vehicle #2's back bumper (case photo #17)

Figure 7: Overhead close-up view of hole punched through case vehicle's bumper fascia by vehicle #2's trailer hitch; Note: tape measure shows radiator penetration and indicates a maximum crush of 24 centimeters (9.5 inches) (case photo #15)

The hood sustained minor damage to the leading edge. The windshield had a spider web crack just left of center from the rearview mirror being knocked into it (see **SELECTED PHOTOGRAPHS**, **Figure 14**). The rearview mirror was struck by the front right passenger air bag during its deployment. The front end damage to the case vehicle had the appearance of an underride type impact. Neither of the front tires were physically restricted from the front end damage. Maximum crush to the bumper was only 3 centimeters (1.2 inches) at C_1. The wheelbase was unaltered from the crash. The left fender sustained induced damage from the frontal impact which also knocked out the left headlight assembly.

Based on the vehicle inspection, the CDC was determined to be: **12-FDEW-1 (360)** for the case vehicle [maximum crush was 11 centimeters (4.5 inches)]. The WinSMASH reconstruction program, missing vehicle algorithm was used on the case vehicle's highest severity impact. The Total, Longitudinal, and Lateral Delta Vs are, respectively: 11.9 km.p.h. (7.4 m.p.h.), -11.9 km.p.h. (-7.4 m.p.h.) and 0.0 km.p.h. (0.0 m.p.h.).

An examination of the interior revealed a brush abrasion to the front right passenger door handle from the deploying front right air bag as seen in previous SCI cases involving these type of minivans.

CASE VEHICLE AUTOMATIC RESTRAINT SYSTEM

As previously mentioned, the 1994 Dodge Grand Caravan 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 back of vehicle #2. The driver's air bag deployed from the steering wheel hub were it was mounted. The module cover consisted of symmetrical cover flaps with overall dimensions of 18 centimeters (7.1 inches) at the horizontal seam and 6 centimeters (2.4 inches) vertically. The air bag was 64 cm. (25.2 in.) in diameter and was untethered. The driver's air bag had two vent ports at the 11:30 and 12:30 clock locations, and they were 2.5 centimeters (1.0 inches) in diameter. There appeared to be a vertical cloth transfer to the right side of the air bag measuring 19 centimeters tall (7.5 inches) and 5 centimeters (2.0 inches) wide (**Figure 8**--shown at top in photo). The mark started 10 centimeters (3.9 inches) down from the top edge and approximately 6 centimeters (2.4 inches) to the left of the right edge. There was a small 3 centimeter (1.2 inches) long red mark to the left side of the air bag (**Figure 8**--shown at bottom in photo) approximately 14 centimeters (5.5 inches) down from the top edge and 8 centimeters (3.1 inches) to the right of the left edge.

Figure 8: Case vehicle's driver air bag with tape indicating areas of skin and cloth transfer; Note: steering wheel rotated approximately 90 degrees counterclockwise (case photo #21)

The front right passenger air bag (**Figure 9**) was mounted on the top of the right instrument panel. The air bag deployed from a single symmetrical rear hinged cover flap. The cover flap opening 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 flap showed no evidence of contact or abnormal deformation. The crash thrust the out-of-position front right passenger forward into the deploying air bag. The passenger's forward momentum and the air bag's outward excursion thrust the passenger rearward into his seat back. The dimensions of the flap were 32 centimeters (12.6 inches) horizontally and 15 centimeters (5.9 inches) vertically. The profile of the Caravan's instrument panel was flush with the leading edge of the cover flap.

Figure 9: Front surface of case vehicle's front right passenger air bag showing no evidence of contact (case photo #29)

The cover flap opened at the designated tear points along the leading and outer edges of the flap. The hinged flap was not capable of contacting the windshield. There was no evidence to indicate contact on the cover flap from the front right passenger.

