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ON-SITE SIDE IMPACT INFLATABLE OCCUPANT PROTECTION INVESTIGATION

CASE NUMBER - IN-02-002
LOCATION - ILLINOIS
VEHICLE - 2001 CHEVROLET IMPALA LS
CRASH DATE - July 2002

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

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

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16. <i>Abstract</i> This report covers an on-site investigation of a side air bag deployment crash that involved a 2001 Chevrolet Impala LS (case vehicle), a 2001 Honda Accord LX (1 st other vehicle), and a 1996 Honda Accord LX (2 nd other vehicle). This crash is of special interest because the case vehicle was equipped with advanced occupant protection systems, including front seat back-mounted side air bags, and the case vehicle's driver (54-year-old male) sustained severe chest and abdominal injuries, resulting in his death. The case vehicle was in a left-hand curve, traveling southward in the inside lane of the southern roadway which was part of a six-lane, divided, Interstate highway. Both Hondas were negotiating a right-hand curve, traveling northward in the inside lane of the northern roadway of the same Interstate highway. The case vehicle's driver lost control and it rotated counterclockwise, departing the southbound roadway, traveling along and across the grassy median, and entering the northbound roadway while traveling backwards. The crash occurred in the northbound roadway. The left side of the case vehicle was impacted by the front of the 2001 Honda, causing only the case vehicle's driver side, seat back-mounted, side impact air bag to deploy. As a result the case vehicle was driven northward and rotated approximately 150 degrees counterclockwise enabling its right side to be impacted by the front of the 1996 Honda. The case vehicle's driver was seated but because of the intrusion damage his seat track's position and the position of the tilt steering wheel could not be determined. He was restrained by his available, active, three-point, lap-and-shoulder, safety belt system and sustained, according to his medical records, severe injuries which included: a ruptured left diaphragm and spleen and a large left hemothorax with resulting respiratory complications that resulted in his death. The front right passenger (54-year-old, female) was seated but because of the intrusion damage her seat track's position could not be determined. She was restrained by her available, active, three-point, lap-and-shoulder, safety belt system and sustained, according to her medical records, critical injuries which included: a right diffuse axonal injury, a right cerebral contusion, bilateral subarachnoid hemorrhages, a nonanatomic brain injury, a splenic laceration, a fracture to her 7 th cervical vertebrae, a right rib fracture, bilateral lung contusions, and multiple pelvic fractures. The three back seat passengers (5-year-old female-back left; 12-year-old female-back center; and 5-year-old male-back right) were all seated in a non-adjustable seat and were restrained by their available, active, three-point, lap-and-shoulder, safety belt systems. According to their medical information, the back left occupant sustained: a traumatic head injury, a laceration to her left kidney, and a fracture to at least one left rib and her right pelvis. The back center occupant sustained a left ankle injury, and the back right occupant sustained a laceration of his spleen, mid-shaft fractures of his left tibia and fibula, and abrasions to both his left leg and right knee.					
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TABLE OF CONTENTS

IN-02-002

	<u>Page No.</u>
BACKGROUND	1
SUMMARY	1
CRASH CIRCUMSTANCES	8
CASE VEHICLE: 2001 CHEVROLET IMPALA LS	11
CASE VEHICLE DAMAGE	12
AUTOMATIC RESTRAINT SYSTEM	15
CRASH DATA RECORDING	16
CASE VEHICLE DRIVER KINEMATICS	17
CASE VEHICLE DRIVER INJURIES	17
CASE VEHICLE FRONT RIGHT PASSENGER KINEMATICS	19
CASE VEHICLE FRONT RIGHT PASSENGER INJURIES	20
CASE VEHICLE BACK LEFT PASSENGER KINEMATICS	22
CASE VEHICLE BACK LEFT PASSENGER INJURIES	22
CASE VEHICLE BACK CENTER PASSENGER KINEMATICS	23
CASE VEHICLE BACK CENTER PASSENGER INJURIES	24
CASE VEHICLE BACK RIGHT PASSENGER KINEMATICS	24
CASE VEHICLE BACK RIGHT PASSENGER INJURIES	25
1 ST OTHER VEHICLE: 2001 HONDA ACCORD LX	26
2 ND OTHER VEHICLE: 1996 HONDA ACCORD LX	27
ADDITIONAL INTERIOR PHOTOGRAPHS	29
EVENT DATA RECORDER DATA	31
CRANIOCEREBRAL IMPACT INJURIES	33
CRASH DIAGRAM	35
SELECTED PHOTOGRAPHS	
Figure 1: Case vehicle’s southerly travel path in leftward curving southern roadway	8

SELECTED PHOTOGRAPHS (Continued)		<u>Page No.</u>
Figure 2:	2001 Honda's northerly travel path in rightward curving northern roadway	8
Figure 3:	Case vehicle's departure into median from southbound roadway . . .	9
Figure 4:	Case vehicle's oblique travel path between roadways through median	9
Figure 5:	Case vehicle's entrance onto northbound roadway while traveling backwards	9
Figure 6:	Damage to case vehicle's left side driver area	10
Figure 7:	Damage to case vehicle's left rear passenger area	10
Figure 8:	2001 Honda's frontal damage from impact with case vehicle's left side	10
Figure 9:	1996 Honda's frontal damage from impact with case vehicle's right side	10
Figure 10:	Damage to case vehicle's right rear passenger area	11
Figure 11:	Damage to case vehicle's right front passenger area	11
Figure 12:	Overhead view of crush to case vehicle's left rear area	12
Figure 13:	Overhead view of crush to case vehicle's driver area	12
Figure 14:	Reference line view of case vehicle's right side crush	12
Figure 15:	Contact evidence on interior of case vehicle's driver door	13
Figure 16:	Contact evidence on interior of case vehicle's left rear door	14
Figure 17:	Contact evidence on interior of case vehicle's right front door	14
Figure 18:	Case vehicle's front seating area showing suspected contacts on left "B"-pillar and left roof side rail	14
Figure 19:	Case vehicle's back seating area showing contacts on left roof side rail and back of driver's seat back	14
Figure 20:	Intrusion and deformation to case vehicle's steering wheel	15
Figure 21:	Cover flap for case vehicle's driver seat back-mounted side impact air bag	15
Figure 22:	Interior surface of case vehicle's deployed driver seat back-mounted side impact air bag	16
Figure 23:	Case vehicle's back seating area, including right rear door	25
Figure 24:	2001 Honda's frontal damage and deployed frontal air bags	26
Figure 25:	2001 Honda's frontal damage viewed from left of front	26

	<u>Page No.</u>
SELECTED PHOTOGRAPHS (Continued)	
Figure 26: 1996 Honda's frontal damage and deployed frontal air bags	27
Figure 27: 1996 Honda's frontal damage viewed from right of front	28
Figure 28: Case vehicle's driver seating area showing intrusions and damage . .	29
Figure 29: Case vehicle's center instrument panel area showing intrusions and deformation of instrument panel areas	29
Figure 30: Case vehicle's front right passenger seating area showing intru- sions and damage	30
Figure 31: EDR-Speed, brake switch status, restraint usage, and Delta V	31
Figure 32: EDR-Case vehicle's pre-crash travel speed and brake switch status	32
Figure 33: EDR-Case vehicle's Delta V versus Delta T	32

This on-site investigation was brought to NHTSA's attention on July 10, 2002 by a traffic crash reconstruction officer with the Illinois State Police. This crash involved a 2001 Chevrolet Impala LS (case vehicle), a 2001 Honda Accord LX (1st other vehicle), and a 1996 Honda Accord LX (2nd other vehicle). The crash occurred in July 2002 at 5:45 p.m. in Illinois and was investigated by the Illinois State Police. This crash is of special interest because the case vehicle was equipped with advanced occupant protection systems, including front seat back-mounted side air bags, and the case vehicle's driver [54-year-old, White (non-Hispanic) male] sustained severe chest and abdominal injuries, resulting in his death. This contractor inspected the scene, 1st and 2nd other vehicles, and interviewed the son of the driver (not an occupant) on July 15, 2002. The case vehicle was inspected on July 16, 2002. This summary is based upon the Police Crash Report, the interview with the driver's son, scene and vehicle inspections, occupant kinematic principles, occupant medical records, and this contractor's evaluation of the evidence.

SUMMARY

Crash Environment: The trafficway on which all vehicles were traveling was a six-lane, divided, Interstate highway, traversing generally in a north-south direction. Both the northerly and southerly roadways had three through lanes. At the time of the crash the light condition was daylight, the atmospheric condition was raining, and the roadway pavement was wet. In fact, according to the Police Crash Report, it was raining heavily at the time of the crash. Traffic density was undetermined, and the site of the crash was primarily rural agricultural; see **CRASH DIAGRAM** at end.

Pre-Crash: The case vehicle was in a left-hand curve, traveling south-southwestward in the inside lane of the southbound roadway. The case vehicle's driver intended to continue in his southerly direction of travel. The 1st and 2nd other vehicles were negotiating a right-hand curve, traveling north-northwestward in the inside lane of the northbound roadway and intended to continue their northerly travel paths. The case vehicle's driver lost control of his vehicle, and it began to rotate counterclockwise. The case vehicle departing the southbound roadway onto the east shoulder and traveled approximately 81 meters (266 feet) longitudinally along and transversely across the grassy median. The case vehicle entered the inside lane of the northbound roadway while continuing to rotate counterclockwise. The avoidance maneuvers, if any, taken by the case vehicle's driver are unknown. The driver of the 2001 Honda steered right toward the center through lane, attempting to avoid the crash. The crash occurred near the lane line that separates the center and inside through lanes of the northbound roadway.

Crash: The left side doors of the case vehicle were impacted by the front of the 2001 Honda, causing only the case vehicle's driver side, seat back-mounted, side impact air bag to deploy. This impact caused the case vehicle to be driven northward and rotate approximately 150 degrees counterclockwise and enabled the case vehicle's right side to be impacted by the front of the 1996 Honda. The driver of the 1996 Accord had, at least, steered sharply to the right, toward the center through lane, in an attempt to avoid involvement in the collision. Although the exact location of the 2nd impact is unknown, it most likely occurred in the center through lane.

Post-Crash: As a result of the second impact the case vehicle was pushed further northward, an unknown distance, while rotating approximately 75 degrees counterclockwise. The exact location of the case vehicle's final rest position is unknown, but the case vehicle most likely came to rest straddling the center and outside lanes of the northbound roadway, heading northeastward. As a result of its frontal impact, the 2001 Accord was deflected approximately 60 degrees clockwise and came to rest straddling the center and outside lanes of the northbound roadway, heading northeastward. The 1996 Accord continued essentially straight ahead after impacting the case vehicle and most likely came to rest primarily in the outside through lane, heading northeastward.