Examination of the front right passenger air bag revealed a small skin transfer to the center of the bottom portion of the air bag only. There was no evidence of contact to the front portion of the front right passenger's air bag (**Figure 9**). The skin evidence on the bottom of the air bag was approximately 4 centimeters (1.6 inches) in diameter (**Figure 10**). The skin evidence started 11 centimeters (4.3 inches) down from the bottom horizontal edge of the air bag and 18 centimeters (7.1 inches) in from the left edge of the air bag. The top portion of the air bag had two long parallel black marks from the cover flap and another to the lower right front portion of the air bag. There was a black scuff to the top portion of the air bag towards the left side from contact with the lower right corner of the rearview mirror (see **SELECTED PHOTOGRAPHS**, **Figures 14** and **15**).

Figure 10: Underside (bottom) of case vehicle's front right passenger air bag showing area of skin transfer (circled area) from front right passenger's face (case photo #33)

The front right passenger air bag was tethered with two 31 centimeter (12.2 inches) wide tethers. The upper tether was located 21 centimeters (8.3 inches) down from the top edge with the other 26 centimeters (10.2 inches) below that. The front right air bag had no vent ports. The air bag's front face was 50 centimeters (19.7 inches) wide and 58 centimeters (22.8 inches) tall.

The front right passenger [152 centimeters and 32 kilograms (60 inches, 70 pounds)] was restrained by his available, active, three-point, lap and shoulder belt. However, according to the case vehicle's driver (i.e., mother), immediately prior to the crash, he was bending forward in the process of retrieving a tissue out of the glove box underneath the front right seat. He was retrieving the tissue for his sister who was seated in the rear bench seat. His feet were on the floor and his right hand was retrieving the tissue (**Figure 11**). His seat track was located between its middle and rearmost positions, and the seat back was sightly reclined. As a result his head was directly in front of the right instrument panel and air bag module. The inspection of the front right passenger's seat belt webbing showed blood evidence on the torso portion. The driver stated that immediately following the crash she saw her son leaning back against his seat back and thought he was fine. The driver said that following the crash while checking on her kids (i.e., three rear seated passengers that were thrown on the floor), she called out his name and heard him moan. When she looked over to him she noticed a small trickle of blood coming from his mouth and eye (unspecified aspect) and then realized that he was seriously injured. As the driver went to open the door an off duty paramedic came up to the right front door to check on the occupants and immediately noticed the front right passenger was in distress. The paramedic called back to his wife in the noncontact vehicle behind the case vehicle to get his phone so he could call for air transport.

Figure 11: Case vehicle's front right seat with glove box beneath seat pulled outward showing box of tissues; envision front right passenger's close proximity to air bag module while leaning forward to get a tissue (case photo #43)

The case vehicle's driver made no pre-crash avoidance maneuvers. As a result and independent of the use of his available safety belts, the front right passenger's body position did not change just prior to impact, and his use of the available seat belt had no injury-prevention role in the crash because of his close proximity to the front right air bag module just prior to the crash. The case vehicle's impact not only deployed the front right passenger air bag, but resulted in the front right passenger moving forward and slightly upward into the excursion area of the deploying air bag. Specifically the front right passenger's forward movement put his head in harms way. In addition, as the air bag deployed, the front right passenger was raising up, looking forward. This fact was determined by finding an imprint of the air bag's fabric on the front right passenger's broken sunglass lens (**Figure 12** above). The front right passenger's head, face, and

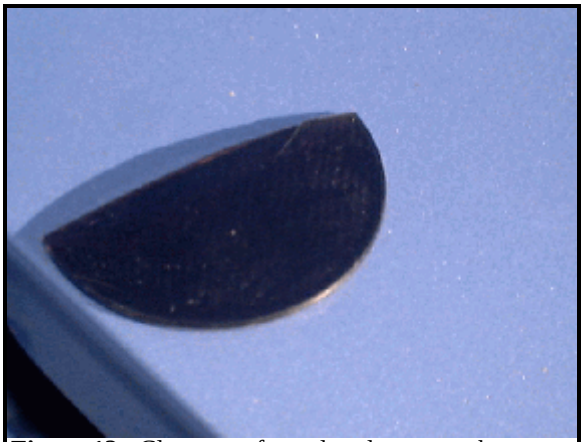


Figure 12: Close-up of sunglass lens worn by case vehicle's front right passenger showing fabric imprint on lens caused by front right air bag (case photo #36)

chest simultaneously contacted the bottom portion of the air bag as it deployed (**Figure 10**). As the air bag reached maximum expansion, it thrust the front right passenger backwards into his seat back where he came to rest in an upright position.

A close examination (**Figure 12**) of the front right passenger's broken sunglass lens shows conclusive evidence (i.e., stitching pattern from air bag's fabric) that direct contact was made with the fabric of the deploying air bag. At final rest the front right passenger was unconscious leaning against his seat back facing forward.

CASE VEHICLE'S FRONT RIGHT PASSENGER INJURIES

The front right occupant was transported by helicopter to the hospital. He sustained fatal brain injuries and was pronounced brain dead approximately 51 hours post-crash. Based on the medical records, the front right passenger sustained: a nonanatomic brain injury, herniations of his brain stem (bilateral tonsillar and uncal), a massive right subdural hematoma, massive cerebral edema, diffuse subarachnoid hemorrhage, a contusion to the right lung with a small apical pneumothorax, an abrasion across the forehead, and contusions to his right eye and upper chest. These injuries resulted from his close proximity to the deploying front right air bag. He was maintained with life support an additional 36 hours for organ harvesting.

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 pupils fixed, dilated, and non-reactive, flaccid, unresponsive to painful stimuli, GCS=3	160214.5 Critical	Air bag, front right passenger's	Certain	Hospitalization records
2	Herniation brain stem, bilateral tonsillar {cerebellar} and uncal {transtentorial} See section on Cerebral Edema and Brain Swelling	140202.5 Critical	Air bag, front right passenger's	Certain	Hospitalization records
3	Hematoma, massive[1], right subdural[2]	140650.4 Severe	Air bag, front right passenger's	Certain	Hospitalization records

[1] The size of the subdural hematoma was not quantified.

[2] A right frontoparietal craniotomy was performed for evacuation of the subdural hematoma. In addition a ventriculostomy was inserted and approximately 10-15 cc of fluid {i.e., type unspecified} was removed.
The following term is defined in DORLAND'S ILLUSTRATED MEDICAL DICTIONARY as follows:
ventriculostomy (ven-trik"u-los'te-me): the operation of establishing a free communication or shunt between the floor of the third ventricle and the underlying cisterna interpeduncularis; for the treatment of hydrocephalus.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
4 5	Edema, massive/significant, cerebrum with midline shift right to left and effacement[3] of basilar cisterns--lateral ventricles not completely effaced [Aspect = Left and Right] See section on Cerebral Edema and Brain Swelling	140674.5 140674.5 Critical	Air bag, front right passenger's	Certain	Hospitalization records
6	Hemorrhage, subarachnoid, in basilar cisterns and diffuse [Aspect = Unknown}	140684.3 Serious	Air bag, front right passenger's	Certain	Hospitalization records
7	Contusion right lung with small apical pneumothorax and ARDS {acute respiratory distress syndrome}	441406.3 Serious	Air bag, front right passenger's	Probable	Hospitalization records
8	Abrasion superior forehead, 4 x 0.5 centimeters (1.6 x 0.2 inches), side-to-side	290202.1 Minor	Air bag, front right passenger's	Certain	Hospitalization records
9	Contusion {black} right eye	297402.1 minor	Air bag, front right passenger's	Certain	Interviewee (driver)
10	Contusion {bruising} upper chest, location not specified, but most likely on left	490402.1 Minor	Air bag, front right passenger's	Certain	EMS treatment record