Case Vehicle: The 2001 Chevrolet Impala LS was a front wheel drive, four door-sedan (VIN: 2G1WH55K919-----). The case vehicle was equipped with four wheel, anti-lock brakes, and advanced occupant protection system features, including dual stage driver and front right passenger air bag inflators, pretensioners, front seat back-mounted side impact air bags, and an Event Data Recorder (EDR).

Vehicle Exterior: Based on the vehicle inspection, the CDCs for the case vehicle were determined to be **09-LPEW-4 (280 degrees)** and **02-RYEW-3 (60 degrees)**. The WinSMASH reconstruction program, damage only algorithm, was used on the case vehicle's two impacts. The Total, Longitudinal, and Lateral Delta Vs for the case vehicle's highest severity (first) impact are, respectively: 41.0 km.p.h. (25.5 m.p.h.), -7.1 km.p.h. (-4.4 m.p.h.), and +40.4 km.p.h. (+25.1 m.p.h.). In this contractor's opinion the calculated Delta Vs represent the minimum Delta Vs that the case vehicle sustained during its initial impact because the crush measurements were taken at the sill level due to door removal during extrication. Based on this contractor's experience, the crush above the sill would have been greater than the sill-level measurements used. For the case vehicle's second highest severity (second) impact, the Total, Longitudinal, and Lateral Delta Vs are, respectively: 23.0 km.p.h. (14.3 m.p.h.), -11.5 km.p.h. (-7.1 m.p.h.), and -19.9 km.p.h. (-12.4 m.p.h.). The case vehicle was towed from the scene due to damage.

Exterior Damage: The case vehicle's contact with the 2001 Honda involved the left center of the vehicle. Direct damage began 42 centimeters (16.5 inches) behind of the left front axle and extended 196 centimeters (77.2 inches) rearward, ending at the forward portion of the left rear wheel well. Residual maximum crush was measured as 51 centimeters (20.1 inches). The measurement was taken along the sill level and 35 centimeters (13.8 inches) forward of C₃. The case vehicle's contact with the 1996 Honda involved the right front and center areas of the vehicle. Direct damage began 45 centimeters (17.7 inches) forward of the right rear axle and extend 138 centimeters (54.3 inches) forward along the right side. Maximum crush for this right side impact was measured as 34 centimeters (13.4 inches) at C₄. The wheelbase on the case vehicle's left side was shortened 17 centimeters (6.7 inches) while the wheelbase on the right side was extended 3 centimeters (1.2 inches). The case vehicle's left side passenger area was heavily damaged, such that both the front and rear doors had to be pried/cut off by rescue personnel. Damage to the case vehicle's right side was similar but extended forward of the right front wheel. Once again, the right side front and rear doors were pried/cut off by rescue personnel. The overall width of the passenger compartment, especially the first row, was narrowed significantly and the roof side rails were buckled inward, but the roof did not intrude downward. The windshield was severely holed and all glazing, except the small second row windows, was disintegrated from impact forces. The

recommended tire size was: P225/60R16, and the case vehicle tires were the recommended size. The case vehicle’s tire data are shown in the table below. In addition, the case vehicle’s left rear tire was restricted.

Tire	Measured Pressure		Recommend Pressure		Tread Depth		Damage	Restricted	Deflated
	kpa	psi	kpa	psi	milli-meters	32 nd of an inch			
LF	262	38	207	30	5	6	None	No	No
RF	255	37	207	30	6	8	None	No	No
LR	269	39	207	30	2	3	None	Yes	No
RR	262	38	207	30	1	1	None	No	No

Vehicle Interior: Inspection of the case vehicle’s interior revealed cracks and scuffs to the driver’s, left rear, and right front interior door surfaces. Furthermore, the center console was cracked possibly by contact from the front right passenger but more likely by the compression that the case vehicle sustained as a result of the intrusion produced by both its left and right side impacts. Furthermore, the driver’s seat back was scuffed from contact by one of the back passengers. There were multiple lateral and vertical intrusions to the case vehicle’s interior. Vertical intrusions occurred to the steering wheel assembly and steering wheel rim; left, center, and right instrument panels and windshield’s glazing; and the front left windshield’s header. The vertical intrusion resulted from the lateral compression (i.e., intrusion) that occurred to both sides of the vehicle. Lateral intrusion occurred to: both the left and right instrument panels, left “A”-pillar, left and right side panels forward of their respective “A”-pillars, left and right “B”-pillars, left front and rear roof side rails, left and right–front and back door sills, driver and front right passenger seat backs and seat cushions, and the back left seat back and seat cushion. In addition, the upper half of the steering wheel rim was deformed 8 centimeters (3.1 inches) laterally toward the hub, most likely by the interior surface of the intruding driver’s door. Finally, it could not be determined if there was any compression to the energy absorbing shear capsules in the steering column.

Supplemental Restraints: The case vehicle’s driver seat back-mounted side impact air bag was located on the outboard side, near the top of the front seat back. An inspection of the air bag module’s cover flap and air bag revealed that the cover flap opened at the designated tear points, and there was no evidence of damage during the deployment to the air bag or cover flap. This side air bag was designed with two tethers, stitched internally, connecting the inboard and outboard sides of the air bag. One tether was located midway between the center and top of the air bag and the other was near the center of the air bag. The top tether was approximately 7 centimeters (2.8 inches) in width, and the bottom tether was approximately 10 centimeters (3.9 inches) in width. There were no vent ports. The deployed side air bag was essentially rectangular with a height of 68 centimeters (26.8 inches) and width of 37 centimeters (14.6 inches). An

inspection of the driver's side air bag fabric revealed only a very small amount of blood/body fluid.

The case vehicle's driver and front right passenger frontal air bags, as well as, the case vehicle's front right passenger seat back-mounted side impact air bag did not deploy during this crash.

Crash Data Recording: The data downloaded from the case vehicle's **EDR** showed the vehicle's SIR warning lamp status, driver's seat belt buckle status, vehicle's speed and brake switch status for the five recorded sample periods preceding the **ALGORITHM ENABLE**, ignition cycles at non-deployment, time from algorithm enable to maximum **SDM** (i.e., **SENSING AND DIAGNOSTIC MODULE**) recorded velocity change, and velocity change (i.e., Delta V). Multiple "near" deployment events occurred during this vehicle's crash sequence. The non-deployment event with highest Longitudinal Delta V change was the event recorded. The recorded event may have occurred when the case vehicle was impacted by the 2001 Honda or by the 1996 Honda, or it may have occurred when it was traveling across the median. It cannot be said with certainty during which event the recording occurred. Downloaded data of interest indicated the following. During the fifth recording period prior to the recorded algorithm enablement, the case vehicle was most likely in a yaw, sliding sideways in the southerly roadway *or* entering or within the median of the trafficway. At the fifth period prior to algorithm enable, the **EDR** recorded a travel speed of 11 km.p.h. (7 m.p.h.). This **EDR** reported travel speed does not reflect the true speed of the vehicle across the ground because of the way the speed is calculated. The vehicle's speed sensor at the drive wheels reads the number of wheel rotations. In a yaw, wheel rotations are slowed down. The number of rotations data are sent to the power control module which calculates the speed and sends the speed data to the speedometer and the **SDM**. Because the wheel rotations are down, the reported speed during the yaw does not reflect the actual speed of the vehicle. Furthermore, the driver's seat belt status showed it was buckled, and the Delta V reached a value of 1.50 km.p.h. (0.93 m.p.h.) at the 150 millisecond mark of recorded data.

1st Other Vehicle: The 2001 Honda Accord LX was a front wheel drive, four-door sedan (VIN: 1HGCG56421A-----). The 2001 Honda was equipped with redesigned, dual-stage, driver and front right passenger air bags and front seat back-mounted side impact air bags. This vehicle's front air bags deployed as a result this vehicle's impact.

Exterior Damage: Based on vehicle inspection, the CDC for the 2001 Accord was determined to be: **12-FDEW-2 (350 degrees)** [maximum crush was 48 centimeters (18.9 inches) and was located 10 centimeters (3.9 inches) to the left of C₂]. The WinSMASH reconstruction program, damage only algorithm, was used on the 2001 Accord's highest severity impact. The Total, Longitudinal, and Lateral Delta Vs are, respectively: 49.0 km.p.h. (30.4 m.p.h.), -48.3 km.p.h. (-30.0 m.p.h.), and +8.5 km.p.h. (+5.3 m.p.h.). The 2001 Accord was towed due to damage.

2nd Other Vehicle: The 1996 Honda Accord LX was a front wheel drive, four-door sedan (VIN: 1HGCG56421A-----). The 1996 Honda was equipped with driver and front right passenger air bags which deployed as a result this vehicle's frontal impact.

Exterior Damage: Based on vehicle inspection, the CDC for the 1996 Accord was determined to be **11-FDEW-02 (340 degrees)** [maximum crush 32 cm (12.5 in) at C₆]. The WinSMASH reconstruction program, damage only algorithm, was used on the 1996 Accord's highest severity impact. The Total, Longitudinal, and Lateral Delta Vs are, respectively: 31.0 km.p.h. (19.3 m.p.h.), -29.1 km.p.h. (-18.1 m.p.h.), and +10.6 km.p.h. +6.6 m.p.h.). The 1996 Accord was towed from the scene due to damage.

Case Vehicle's Driver: The exact posture of the case vehicle's driver [54-year-old, White (non-Hispanic) male; 183 centimeters and 86 kilograms (72 inches, 190 pounds)] immediately prior to the crash is unknown; although, presumably he was seated in an upright posture with his back against the seat back, his left foot on the floor, and his hands on the steering wheel. However, because of the case vehicle was rotating counterclockwise just prior to impact, the location of his right foot and the exact positions of his hands on the steering wheel are unknown. Because of the intrusion damage to the driver's seating position, the exact pre-crash positions of his seat track, seat back, and tilt steering wheel cannot be determined. Post crash, the front of the seat cushion was 52 centimeters (20.5 inches) forward of the "B"-pillar, and the seat back, while deformed, was at a slightly reclined position.

Based on this contractor's vehicle inspection and supported by the **EDR** data, the case vehicle's driver was restrained by his available, active, three-point, lap-and-shoulder, safety belt system; the belt system was equipped with a retractor-mounted pretensioner, housed within the "B"-pillar. Furthermore, the inspection of the driver's seat belt webbing, "D"-ring, and latch plate showed blood stains and scuff marks on the seat belt's webbing. In addition, the belt was cut off the driver by rescue personnel.

It is unknown what, if any, avoidance maneuvers the driver made while attempting to avoid the crash; although, it is highly likely he braked and/or steered attempting to regain control of the vehicle. Independent of the use of his available safety belts, his pre-impact body position most likely did not significantly change just prior to impact. The case vehicle's impact with the 2001 Accord caused the case vehicle's driver to move leftward and slightly forward along a path opposite the case vehicle's **280 degree** Direction of Principal Force as the case vehicle decelerated. As the case vehicle rebounded and rotated counterclockwise from its initial impact, the driver most likely moved forward toward the steering column and center instrument panel; however, his belt system limited his movement enabling him to remain in the driver's seating position. The case vehicle's impact with the 1996 Accord enabled the driver to move rightward and forward along a path opposite the **60 degree** Direction of Principal Force as the case vehicle decelerated. After the second impact the case vehicle continued to rotate counterclockwise and the driver most likely rebounded back towards his seat back and left "B"-pillar areas. The driver's exact position at final rest is unknown.