CASE VEHICLE DRIVER KINEMATICS

The case vehicle's driver [38-year-old, White (non-Hispanic) female] was seated in an upright posture with her back partially against the seat back, her left foot on the floor, her right foot on the brake, and both hands on the steering wheel. Her seat track was located between its middle and rearmost positions, her seat back was upright, and her tilt steering wheel was located between its middle and upmost positions. The case vehicle's driver [170 centimeters and 54 kilograms (67 inches, 119 pounds)] was also restrained by her available, active, three-point, lap and shoulder belt. The inspection of the driver's seat belt webbing, "D"-ring, and latch plate showed no conclusive evidence of loading or separation of the buckle webbing assembly energy management loop. The upper anchorage for the driver's shoulder belt was adjusted to the full-up position.

Since there were no avoidance maneuvers, the driver's upper torso would have remained against her seat back just prior to impact. The case vehicle's primary impact with vehicle #2 deployed both the

[3] According to the RANDOM HOUSE WEBSTER'S UNABRIDGED DICTIONARY, this term is defined as follows: ***effaced***: 1. to wipe out; do away with; expunge. 2. to rub out, erase, or obliterate (outlines, traces, inscriptions, etc.).

driver the front right passenger's air bags. At impact the case vehicle driver's upper torso reacted by moving forward towards the deploying air bag, contacting it with her chin causing an abrasion. The driver's manual, three-point lap and shoulder belt locked up during the impact preventing her from contacting the knee bolster. An inspection of the driver's air bag, which was located in the steering wheel hub, showed either a small lip stick or blood mark to the left side with an apparent vertical cloth transfer on the right side of the air bag (**Figure 8** above). The driver's interaction with the deploying air bag knocked her rearwards into her seat back.

CASE VEHICLE DRIVER INJURIES

The case vehicle's driver did not seek treatment nor was she treated, but she did sustain an abrasion to her chin and complained of back soreness.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1	Abrasion chin	290202.1 minor	Air bag, driver's	Certain	Interviewee (same person)

CASE VEHICLE REAR LEFT PASSENGER KINEMATICS

The case vehicle's rear left passenger [10-year-old, White (non-Hispanic) male, 152 centimeters and 31 kilograms (60 inches and 68 pounds)] was unrestrained and seated upright with his back against the seat back, both hands on his lap, and both feet on the floor. The rear bench seat was adjusted to the rearmost position. The case vehicle's center (two-seat) bench seat (**Figure 13**) had been removed to make room for trip supplies (i.e., beverage cooler, etc.).

Figure 13: Case vehicle's back seat area where three child passengers were seated; Note: outboard three-point safety belts and removed center bench seat which made more room (case photo #54)

The impact caused this passenger to be thrust forward out of his seat onto the cooler that was on the floor behind the driver's seat. The left rear passenger sustained a laceration below his left eye from contacting the cooler. At final rest the left rear passenger was lying in an unknown position on the floor behind the driver's seat.

This passenger was subsequently transported by ambulance to the hospital where he was treated and released.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1	Abrasion left face	290202.1 minor	Interior loose object (i.e., cooler)	Probable	Interviewee (driver)
2	Laceration left face	290600.1 minor	Interior loose object (i.e., cooler)	Probable	Interviewee (driver)

CASE VEHICLE'S REAR CENTER PASSENGER KINEMATICS

The case vehicle's rear center passenger [3-year-old, White (non-Hispanic) female, 76 centimeters and 14 kilograms (30 inches and 30 pounds)] was unrestrained and seated upright with her back against the seat back, both hands on her lap, and both feet sticking out forward of the seat cushion. The rear bench seat was adjusted to the rearmost position.

The impact caused this passenger to be thrust forward out of her seat onto the floor next to the cooler behind the driver's seat (**Figure 13** above). At final rest the center rear passenger was lying in an unknown position on the floor. This passenger did not sustain any injuries as a result of the crash and left the scene in a police squad car with the driver and other siblings.

CASE VEHICLE'S REAR RIGHT PASSENGER KINEMATICS

The case vehicle's rear right passenger [7-year-old, White (non-Hispanic) male, 127 centimeters and 23 kilograms (50 inches and 50 pounds)] was unrestrained and seated upright with his back against the seat back, both hands on his lap, and both feet on the floor. The rear bench seat was adjusted to the rearmost position.

The impact caused this passenger to be thrust forward out of his seat onto the floor between the driver's and front right passenger's seats. At final rest the rear right passenger was lying in an unknown position on the floor. This passenger did not sustain any injuries in the crash and left the scene in a police vehicle with the driver and other siblings.

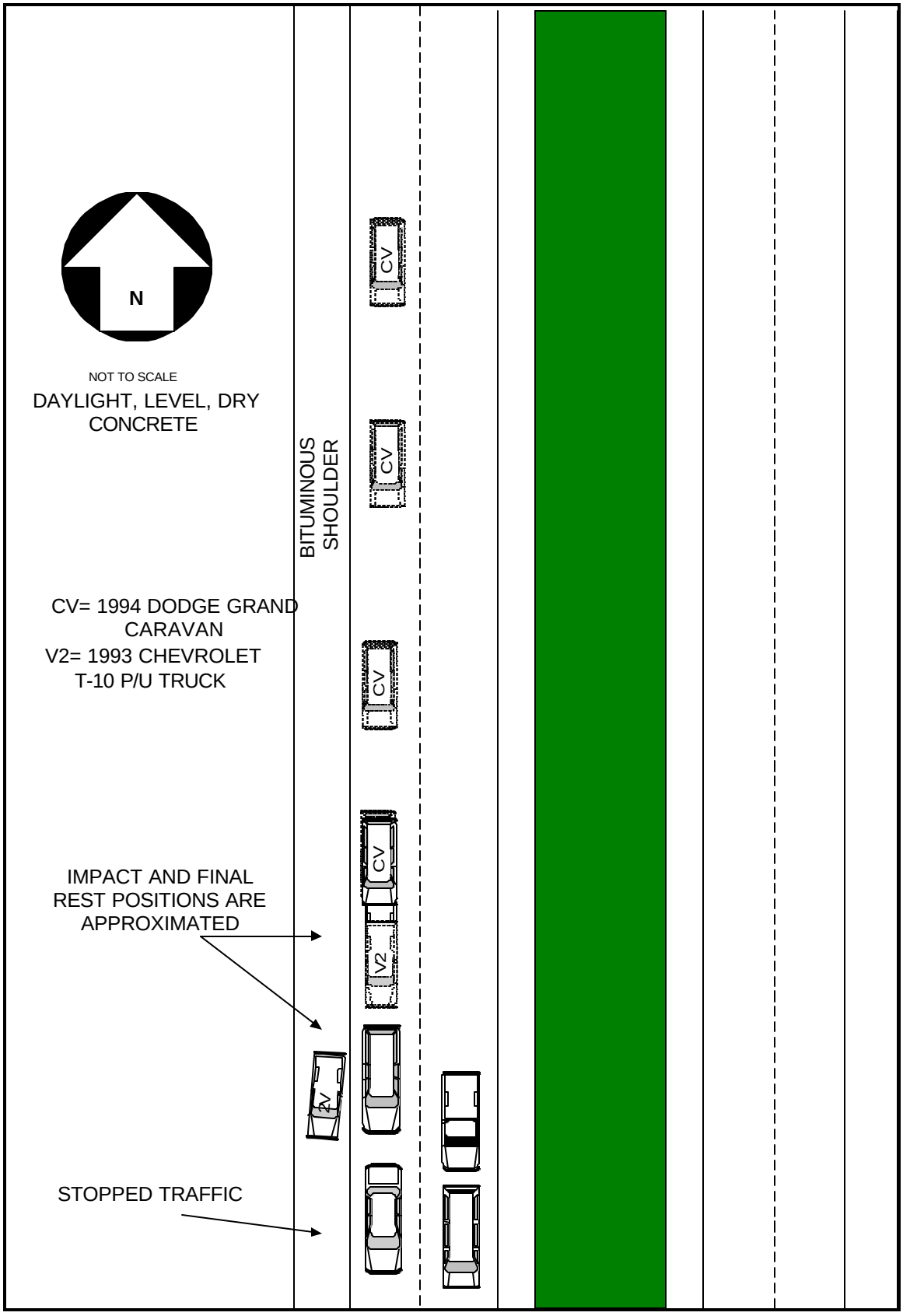
VEHICLE #2

Vehicle #2 was a four wheel drive 1993 Chevrolet T-10, regular cab, standard bed pickup truck with cap (VIN: not available). Standard equipment was a 4.3L, EFI, V-6 engine and a five-speed manual transmission. It is unknown if this vehicle was equipped with anti-lock brakes. Vehicle #2's wheel base was 275 centimeters (108.3 inches), and the odometer reading at impact is unknown because vehicle #2

was not inspected. Based on police photographs, vehicle #2 was presumably equipped with manual, three-point, lap and shoulder restraints, and vehicle #2 was not equipped with a supplemental restraint system. The seating type is unknown. Vehicle #2 had a extended bumper hitch (**Figures 4** and **7**).

The direct damage to vehicle #2 appears to extended from the right rear bumper corner across ¾ of the bumper. There was direct damage to vehicle #2's tailgate on the left side from the case vehicle's hood edge (**Figure 4**). The rear bumper was rotated slightly downward due to the impact (**Figure 7**). The cap on the bed of vehicle #2 was shifted rearward due to the rear impact (see **SELECTED PHOTOGRAPHS**, **Figure 17**). No other visible damage was observed. Vehicle #2 was driven from the scene.