The driver was transported by ambulance to the hospital. He sustained severe injuries and was pronounced dead by emergency medicine physicians approximately 70 minutes after the crash. According to the autopsy summary, the injuries sustained by the case vehicle's driver included: a ruptured left diaphragm and spleen which resulted in the spleen herniating through the torn diaphragm causing a large left hemothorax and respiratory complications that resulted in his death

(i.e., atelectasis of the left lung and severe congestion and edema of the right lung). In addition, the driver sustained lacerations to his liver and multiple soft tissue injuries, including a contusion to his left chest. The driver's diaphragm, spleen, liver, and chest injuries were probably caused by contact with the left door/armrest.

Case Vehicle's Front Right Passenger: The exact pre-crash posture of the case vehicle's front right passenger [wife of driver; 54-year-old, White (non-Hispanic) female; 152 centimeters and 64 kilograms (60 inches, 140 pounds)] is unknown, but presumably she was seated in an upright posture with her back against the seat back and her feet on the floor; however, the exact position of her hands is unknown. Because of the intrusion damage to the front right passenger's seating position, the exact pre-crash positions of her seat track and seat back cannot be determined. Post crash, the front of the seat cushion was 43 centimeters (16.9 inches) forward of the "B"-pillar, and the seat back, while significantly damaged by intrusion, was mostly in an upright position.

The case vehicle's front right passenger was restrained by her available, active, three-point, lap-and-shoulder, safety belt system; the belt system was equipped with a retractor-mounted pretensioner, housed within the "B"-pillar. Furthermore, the inspection of the front right passenger's seat belt webbing, "D"-ring, and latch plate showed blood stains on the seat belt's webbing. In addition, the belt was cut off this occupant by rescue personnel.

The front right passenger was transported by ambulance to the hospital in critical condition. She sustained critical injuries and was hospitalized 23 days post-crash. According to her medical records and an interview with her son (i.e., not an occupant), the injuries sustained by the case vehicle's front right passenger included: a right diffuse axonal injury, a right temporal lobe contusion, bilateral subarachnoid hemorrhages, a nonanatomic brain injury, a grade 1 splenic laceration, a fracture to the lamina of her 7th cervical vertebrae, at least one fracture to her right ribs, bilateral lung contusions, multiple pelvic fractures, and contusions on her left forehead, forearm, scapula, sternum, and across her lower abdomen. This occupant's primary brain, cervical, and chest injuries were most likely caused by her contact with the interior surface of the case vehicle's right front door and/or right "B"-pillar. She also most likely contacted her husband (i.e., driver) causing several left side contusions and possibly a serious brain injury. The impact to the case vehicle's left side did cause her to move laterally to the left, possibly contacting the center console. Her chest and abdominal contusions as well as her splenic laceration were caused by her safety belts.

Case Vehicle's Back Left Passenger: The exact posture of the case vehicle's back left passenger [unknown relationship; 5-year-old, White (non-Hispanic) female; 104 centimeters and 20 kilograms (41 inches, 45 pounds)] is unknown but, presumably because of the crowded nature of the case vehicle's back seat, she was seated in an upright posture with her back against the seat back, and her feet dangling over the front edge of the seat's cushion. The exact position of her hands, however, is unknown. Her seat track and seat back were not adjustable.

The case vehicle's back left passenger was restrained by her available, active, three-point, lap-and-shoulder, safety belt system. However, given the child's age and stature, it is unknown if she was properly restrained by the shoulder portion of her belt system. Furthermore, the

inspection of the back left passenger's seat belt webbing and latch plate showed scuff marks made by the belt at the top left portion of the seat back.

Based on the Police Crash Report, the back left passenger was transported by ambulance to the hospital in critical condition. She sustained at least moderate injuries and was hospitalized for 27 days post-crash. Based on the limited medical records that were made available to this contractor, she sustained: a traumatic head injury, a laceration to her left kidney, and a fracture to at least one left rib and her right pelvis. Her left kidney and rib lesions were caused by her left rear door's intruding surface. The cause of her head and right pelvic injuries could not be determined.

Case Vehicle's Back Center Passenger: The exact posture of the case vehicle's back center passenger [granddaughter; 12-year-old, White (non-Hispanic) female; 147 centimeters and 39 kilograms (58 inches, 85 pounds)] is unknown but, presumably because of the crowded nature of the case vehicle's back seat, she was seated in an upright posture with her back against the seat back, and her feet on the floor. The exact position of her hands, however, is unknown. Her seat track and seat back were not adjustable.

The case vehicle's back center passenger was restrained by her available, active, three-point, lap-and-shoulder, safety belt system. Furthermore, the inspection of the back center passenger's seat belt webbing and latch plate showed scuff marks present on the portion of the belt's webbing that would have been touching the occupant.

The back center passenger was transported by ambulance to the hospital. She sustained only minor injuries but was still hospitalized at the time this contractor interviewed her father. Based on the interview, this occupant sustained an injury to her left ankle. No medical records could be located for this occupant.

Case Vehicle's Back Right Passenger: The exact posture of the case vehicle's back right passenger [grandson; 5-year-old, White (non-Hispanic) male; 114 centimeters and 20 kilograms (45 inches, 45 pounds)] is unknown but, presumably because of the crowded nature of the case vehicle's back seat, he was seated in an upright posture with his back against the seat back and his feet dangling over the front edge of the seat's cushion. The exact position of his hands, however, is unknown. His seat track and seat back were not adjustable.

The case vehicle's back right passenger was restrained by his available, active, three-point, lap-and-shoulder, safety belt system. However, given the child's age and stature, it is unknown if he was properly restrained by the shoulder portion of his belt system. In addition, the inspection of the back right passenger's seat belt webbing and latch plate did not show any evidence of loading, but the belt was cut off this occupant by rescue personnel.

The back right passenger was transported by ambulance to the hospital. He sustained at least a moderate injury and was hospitalized for 5 days post-crash. According to his medical records and the interview with his father, the injuries he sustained included: a grade 1 laceration of his spleen, fractures of his left tibia and fibula, midway between the ankle and knee, and abrasions

to both his left leg and right knee. This occupant's splenic laceration was possibly caused by contact with the back center passenger and his left fractures most likely resulted from contact with the lower portion of the front right passenger's seat back.

2001 Honda's Occupants: According to the Police Crash Report, the 2001 Accord's driver [19-year-old, (unknown race and/or ethnic origin) male], the front right passenger [25-year-old, (unknown race and/or ethnic origin) male], and the back right passenger [22-year-old, (unknown race and/or ethnic origin) male] were restrained by their available, active, three-point, lap-and-shoulder, safety belt systems. None of the three occupants were transported by ambulance to the hospital, and they did not sustain any police-reported injuries as a result of this crash.

1996 Honda's Occupants: According to the Police Crash Report, the 1996 Accord's driver [23-year-old, (unknown race and/or ethnic origin) male] was restrained by his available, active, three-point, lap-and-shoulder, safety belt system. The driver was not transported by ambulance to the hospital, and he did not sustain any police-reported injuries as a result of this crash.

CRASH CIRCUMSTANCES



Figure 1: Case vehicle's southerly travel path in inside lane of southern roadway's left-hand curve (case photo #03)



Figure 2: 2001 Honda's northerly travel path in inside lane of northern roadway's right-hand curve; Note: 1996 Honda following 2001 Honda in center lane of roadway (case photo #11)

Crash Environment: The trafficway on which all vehicles were traveling was a six-lane, divided, Interstate highway, traversing generally in a north-south direction. Both the northerly and southerly roadways had three through lanes. The interstate highway was curved to the left for southbound traffic (**Figure 1**) and level in both the case vehicle's and the other vehicles's direction of travel, at the area of impact. The pavement was concrete, and the width of the travel lane for the inside southerly lane was 3.7 meters (12 feet) and was 3.7 meters (12 feet) for both the inside and center northerly travel lanes. The eastern shoulder for the southern roadway was improved (i.e., bituminous), with a 3.6 meter (11.8 foot) wide paved shoulder prior to the 10.3 meter (33.8 foot) wide unprotected grassy median. For the northern roadway (**Figure 2**) the western shoulder was also improved and measured 3.4 meters (11.2 feet) prior to the same grassy median. Pavement markings consisted of a single solid yellow "no passing" line for both the northern and southern roadways, and the through lanes were divided by a dashed white lines. In addition, both

the northern and southern roadways were bordered by a solid white edge line on far eastern and western sides. The estimated wet coefficient of friction was 0.45. There were no visible traffic controls in the immediate area of the crash. No regulatory speed limit sign was posted near the crash site. At the time of the crash the light condition was daylight, the atmospheric condition was raining, and the roadway pavement was wet. In fact, according to the Police Crash Report, it was raining heavily at the time of the crash. Traffic density was undetermined, and the site of the crash was primarily rural agricultural; see **CRASH DIAGRAM** at end.

Pre-Crash: The case vehicle was in a left-hand curve (**Figure 1** above), traveling south-southwestward in the inside lane of the southbound roadway. The case vehicle's driver intended to continue in his southerly direction of travel. The 1st and 2nd other vehicles were negotiating a right-hand curve (**Figure 2** above), traveling north-northwestward in the inside lane of the northbound roadway and intended to continue their northerly travel paths. The case vehicle's driver lost control of his vehicle, and it began to rotate counterclockwise. The case vehicle departed the southbound roadway (**Figure 3**) onto the east shoulder and traveled approximately 81 meters (266 feet) longitudinally along and transversely across the grassy median (**Figure 4**). The case vehicle entered the inside lane of the northbound roadway (**Figure 5**) while continuing to rotate counterclockwise. The avoidance maneuvers, if any, taken by the case vehicle's driver are unknown. The driver of the 2001 Honda steered right toward the center through lane, attempting to avoid the crash. The crash occurred near the lane line that separates the center and inside through lanes of the northbound roadway.

Crash: The left side doors (**Figures 6** and **7** below) of the case vehicle were impacted by the front (**Figure 8** below) of the 2001 Honda,



Figure 3: Case vehicle's southerly departure into median from southbound roadway of interstate trafficway (case photo #04)



Figure 4: Case vehicle's oblique travel path from southern roadway through median toward northern roadway; Note: vehicle rotating counterclockwise while traversing median (case photo #06)



Figure 5: Case vehicle's oblique travel path across median and onto northern roadway; Note: case vehicle traveling backwards upon entry onto northern roadway (case photo #07)

causing only the case vehicle's driver side, seat back-mounted, side impact air bag to deploy. This impact caused the case vehicle to be driven northward and rotate approximately 150 degrees counterclockwise and enabled the front (Figure 9) of the 1996 Honda to impact the case vehicle's right side (Figures 10 and 11 below). The driver of the 1996 Accord had, at least, steered sharply to the right, toward the center through lane, in an attempt to avoid involvement in the collision. Although the exact location of the 2nd impact is unknown, it most likely occurred in the center through lane.