Based on the available photographs, the CDC was determined to be: **06-BDEW-1 (180)** for vehicle #2. The WinSMASH reconstruction program, missing vehicle algorithm was used on vehicle #2's highest severity impact. The Total, Longitudinal, and Lateral Delta Vs are, respectively: 13.8 km.p.h. (8.6 m.p.h.), -13.8 km.p.h. (+8.6 m.p.h.) and 0.0 km.p.h. (0.0 m.p.h.).


N
NOT TO SCALE
DAYLIGHT, LEVEL, DRY CONCRETE
BITUMINOUS SHOULDER
CV= 1994 DODGE GRAND CARAVAN
V2= 1993 CHEVROLET T-10 P/U TRUCK
IMPACT AND FINAL REST POSITIONS ARE APPROXIMATED
STOPPED TRAFFIC
CV
CV
CV
CV
V2
V2

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 Six: Trauma to the Skull and Brain: Craniocerebral Injuries, ***Traumatic Brain Swelling and Edema***, pages 165-167.

Following significant head injury, whether clinically mild or severe, swelling of the brain may occur. Brain swelling may be focal, adjacent to an area of brain injury; be diffuse, involving both cerebral hemispheres; or involved only a single hemisphere. This latter condition is seen most commonly following evacuation of an acute subdural hematoma and involves the ipsilateral[4] hemisphere. The secondary swelling may, in fact, cause a more serious mass effect than the original hematoma.

BRAIN SWELLING can be due to either **an increase in intravascular cerebral blood volume secondary to vasodilation** *or* **an absolute increase in the water content of the brain tissue**. This latter condition is called **CEREBRAL EDEMA** and is often incorrectly considered synonymously with brain swelling. If continued long enough, brain swelling due to an increase in the intravascular cerebral blood volume progresses to cerebral edema, presumably due to increased vascular permeability. The magnitude of the brain swelling does not necessarily correspond to the severity of the injury.