Figure 6: Damage to case vehicle's left side and specifically driver's area from impact (1st event) with 2001 Accord; Note: doors removed for occupant extrication (case photo #17)



Figure 7: Damage to case vehicle's left side and specifically back left area from impact (1st event) with 2001 Accord; Note: doors removed for occupant extrication (case photo #18)

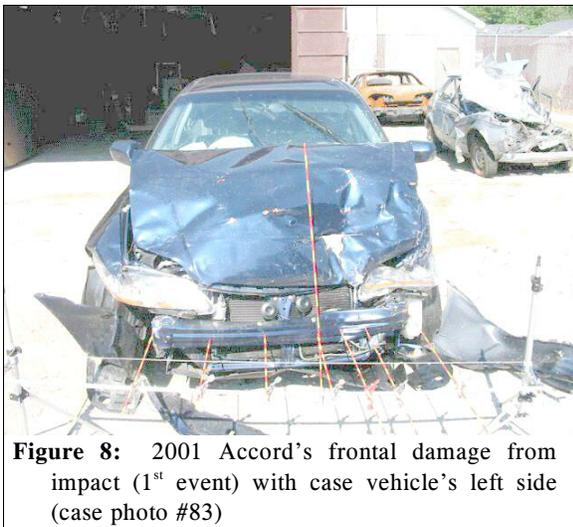


Figure 8: 2001 Accord's frontal damage from impact (1st event) with case vehicle's left side (case photo #83)

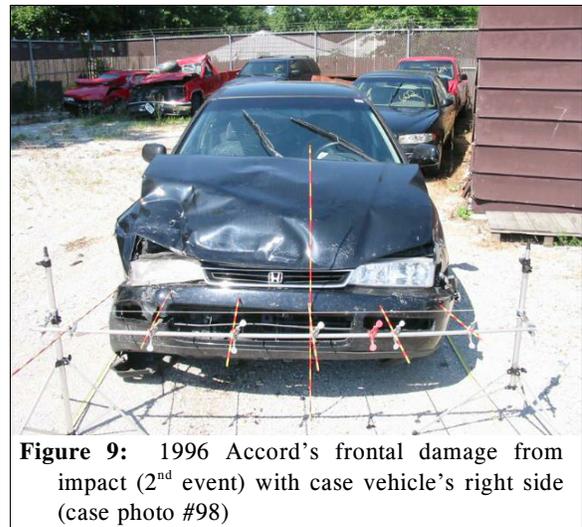


Figure 9: 1996 Accord's frontal damage from impact (2nd event) with case vehicle's right side (case photo #98)

Post-Crash: As a result of the second impact the case vehicle was pushed further northward, an unknown distance, while rotating approximately 75 degrees counterclockwise. The exact location of the case vehicle's final rest position is unknown, but the case vehicle most likely came to rest straddling the center and outside lanes of the northbound roadway, heading northeastward. As a result of its frontal impact, the 2001 Accord was deflected approximately 60 degrees clockwise and came to rest straddling the center and outside lanes of the northbound roadway, heading northeastward. The 1996 Accord continued essentially straight ahead after impacting the case

vehicle and most likely came to rest primarily in the outside through lane, heading northeastward.

CASE VEHICLE

The 2001 Chevrolet Impala LS was a front wheel drive, six-passenger, four-door sedan (VIN: 2G1WH55K919-----) equipped with a 3.8L, V-6 engine, and a four-speed automatic transmission. Braking was achieved by a power-assisted, front disc and rear drum, four-wheel, anti-lock system. The case vehicle's wheelbase was 281 centimeters (110.5 inches), and the odometer reading at inspection is unknown because the case vehicle was equipped with an electronic odometer. The case vehicle was equipped with advanced occupant protection system features, including dual stage driver and front right passenger air bag inflators, pretensioners, and front seat back-mounted side impact air bags. Furthermore, the case vehicle was equipped with a LATCH system. Finally, the case vehicle was also equipped with an Event Data Recorder (EDR).

Inspection of the vehicle's interior revealed adjustable front bucket seats with adjustable head restraints; a non-adjustable back bench seat with integral head restraints for all three back seating positions; and continuous loop, three-point, lap-and-shoulder, safety belt systems at all five front and back positions. The front seat belt systems were equipped with manually operated, upper anchorage adjusters for the "D"-rings. Both the driver and front right passenger had their upper anchorage adjusters located in the upmost positions. The vehicle was equipped with knee bolsters for both the driver and front right passenger, neither of which showed evidence of contact or deformation. Automatic restraint was provided by a Supplemental Restraint System (SRS) that consisted of a frontal air bag for the driver and front right passenger seating positions. In addition, the vehicle was equipped with front, seat back-mounted, side impact air bags. Neither frontal air bag deployed as a result of the case vehicle's left and right side impacts with the two Honda Accords. The driver's seat back-mounted side impact air bag deployed as a result of the case vehicle's left side impact with the 2001 Honda. The front right passenger's seat back-mounted side air bag did not deploy.

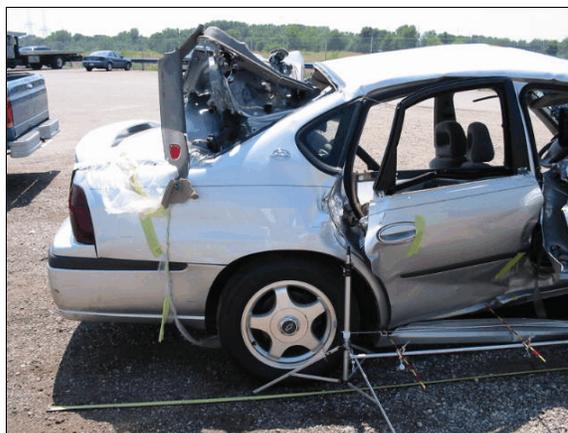


Figure 10: Damage to case vehicle's right side, rear half, from impact (2nd event) with 1996 Accord; Note: distortion to right rear door and intrusion at sill level near "B"-pillar (case photo #28)

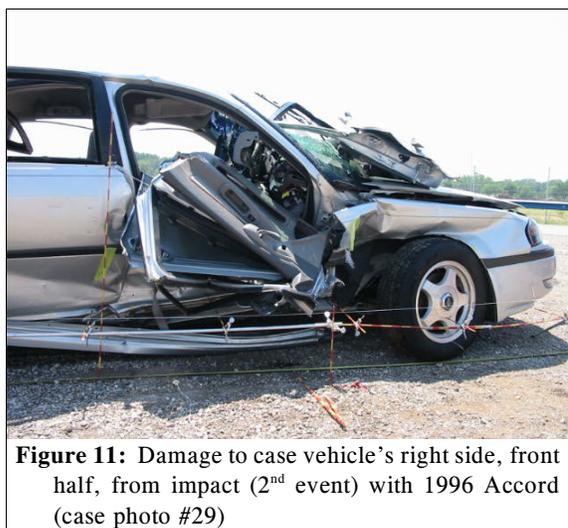
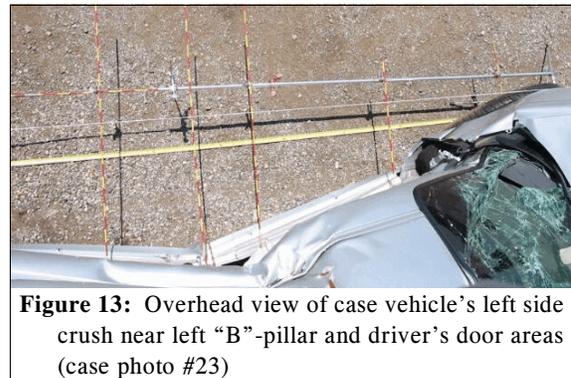
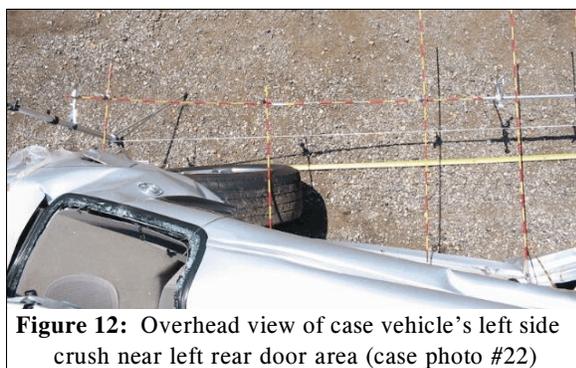
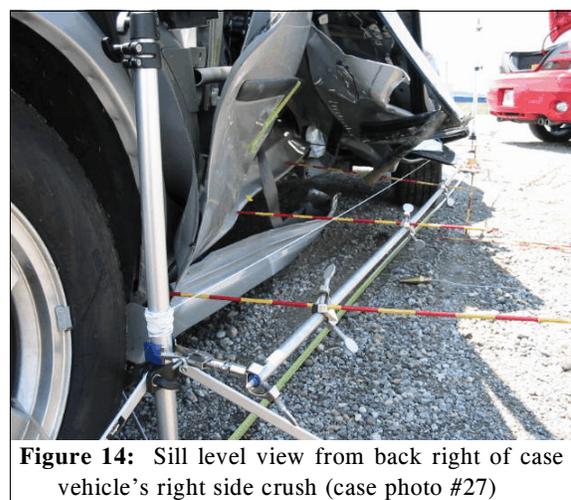


Figure 11: Damage to case vehicle's right side, front half, from impact (2nd event) with 1996 Accord (case photo #29)



Exterior Damage: The case vehicle's contact with the 2001 Honda involved the left center of the vehicle (**Figures 6 and 7** above). Direct damage began 42 centimeters (16.5 inches) behind of the left front axle and extended 196 centimeters (77.2 inches) rearward, ending at the forward portion of the left rear wheel well (**Figures 12 and 13**). Residual maximum crush was measured as 51 centimeters (20.1 inches). The measurement was taken along the sill level and 35 centimeters (13.8 inches) forward of C₃. The case vehicle's contact with the 1996 Honda involved the right front and center areas of the vehicle (**Figures 10 and 11** above). Direct damage began 45 centimeters (17.7 inches) forward of the right rear axle and extend 138 centimeters (54.3 inches) forward along the right side (**Figure 14**). Maximum crush for this right side impact was measured as 34 centimeters (13.4 inches) at C₄.