With severe brain injury, diffuse brain swelling of a severe degree may occur immediately without the individual regaining consciousness. Brain swelling, however, may not occur immediately after an injury, but rather develop minutes to hours later. Delayed brain swelling of a significant degree is rare. It is usually diffuse and more often associated with the less severe forms of brain injury. Typically, the patient receives a concussion *{non-anatomic brain injury}*, regains consciousness, only to become stuporous and lapse into coma minutes to hours later. The most severe form of delayed brain swelling is more common in children between the ages of 4 and 10 years of age.

If brain swelling, whether it be acute or delayed, focal or diffuse, due to increased intravascular cerebral blood volume or due to cerebral edema, develops to a severe degree and continues over a sufficient time, one may get herniation of the brain and/or secondary brain stem hemorrhage.

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[4] The following term is defined in DORLAND'S ILLUSTRATED MEDICAL DICTIONARY as follows:
ipsilateral (ip"sĭ-lat■r-al): situated on, pertaining to, or affecting the same side, as opposed to contralateral.

A rapid expanding intracranial mass or severe brain swelling can produce tonsillar[5],transtentorial[5], and/or subfalcial[5] herniation[5] of the brain with resultant necrosis[6], secondary infarction[6], and Duret hemorrhages[7] (Figure 6.14). Herniation may be either symmetrical, due to brain swelling, or asymmetrical, due to a mass in one side of the brain or subdural space, for example, a subdural hematoma or intracerebral hemorrhage. In the case of diffuse brain swelling, there is usually symmetrical herniation of the cerebellar tonsils without brain stem hemorrhage. The brain stem and cerebellar tonsils are forced into the foramen magnum with resultant dysfunction or even infarction of the brain stem. The individual becomes

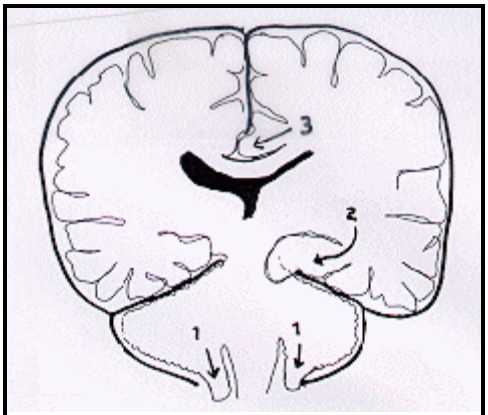

Figure 6.14. Drawing illustrating (1) tonsillar, (2) transtentorial, and (3) subfalcial herniation of brain

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[5] The following terms are defined in DORLAND'S ILLUSTRATED MEDICAL DICTIONARY as follows:
falcial (fal'shal): pertaining to a falx.
falx (falks) pl. ***falces***: a sickle-shaped organ or structure; used as a general term in anatomical nomenclature to designate such a structure.
f. cerebri, f. of cerebrum: the sickle-shaped fold of dura mater that extends downward in the longitudinal cerebral fissure and separates the two cerebral hemispheres.
herniation (her"ne-a'shen): the abnormal protrusion of an organ or other body structure through a defect or natural opening in a covering, membrane, muscle, or bone.
caudal transtentorial h.: tentorial h.
subfalcial h.: not defined in Dorland's, but means below a falx (see falcial above).
tentorial h.: downward displacement of the medially-placed cerebral structures through the tentorial notch, caused by a supratentorial mass. Pressure is exerted on underlying structures, including the brain stem. Called also *caudal transtentorial h.*, *transtentorial h.*, and *uncal h.*
tonsillar h.: protrusion of the cerebellar tonsils through the foramen magnum, exerting pressure on the medulla oblongata. Called also *tonsillar hernia*.
transtentorial h.: tentorial h.
uncal h.: tentorial h.
tonsil (ton'sil): a small rounded mass of tissue, especially of lymphoid tissue. The term is often used without qualification to designate the palatine tonsil. Called also *tonsilla.*
t. of cerebellum: tonsilla cerebelli.
tonsilla (ton-sil'a) pl. ***tonsillae***: tonsil -- a general term for a small rounded mass of tissue, especially of lymphoid tissue.
t. cerebelli, t. of cerebellum: a rounded mass forming part of the caudal lobe of the hemisphere of the cerebellum continuous with the uvula of the vermis; called also *amygdala of cerebellum.*
tonsillar (ton'si-lar): of or pertaining to a tonsil; amygdaline.
uncal (ung'kal): of or pertaining to the uncus.
uncus (ung'kas): 1. any hook-shaped structure. 2. the medially curved anterior end of the parahippocampal gyrus; called also *u. gyri fornicati*, *u. gyri hippocampi*, and *u. gyri parahippocampalis*.