Units	Event	Direct Damage		Field L	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	Direct	Field L
		Width CDC	Max Crush								±D	±D
cm	1	196	57	308	6	55	48	53	25	3	-8	-28
in		77.2	22.4	121.3	2.4	21.7	18.9	20.9	9.8	1.2	-3.2	-11.0
cm	2	138	34	296	3	8	19	34	16	7	57	48
in		54.3	13.4	116.5	1.2	3.2	7.5	13.4	6.3	2.8	22.4	18.9

The wheelbase on the case vehicle's left side was shortened 17 centimeters (6.7 inches) while the wheelbase on the right side was extended 3 centimeters (1.2 inches). The case vehicle's left side passenger area was heavily damaged, such that both the front and rear doors had to be pried/cut off by rescue personnel (**Figures 6 and 7** above). Damage to the case vehicle's right side

was similar but extended forward of the right front wheel. Once again, the right side front and rear doors were pried/cut off by rescue personnel. The overall width of the passenger compartment, especially the first row, was narrowed significantly and the roof side rails were buckled inward, but the roof did not intrude downward. The windshield was severely holed and all glazing, except the small second row windows, was disintegrated from impact forces. The recommended tire size was: P225/60R16, and the case vehicle tires were the recommended size. The case vehicle’s tire data are shown in the table below. In addition, the case vehicle’s left rear tire was restricted.

Tire	Measured Pressure		Recommend Pressure		Tread Depth		Damage	Restricted	Deflated
	kpa	psi	kpa	psi	milli-meters	32 nd of an inch			
LF	262	38	207	30	5	6	None	No	No
RF	255	37	207	30	6	8	None	No	No
LR	269	39	207	30	2	3	None	Yes	No
RR	262	38	207	30	1	1	None	No	No

Interior Damage: Inspection of the case vehicle’s interior revealed cracks and scuffs to the driver’s (Figure 15), left rear (Figure 16 below), and right front interior door surfaces (Figure 17 below). Furthermore, the center console was cracked possibly by contact from the front right passenger but more likely by the compression that the case vehicle sustained as a result of the intrusion produced by both its left and right side impacts. There was possible contact evidence on the left “B”-pillar and evidence of contact on the left roof side rail, just forward of the left “B”-pillar (Figures 18 and 19 below). In addition, the driver’s seat back was scuffed from contact by one of the back passengers (Figure 19). There were multiple lateral and vertical intrusions to the case vehicle’s interior. Vertical intrusions occurred to the steering wheel assembly and steering wheel rim; left, center, and right instrument panels and windshield’s glazing; and the front left windshield’s header; see **ADDITIONAL INTERIOR PHOTOGRAPHS** below (i.e., specifically Figure 28 through Figure 30). The vertical intrusion resulted from the lateral compression (i.e.,



Figure 15: Interior surface of case vehicle’s left front door showing driver’s contacts and damage from intrusion (case photo #81)

intrusion) that occurred to both sides of the vehicle. Lateral intrusion occurred to: both the left and right instrument panels, left “A”-pillar, left and right side panels forward of their respective “A”-pillars, left and right “B”-pillars, left front and rear roof side rails, left and right–front and back door sills, driver and front right passenger seat backs and seat cushions, and the back left seat back and seat cushion. In addition, the upper half of the steering wheel rim was deformed 8 centimeters (3.1 inches) laterally toward the hub, most likely by the interior surface of the intruding driver’s door (**Figure 20** below). Finally, it could not be determined if there was any compression to the energy absorbing shear capsules in the steering column.



Figure 17: Interior surface of case vehicle’s right front door showing suspected areas of occupant contact (case photo #51)



Figure 16: Interior surface of case vehicle’s left rear door showing intrusion damage and evidence of possible occupant contacts (case photo #78)



Figure 18: Case vehicle’s front seating area showing suspected occupant contacts to left roof side rail and left “B”-pillar areas (case photo #54)



Figure 19: Case vehicle’s back seating area showing contact evidence on left roof side rail near left “B”-pillar and back left of driver’s seat back; Note: removed left side doors (case photo #77)

Damage Classification: Based on the vehicle inspection, the CDCs for the case vehicle were determined to be **09-LPEW-4 (280 degrees–1st event)** and **02-RYEW-3 (60 degrees–2nd event)**. The WinSMASH reconstruction program, damage only algorithm, was used on the case vehicle's two impacts. The Total, Longitudinal, and Lateral Delta Vs for the case vehicle's highest severity (first) impact are, respectively: 41.0 km.p.h. (25.5 m.p.h.), -7.1 km.p.h. (-4.4 m.p.h.), and +40.4 km.p.h. (+25.1 m.p.h.). In this contractor's opinion the calculated Delta Vs represent the minimum Delta Vs that the case vehicle sustained during its initial impact because the crush measurements were taken at the sill level due to door removal during extrication. Based on this contractor's experience, the crush above the sill would have been greater than the sill-level measurements used. For the case vehicle's second highest severity (second) impact, the Total, Longitudinal, and Lateral Delta Vs are, respectively: 23.0 km.p.h. (14.3 m.p.h.), -11.5 km.p.h. (-7.1 m.p.h.), and -19.9 km.p.h. (-12.4 m.p.h.). The case vehicle was towed from the scene due to damage.

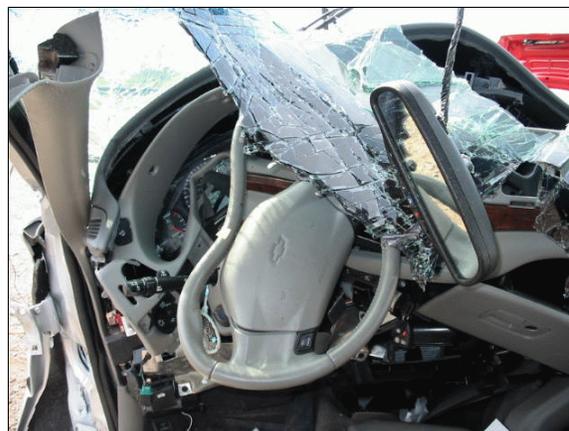


Figure 20: Case vehicle's steering wheel rim and left instrument panel deformed by lateral intrusion into driver's door (case photo #47)

AUTOMATIC RESTRAINT SYSTEM

The case vehicle was equipped with a Supplemental Restraint System (SRS) that contained dual stage frontal air bags at the driver and front right passenger positions. In addition, the vehicle was equipped with front, seat back-mounted, side impact air bags. Neither frontal air bag deployed as a result of the case vehicle's left and right side impacts with the two Honda Accords. The driver's seat back-mounted side impact air bag deployed as a result of the case vehicle's left side impact with the 2001 Honda. The front right passenger's seat back-mounted side air bag did not deploy.

The case vehicle's driver seat back-mounted side impact air bag was located on the outboard side, near the top of the front seat back. An inspection of the air bag module's cover flap and air bag revealed that the cover flap opened at the designated tear points, and there was no evidence of damage during the deployment to the air bag or cover flap (**Figure 21**). This side air bag was

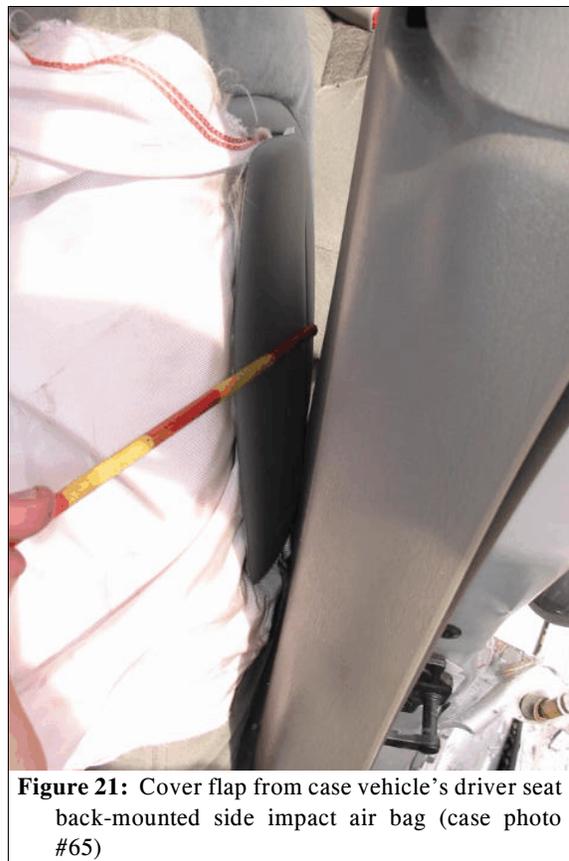


Figure 21: Cover flap from case vehicle's driver seat back-mounted side impact air bag (case photo #65)

designed with two tethers, stitched internally, connecting the inboard and outboard sides of the air bag. One tether was located midway between the center and top of the air bag and the other was near the center of the air bag. The top tether was approximately 7 centimeters (2.8 inches) in width, and the bottom tether was approximately 10 centimeters (3.9 inches) in width. There were no vent ports. The deployed side air bag was essentially rectangular with a height of 68 centimeters (26.8 inches) and width of 37 centimeters (14.6 inches). An inspection of the driver's side air bag fabric revealed only a very small amount of blood/body fluid (**Figure 22**).

CRASH DATA RECORDING

The data downloaded from the case vehicle's **EDR** showed the vehicle's SIR warning lamp status, driver's seat belt buckle status, vehicle's speed and brake switch status for the five recorded sample periods preceding the **ALGORITHM ENABLE**, ignition cycles at non-deployment, time from algorithm enable to maximum **SDM** (i.e., **SENSING AND DIAGNOSTIC MODULE**) recorded velocity change, and velocity change (i.e., Delta V). Multiple "near" deployment events occurred during this vehicle's crash sequence. The non-deployment event with highest Longitudinal Delta V change was the event recorded. The recorded event may have occurred when the case vehicle was impacted by the 2001 Honda or by the 1996 Honda, or it may have occurred when it was traveling across the median. It cannot be said with certainty during which event the recording occurred. Downloaded data of interest indicated the following. During the fifth recording period prior to the recorded algorithm enablement, the case vehicle was most likely in a yaw, sliding sideways in the southerly roadway *or* entering or within the median of the trafficway. At the fifth period prior to algorithm enable, the **EDR** recorded a travel speed of 11 km.p.h. (7 m.p.h.). This **EDR** reported travel speed does not reflect the true speed of the vehicle across the ground because of the way the speed is calculated. The vehicle's speed sensor at the drive wheels reads the number of wheel rotations. In a yaw, wheel rotations are slowed down. The number of rotations data are sent to the power control module which calculates the speed and sends the speed data to the speedometer and the **SDM**. Because the wheel rotations are down, the reported speed during the yaw does not reflect the actual speed of the vehicle. Furthermore, the driver's seat belt status showed it was buckled, and the Delta V reached a value of 1.50 km.p.h. (0.93 m.p.h.) at the 150 millisecond mark of recorded data; see **EVENT DATA RECORDER DATA** (**Figures 31 through 33**) below.



Figure 22: Inboard view of case vehicle's driver seat back-mounted side air bag showing internal tether stitching and faint occupant contact (arrow) on air bag's fabric (case photo #60)

The exact posture of the case vehicle's driver [54-year-old, White (non-Hispanic) male; 183 centimeters and 86 kilograms (72 inches, 190 pounds)] immediately prior to the crash is unknown; although, presumably he was seated in an upright posture with his back against the seat back, his left foot on the floor, and his hands on the steering wheel. However, because of the case vehicle was rotating counterclockwise just prior to impact, the location of his right foot and the exact positions of his hands on the steering wheel are unknown. Because of the intrusion damage to the driver's seating position, the exact pre-crash positions of his seat track, seat back, and tilt steering wheel cannot be determined. Post crash, the front of the seat cushion was 52 centimeters (20.5 inches) forward of the "B"-pillar, and the seat back, while deformed, was at a slightly reclined position.

Based on this contractor's vehicle inspection and supported by the **EDR** data, the case vehicle's driver was restrained by his available, active, three-point, lap-and-shoulder, safety belt system; the belt system was equipped with a retractor-mounted pretensioner, housed within the "B"-pillar. Furthermore, the inspection of the driver's seat belt webbing, "D"-ring, and latch plate showed blood stains and scuff marks on the seat belt's webbing. In addition, the belt was cut off the driver by rescue personnel.

It is unknown what, if any, avoidance maneuvers the driver made while attempting to avoid the crash; although, it is highly likely he braked and/or steered attempting to regain control of the vehicle. Independent of the use of his available safety belts, his pre-impact body position most likely did not significantly change just prior to impact. The case vehicle's impact with the 2001 Accord caused the case vehicle's driver to move leftward and slightly forward along a path opposite the case vehicle's **280** degree Direction of Principal Force as the case vehicle decelerated. As a result, the driver loaded the interior surface of his intruding door (**Figure 15** above) and his deployed seat back-mounted side impact air bag (**Figure 22** above). As the case vehicle rebounded and rotated counterclockwise from its initial impact, the driver most likely moved forward toward the steering column and center instrument panel; however, his belt system limited his movement enabling him to remain in the driver's seating position. The case vehicle's impact with the 1996 Accord enabled the driver to move rightward and forward along a path opposite the **60** degree Direction of Principal Force as the case vehicle decelerated. After the second impact the case vehicle continued to rotate counterclockwise and the driver most likely rebounded back towards his seat back, left "B"-pillar, and left roof side rail areas (**Figures 18 and 19** above). The driver's exact position at final rest is unknown. According to his son (i.e., interviewee) and his medical records, he was unconscious, required extrication, was removed from the vehicle by emergency medical technicians because of the severity of his injuries.

CASE VEHICLE DRIVER INJURIES

The driver was transported by ambulance to the hospital. He sustained severe injuries and was pronounced dead by emergency medicine physicians approximately 70 minutes after the crash. According to the autopsy summary, the injuries sustained by the case vehicle's driver included: a ruptured left diaphragm and spleen which resulted in the spleen herniating through the torn diaphragm causing a large left hemothorax and respiratory complications that resulted in his death

(i.e, atelectasis of the left lung and severe congestion and edema of the right lung). In addition, the driver sustained lacerations to his liver and multiple soft tissue injuries, including a contusion to his left chest. The driver's diaphragm, spleen, liver, and chest injuries were probably caused by contact with the left door/armrest. It should be noted that the driver did not sustain any reported brain injuries which indicates that the deployed side air bag worked in that regard.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1	Hemothorax, large (1100 cc ¹), left pleural cavity with complications, including: atelectasis left lung, severe congestion and edema right lung, resulting in asphyxia ² due to mobility of mediastinum; Pre-existing conditions included cardiomegaly due to left ventricular hypertrophy	serious 442202.3,2	Left side interior hardware and/or armrest	Probable	Autopsy
2	Rupture {massive tear} left leaflet of diaphragm allowing spleen to protrude through diaphragm into left pleural cavity	severe 440606.4,8	Left side interior hardware and/or armrest	Probable	Autopsy
3	Lacerations liver, not further specified	moderate 541820.2,1	Unknown contact mechanism	Unknown	Autopsy
4	Rupture {lacerations, multiple, massive} of spleen, not further specified	serious 544240.3,2	Left side interior hardware and/or armrest	Certain	Autopsy
5	Contusion {bruise} left chest, not further specified	minor 490402.1,2	Left side interior surface, excluding hardware and/or armrest	Probable	Autopsy
6	Lacerations, scalp, not further specified	minor 190600.1,9	Noncontact injury: flying glass, left front glazing	Probable	Emergency room records
7	Laceration left forehead, above eye, not further specified	minor 290600.1,7	Noncontact injury: flying glass, left front glazing	Probable	Emergency room records
8	Laceration right cheek, not further specified	minor 290600.1,1	Noncontact injury: flying glass, left front glazing	Possible	Emergency room records

¹ Based on this occupant's estimated weight of 90.7 kilograms (200 pounds), 1,361 cc of blood loss would be required to exceed the 20% by volume blood loss criterion.

² According to the emergency room physicians this occupant had a traumatic (blunt force) cardiac arrest, and his initial assessment indicated that he should be declared (dead) due to unsalvageable injury.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
9	Abrasion left proximal, anterior forearm	minor 790202.1,2	Air bag, driver's side impact	Probable	Emergency room records
10	Laceration left elbow <i>or</i> posterior proximal left forearm	minor 790600.1,2	Noncontact injury: flying glass, left front glazing	Possible	Emergency room records
11	Contusions, superficial, on surface of body, not further specified	minor 990400.1,9	Unknown contact mechanism	Unknown	Autopsy

CASE VEHICLE FRONT RIGHT PASSENGER KINEMATICS

The exact pre-crash posture of the case vehicle's front right passenger [wife of driver; 54-year-old, White (non-Hispanic) female; 152 centimeters and 64 kilograms (60 inches, 140 pounds)] is unknown, but presumably she was seated in an upright posture with her back against the seat back and her feet on the floor; however, the exact position of her hands is unknown. Because of the intrusion damage to the front right passenger's seating position, the exact pre-crash positions of her seat track and seat back cannot be determined. Post crash, the front of the seat cushion was 43 centimeters (16.9 inches) forward of the "B"-pillar, and the seat back, while significantly damaged by intrusion, was mostly in an upright position.

The case vehicle's front right passenger was restrained by her available, active, three-point, lap-and-shoulder, safety belt system; the belt system was equipped with a retractor-mounted pretensioner, housed within the "B"-pillar. Furthermore, the inspection of the front right passenger's seat belt webbing, "D"-ring, and latch plate showed blood stains on the seat belt's webbing. In addition, the belt was cut off this occupant by rescue personnel.

It is unknown what, if any, avoidance maneuvers the driver made while attempting to avoid the crash; although, it is highly likely the driver braked and/or steered attempting to regain control of the vehicle. Independent of the use of her available safety belts, the front right passenger's pre-impact body position most likely did not significantly change just prior to impact. The case vehicle's impact with the 2001 Accord caused the case vehicle's front right passenger to move leftward and slightly forward along a path opposite the case vehicle's **280** degree Direction of Principal Force as the case vehicle decelerated. As a result, the front right passenger may have slipped out from under the torso portion of her safety belt and contacted the case vehicle's driver. This occupant may have contacted the center console as well. As the case vehicle rebounded and rotated counterclockwise from its initial impact, the front right passenger most likely moved forward toward the right instrument panel and right "A"-pillar; however, her belt system limited her movement enabling her to remain in the front right seating position. The case vehicle's impact with the 1996 Accord enabled the front right passenger to move rightward and forward along a path opposite the **60** degree Direction of Principal Force as the case vehicle decelerated. As a result

she most likely loaded the interior surface of her intruding right front door (**Figure 17** above). After the second impact the case vehicle continued to rotate counterclockwise and the front right passenger most likely rebounded back towards her seat back and/or the center console. The front right passenger's exact position at final rest is unknown. According to her son (i.e., interviewee) and her medical records, she required extrication and was removed from the vehicle by emergency medical technicians because of the severity of her injuries.

CASE VEHICLE FRONT RIGHT PASSENGER INJURIES

The front right passenger was transported by ambulance to the hospital in critical condition. She sustained critical injuries and was hospitalized 23 days post-crash. According to her medical records and an interview with her son (i.e., not an occupant), the injuries sustained by the case vehicle's front right passenger included: a right diffuse axonal injury, a right temporal lobe contusion, bilateral subarachnoid hemorrhages, a nonanatomic brain injury, a grade 1 splenic laceration, a fracture to the lamina of her 7th cervical vertebrae, at least one fracture to her right ribs, bilateral lung contusions, multiple pelvic fractures, and contusions on her left forehead, forearm, scapula, sternum, and across her lower abdomen. This occupant's primary brain, cervical, and chest injuries were most likely caused by her contact with the interior surface of the case vehicle's right front door and/or right "B"-pillar. She also most likely contacted her husband (i.e., driver) causing several left side contusions and possibly a serious brain injury. The impact to the case vehicle's left side did cause her to move laterally to the left, possibly contacting the center console. Her chest and abdominal contusions as well as her splenic laceration were caused by her safety belts.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1	Diffuse axonal (white matter shearing) injury ³ on right	critical 140628.5,1	Right "B"-pillar	Possible	Hospitalization records
2	Hematoma, small, right temporal lobe, not further specified	serious 140606.3,1	Right "B"-pillar	Possible	Emergency room records
3	Hemorrhage, subarachnoid, on right, not further specified	serious 140684.3,1	Right "B"-pillar	Possible	Hospitalization records
4	Hemorrhage, subarachnoid, left temporal-parietal area	serious 140684.3,2	Other occupant: driver	Possible	Emergency room records
5	Nonanatomic brain injury with confusion on admission, inappropriate moans, unintelligible verbalizations, and prior unconsciousness of unknown duration; GCS = 11; and neurologic deficit (i.e., unequal pupils)	serious 160608.3,0	Right "B"-pillar	Possible	Hospitalization records

³ See material pertaining to Craniocerebral Impact Injuries beginning on page 33.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
6	Laceration, spleen, subcapsular, Grade 1 with splenectomy	moderate 544222.2,2	Lap portion of safety belt system	Probable	Hospitalization records
7	Fracture C ₇ lamina, not further specified	serious 650224.3,6	Right "B"-pillar	Possible	Hospitalization records
8	Contusions lungs, bilaterally, not further specified	severe 441410.4,3	Right side interior hardware and/or armrest	Probable	Hospitalization records
9	Fracture right rib ⁴ with right pneumothorax from rib penetration	serious 450214.3,1	Right side interior hardware and/or armrest	Certain	Hospitalization records
10	Fracture right superior and inferior pubic ramii	moderate 852602.2,5	Right side interior surface, excluding hardware and/or armrest	Probable	Hospitalization records
11	Fracture right sacral wing, not further specified	moderate 852602.2,6	Right side interior surface, excluding hardware and/or armrest	Probable	Hospitalization records
12	Contusion {hematoma} left forehead (i.e., above left eye)	minor 290402.1,7	Other occupant: driver	Probable	Emergency room records
13	Contusion {bruising} over left sternum (i.e., seat belt-related)	minor 490402.1,4	Torso portion of safety belt system	Certain	Emergency room records
14	Contusions {bruising, ecchymosis} across lower abdomen consistent with seat belt use	minor 590402.1,8	Lap portion of safety belt system	Certain	Hospitalization records
15	Contusion {ecchymosis}, large, over left scapula [Aspect = Superior]	minor 690402.1,2	Other occupant: driver	Probable	Hospitalization records
16	Contusion {ecchymosis} left forearm, not further specified	minor 790402.1,2	Other occupant: driver	Probable	Hospitalization records

⁴ The actual number of right rib fractures was not specified in the medical records. In one instance the word fracture was used in the plural; in another instance, the singular was used.