[6] The following terms are defined in DORLAND'S ILLUSTRATED MEDICAL DICTIONARY as follows:
infarct (in'fahrkt): an area of coagulation necrosis in a tissue due to local ischemia resulting from obstruction of circulation to the area, most commonly by a thrombus or embolus.
infarction (in-fahrk'shen): 1. the formation of an infarct. 2. an infarct.
necrosis (na-kro'sis) pl. ***necroses***: the sum of the morphological changes indicative of cell death and caused by the progressive degradative action of enzymes; it may affect groups of cells or part of a structure or an organ.

[7] The following term is defined in DORLAND'S ILLUSTRATED MEDICAL DICTIONARY as follows:
lesion (le'zhen): any pathological or traumatic discontinuity of tissue or loss of function of a part.
Duret's l.: effusion of blood in the region of the fourth ventricle of the cerebrum as a result of slight injury.

unconscious and develops respiratory difficulty that proceeds to arrest and death. Severe herniation of the cerebellar tonsils can result in infarction. In some individuals with prolonged survival, the authors have seen the upper spinal cord encased in necrotic cerebellar tissues shed into the cerebrospinal fluid. If one is dealing with an asymmetrical herniation due to a subdural hematoma, in addition to ipsilateral cerebellar tonsil herniation, one often has a secondary brain stem hemorrhage (a Duret hemorrhage) involving the midbrain and pons.

Transtentorial or uncal herniation is due to a rapidly expanding supratentorial mass lesion. It may be either unilateral or bilateral, though unilateral herniation is more common due to the fact that rapidly expanding lesions are usually unilateral. If one has a rapidly expanding mass in a cerebral hemisphere, one expects ipsilateral uncal herniation. If severe enough, there will be displacement of the brain stem against the contralateral tentorial edge with injury to the brain stem and production of Kernohan's notch[8].

The third type of herniation is subfalcial or transfalcial herniation. This occurs when there is a rapidly expanding mass in one cerebral hemisphere or at least in the subdural space on one side. This causes herniation of the cerebral hemisphere, across the midline below the edge of the falx. The herniating tissue is most often the cingulate or supracingulate gyrus.

As previously noted, herniation with compression of the brain stem can result in Duret hemorrhages. These are secondary herniation hemorrhages of the midbrain and pons. They may range from small streaks to massive confluent hemorrhage. They are in the midline and are most commonly associated with asymmetrical herniation of the brain stem. Duret hemorrhages may develop in only 30 minutes.

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[8] The following term is defined in DORLAND'S ILLUSTRATED MEDICAL DICTIONARY as follows:
notch (noch): an indentation or depression, especially one on the edge of a bone or other organ. See also *incisura.*
Kernohan's n.: a groove in the cerebral peduncle caused by displacement of the brain stem against the tentorium in some cases of transtentorial herniation.

Figure 14: Close-up of crack to case vehicle's windshield caused by contact from rearview mirror (case photo #47)

Figure 15: Top surface of case vehicle's front right air bag showing no contact from front right passenger, but contact evidence is present from rearview mirror (small highlight) and cover flap transfer (large highlight) (case photo #31)

Figure 16: Blood spots on shoulder portion of case vehicle's front right seat belt; Note: spots to left of yellow tape (case photo #39)

Figure 17: Left side view of vehicle #2's truck bed cap; Note: cap shifted rearward toward direction of principal force (case photo #59)