The exact posture of the case vehicle's back left passenger [unknown relationship; 5-year-old, White (non-Hispanic) female; 104 centimeters and 20 kilograms (41 inches, 45 pounds)] is unknown but, presumably because of the crowded nature of the case vehicle's back seat, she was seated in an upright posture with her back against the seat back, and her feet dangling over the front edge of the seat's cushion. The exact position of her hands, however, is unknown. Her seat track and seat back were not adjustable.

The case vehicle's back left passenger was restrained by her available, active, three-point, lap-and-shoulder, safety belt system. However, given the child's age and stature, it is unknown if she was properly restrained by the shoulder portion of her belt system. Furthermore, the inspection of the back left passenger's seat belt webbing and latch plate showed scuff marks made by the belt at the top left portion of the seat back.

It is unknown what, if any, avoidance maneuvers the driver made while attempting to avoid the crash; although, it is highly likely the driver braked and/or steered attempting to regain control of the vehicle. Independent of the use of her available safety belts, the back left passenger's pre-impact body position most likely did not significantly change just prior to impact. The case vehicle's impact with the 2001 Accord caused the case vehicle's back left passenger to move leftward and slightly forward along a path opposite the case vehicle's **280** degree Direction of Principal Force as the case vehicle decelerated. As a result, the back left passenger contacted the interior surface of the intruding left rear door (**Figure 16** above). As the case vehicle rebounded and rotated counterclockwise from its initial impact, the back left passenger most likely moved forward toward the back surface of the driver's seat back. This occupant most likely the back surface of the driver's seat back and may have contacted the back portion of the center console as well; however, her belt system limited her movement enabling her to remain in the back left seating position. The case vehicle's impact with the 1996 Accord enabled to back left passenger to move rightward and forward along a path opposite the **60** degree Direction of Principal Force as the case vehicle decelerated. As a result she most likely contacted the back center passenger. After the second impact the case vehicle continued to rotate counterclockwise and the back left passenger most likely rebounded back towards her seat back and/or the intruded left rear door's surface. The back left passenger's exact position at final rest is unknown. According to the interviewee and her medical records, she required extrication and was removed from the vehicle by emergency medical technicians. Because of her limited medical records, her state of consciousness and ability to exit the case vehicle are unknown.

CASE VEHICLE BACK LEFT PASSENGER INJURIES

Based on the Police Crash Report, the back left passenger was transported by ambulance to the hospital in critical condition. She sustained at least moderate injuries and was hospitalized for 27 days post-crash. Based on the limited medical records that were made available to this contractor, she sustained: a traumatic head injury, a laceration to her left kidney, and a fracture to at least one left rib and her right pelvis. Her left kidney and rib lesions were caused by her left rear door's intruding surface. The cause of her head and right pelvic injuries could not be determined.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1	Traumatic head injury, not further specified	unknown 115099.7,0	Unknown contact mechanism	Unknown	EMS treatment record
2	Fracture left rib, not further specified	minor 450212.1,2	Left side interior surface, excluding hardware and/or armrest	Certain	Hospitalization records
3	Laceration {fracture} left kidney, not further specified	moderate 541620.2,2	Left side interior surface, excluding hardware and/or armrest	Probable	Hospitalization records
4	Fracture right pelvis, not further specified	moderate 852600.2,1	Unknown contact mechanism	Unknown	Hospitalization records

CASE VEHICLE BACK CENTER PASSENGER KINEMATICS

The exact posture of the case vehicle's back center passenger [granddaughter; 12-year-old, White (non-Hispanic) female; 147 centimeters and 39 kilograms (58 inches, 85 pounds)] is unknown but, presumably because of the crowded nature of the case vehicle's back seat, she was seated in an upright posture with her back against the seat back, and her feet on the floor. The exact position of her hands, however, is unknown. Her seat track and seat back were not adjustable.

The case vehicle's back center passenger was restrained by her available, active, three-point, lap-and-shoulder, safety belt system. Furthermore, the inspection of the back center passenger's seat belt webbing and latch plate showed scuff marks present on the portion of the belt's webbing that would have been touching the occupant.

It is unknown what, if any, avoidance maneuvers the driver made while attempting to avoid the crash; although, it is highly likely the driver braked and/or steered attempting to regain control of the vehicle. Independent of the use of her available safety belts, the back center passenger's pre-impact body position most likely did not significantly change just prior to impact. The case vehicle's impact with the 2001 Accord caused the case vehicle's back center passenger to move leftward and slightly forward along a path opposite the case vehicle's **280** degree Direction of Principal Force as the case vehicle decelerated. As a result, the back center passenger may have slipped out from under the torso portion of her safety belt and contacted the back left passenger, the interior surface of the intruding left rear door, and/or the back right side of the driver's seat back. As the case vehicle rebounded and rotated counterclockwise from its initial impact, the back center passenger most likely moved forward toward the back surface of the driver's seat back and/or back portion of the center console. This occupant may have contacted the back surface of the driver's seat back and may have contacted the back portion of the center console as well; however, her belt system limited her movement enabling her to remain in the back center seating

position. The case vehicle’s impact with the 1996 Accord enabled to back center passenger to move rightward and forward along a path opposite the **60** degree Direction of Principal Force as the case vehicle decelerated. As a result she most likely contacted the back left portion of the front right passenger seat back and/or the back right passenger. After the second impact the case vehicle continued to rotate counterclockwise and the back center passenger most likely rebounded back towards her seat back. The back center passenger’s exact position at final rest is unknown. According to the interviewee, she required extrication and was removed from the vehicle by emergency medical technicians. Her state of consciousness and ability to exit the case vehicle are unknown.

CASE VEHICLE BACK CENTER PASSENGER INJURIES

The back center passenger was transported by ambulance to the hospital. She sustained only minor injuries but was still hospitalized at the time this contractor interviewed her father. Based on the interview, this occupant sustained an injury to her left ankle. No medical records could be located for this occupant.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1	Injury left ankle, not further specified	unknown 850299.1,2	Unknown contact mechanism	Unknown	Interviewee (relative)

CASE VEHICLE BACK RIGHT PASSENGER KINEMATICS

The exact posture of the case vehicle's back right passenger [grandson; 5-year-old, White (non-Hispanic) male; 114 centimeters and 20 kilograms (45 inches, 45 pounds)] is unknown but, presumably because of the crowded nature of the case vehicle’s back seat, he was seated in an upright posture with his back against the seat back and his feet dangling over the front edge of the seat’s cushion. The exact position of his hands, however, is unknown. His seat track and seat back were not adjustable.

The case vehicle's back right passenger was restrained by his available, active, three-point, lap-and-shoulder, safety belt system. However, given the child’s age and stature, it is unknown if he was properly restrained by the shoulder portion of his belt system. In addition, the inspection of the back right passenger’s seat belt webbing and latch plate did not showed any evidence of loading, but the belt was cut off this occupant by rescue personnel.

It is unknown what, if any, avoidance maneuvers the driver made while attempting to avoid the crash; although, it is highly likely the driver braked and/or steered attempting to regain control of the vehicle. Independent of the use of his available safety belts, the back right passenger’s pre-impact body position most likely did not significantly change just prior to impact. The case vehicle's impact with the 2001 Accord caused the case vehicle’s back right passenger to move leftward and slightly forward along a path opposite the case vehicle’s **280** degree Direction of

Principal Force as the case vehicle decelerated. As a result, the back right passenger may have slipped out from under the torso portion of his safety belt and contacted the case vehicle’s back center passenger and/or the back left side of the front right passenger’s seat back. As the case vehicle rebounded and rotated counterclockwise from its initial impact, the back right passenger most likely moved forward toward the back surface of the front right passenger’s seat back and right “B”-pillar; however, his belt system limited his movement enabling him to remain in the back right seating position. The case vehicle’s impact with the 1996 Accord enabled to back right passenger to move rightward and forward along a path opposite the 60 degree Direction of Principal Force as the case vehicle decelerated. As a result he most likely loaded the interior surface of his intruding right rear door (Figure 23). After the second impact the case vehicle continued to rotate counterclockwise and the back right passenger most likely rebounded back towards his seat back and/or the back center seating position. The back right passenger’s exact position at final rest is unknown. According to his father (i.e., interviewee) and his medical records, he required extrication and was removed from the vehicle by emergency medical technicians. His state of consciousness and ability to exit the case vehicle are unknown.

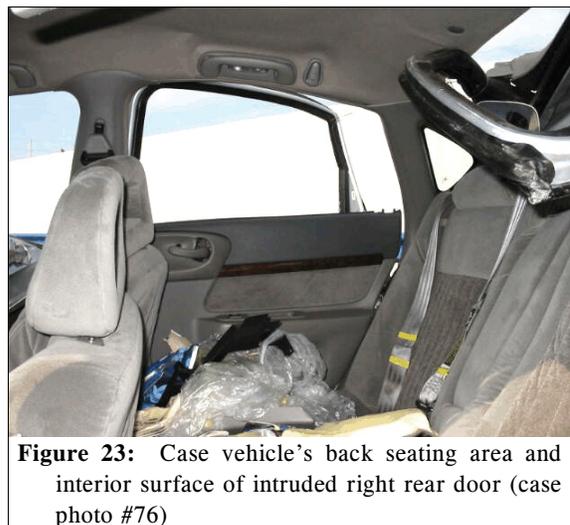


Figure 23: Case vehicle’s back seating area and interior surface of intruded right rear door (case photo #76)

CASE VEHICLE BACK RIGHT PASSENGER INJURIES

The back right passenger was transported by ambulance to the hospital. He sustained at least a moderate injury and was hospitalized for 5 days post-crash. According to his medical records and the interviewed with his father, the injuries he sustained included: a grade 1 laceration of his spleen, fractures of his left tibia and fibula, midway between the ankle and knee, and abrasions to both his left leg and right knee. This occupant’s splenic laceration was possibly caused by contact with the back center passenger and his left fractures most likely resulted from contact with the lower portion of the front right passenger’s seat back.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1	Laceration spleen, grade 1	moderate 544222.2,2	Other occupant: back center passenger	Possible	Hospitalization records
2 3	Fracture left tibia and fibula, not further specified, with closed reduction	moderate 851605.2,2 853404.2,2	Seat back, front right passenger’s	Probable	Hospitalization records

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
4	Abrasion left lower extremity, not further specified	minor 890202.1,2	Seat back, front right passenger's	Probable	Hospitalization records
5	Abrasion right knee, not further specified	minor 890202.1,1	Right side interior surface, excluding hardware and/or armrest	Probable	Hospitalization records

1ST OTHER VEHICLE

The 2001 Honda Accord LX was a front wheel drive, five-passenger, four-door sedan (VIN: 1FAFP13P9WW-----) equipped with a 2.3L, I-4 engine and a four-speed automatic transmission. Braking was achieved by a power-assisted, front disc and rear drum system. The case vehicle's wheelbase was 272 centimeters (106.9 inches), and the odometer reading is unknown because this vehicle's interior was not inspected. The 2001 Honda was equipped with advanced occupant protection system features including redesigned, dual-stage, driver and front right passenger air bags and front seat back-mounted side impact air bags. This vehicle's front air bags deployed as a result this vehicle's frontal impact (**Figure 24**).



Figure 24: 2001 Accord's frontal damage viewed from left; Note: severity of crush and deployed frontal air bags (case photo #88)

Exterior Damage: Based on vehicle inspection (**Figure 25**), the CDC for the 2001 Accord was determined to be: **12-FDEW-2 (350 degrees-1st event)**. The crush profile for the 2001 Accord is shown in the table below; maximum crush was 48 centimeters (18.9 inches) and was located 10 centimeters (3.9 inches) to the left of C₂. The WinSMASH reconstruction program, damage only algorithm, was used on the 2001 Accord's highest severity impact. The Total, Longitudinal, and Lateral Delta Vs are, respectively: 49.0 km.p.h. (30.4 m.p.h.), -48.3 km.p.h. (-30.0 m.p.h.), and +8.5 km.p.h. (+5.3 m.p.h.). The 2001 Accord was towed due to damage.

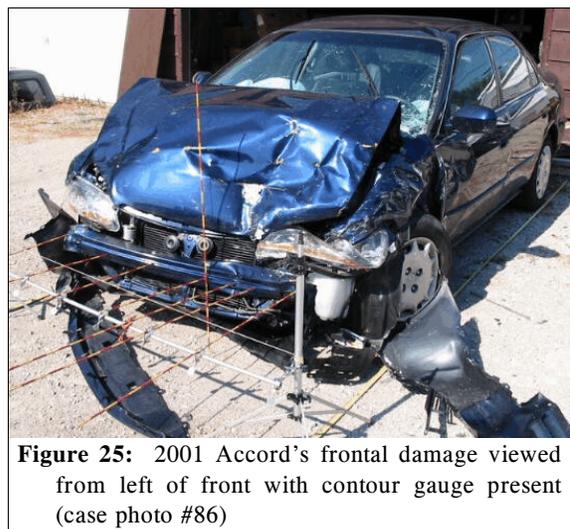


Figure 25: 2001 Accord's frontal damage viewed from left of front with contour gauge present (case photo #86)

Units	Event	Direct Damage		Field L	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	Direct	Field L
		Width CDC	Max Crush								±D	±D
cm	1	115	48	150	37	44	43	25	26	11	0	0
in		45.3	18.9	59.1	14.6	17.3	16.9	9.8	10.2	4.3	0.0	0.0

The recommended tire size was: P195/65R15, and this vehicle’s tires were the recommended size. The 2001 Honda’s tire data are shown in the table below.

Tire	Measured Pressure		Recommend Pressure		Tread Depth		Damage	Restricted	Deflated
	kpa	psi	kpa	psi	milli-meters	32 nd of an inch			
LF	210	31	200	29	6	8	None	Yes	No
RF	217	32	200	29	6	8	None	No	No
LR	207	30	200	29	6	8	None	No	No
RR	207	30	200	29	5	6	None	No	No

2001 Honda’s Occupants: According to the Police Crash Report, the 2001 Accord's driver [19-year-old, (unknown race and/or ethnic origin) male], the front right passenger [25-year-old, (unknown race and/or ethnic origin) male], and the back right passenger [22-year-old, (unknown race and/or ethnic origin) male] were restrained by their available, active, three-point, lap-and-shoulder, safety belt systems. None of the three occupants were transported by ambulance to the hospital, and they did not sustain any police-reported injuries as a result of this crash.

2ND OTHER VEHICLE

The 1996 Honda Accord LX was a front wheel drive, five-passenger, four-door sedan (VIN: 1HGCG56421A-----) equipped with a 2.2L, I-4 engine and a four-speed automatic transmission. Braking was achieved by a power-assisted, front disc and rear drum system. The case vehicle’s wheelbase was 272 centimeters (106.9 inches), and the odometer reading is unknown because this vehicle’s interior was not inspected. This 1996 Honda was equipped with driver and front right passenger air bags which deployed as a result this vehicle’s frontal impact (Figure 26).

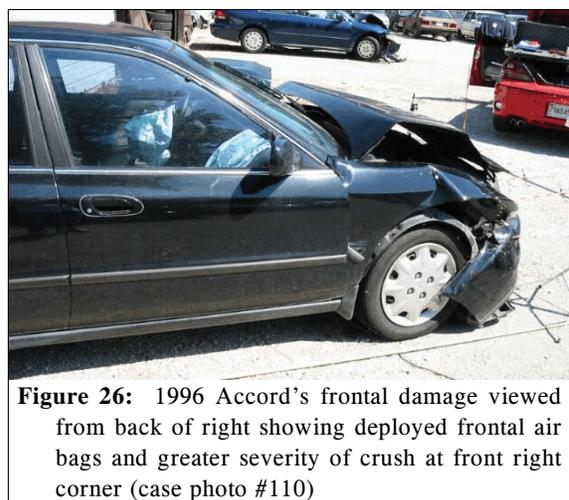


Figure 26: 1996 Accord’s frontal damage viewed from back of right showing deployed frontal air bags and greater severity of crush at front right corner (case photo #110)

Exterior Damage: Based on vehicle inspection (Figure 27), the CDC for the 1996 Accord was determined to be **11-FDEW-02** (340 degrees–2nd event). The crush profile for the 1996 Accord is shown in the table below; maximum crush 32 cm (12.5 in) at C₆. The WinSMASH reconstruction program, damage only algorithm, was used on the 1996 Accord's highest severity impact. The Total, Longitudinal, and Lateral Delta Vs are, respectively: 31.0 km.p.h. (19.3 m.p.h.), -29.1 km.p.h. (-18.1 m.p.h.), and +10.6 km.p.h. +6.6 m.p.h.). The 1996 Accord was towed from the scene due to damage.

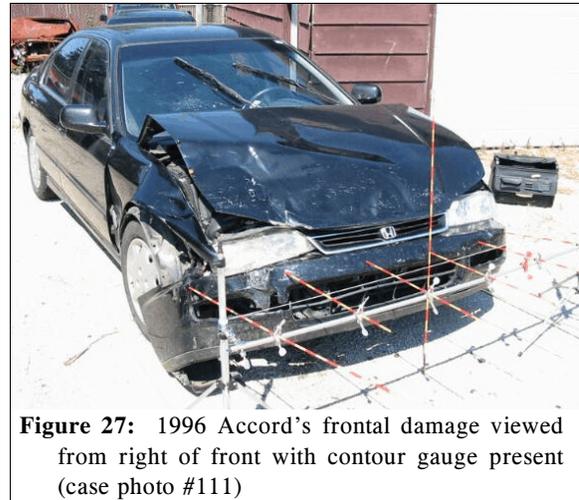


Figure 27: 1996 Accord's frontal damage viewed from right of front with contour gauge present (case photo #111)

Units	Event	Direct Damage		Field L	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	Direct	Field L
		Width CDC	Max Crush								±D	±D
cm	1	153	32	160	7	16	20	24	28	32	0	0
in		60.2	12.6	63.0	2.8	6.3	7.9	9.4	11.0	12.6	0.0	0.0

The recommended tire size was: P185/65R15, and this vehicle's tires were the recommended size. The 1996 Honda's tire data are shown in the table below.

Tire	Measured Pressure		Recommend Pressure		Tread Depth		Damage	Restricted	Deflated
	kpa	psi	kpa	psi	milli-meters	32 nd of an inch			
LF	183	27	221	32	7	9	None	No	No
RF	172	25	221	32	7	9	None	No	No
LR	179	26	221	32	7	9	None	No	No
RR	183	27	221	32	5	6	None	No	No

1996 Honda's Occupants: According to the Police Crash Report, the 1996 Accord's driver [23-year-old, (unknown race and/or ethnic origin) male] was restrained by his available, active, three-point, lap-and-shoulder, safety belt system. The driver was not transported by ambulance to the hospital, and he did not sustain any police-reported injuries as a result of this crash.

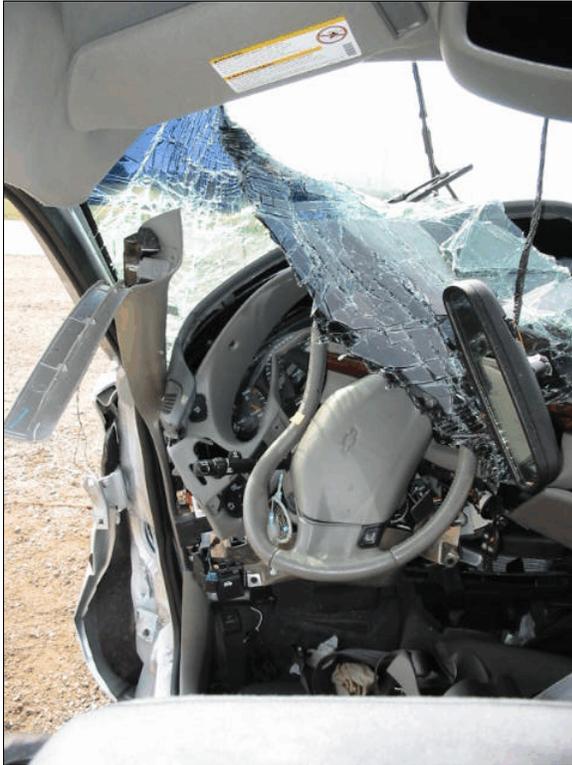


Figure 28: Case vehicle's driver seating area showing holed windshield, deformed steering wheel rim, and lateral and vertical intrusion to left instrument panel; Note: driver's door was removed during extrication (case photo #48)

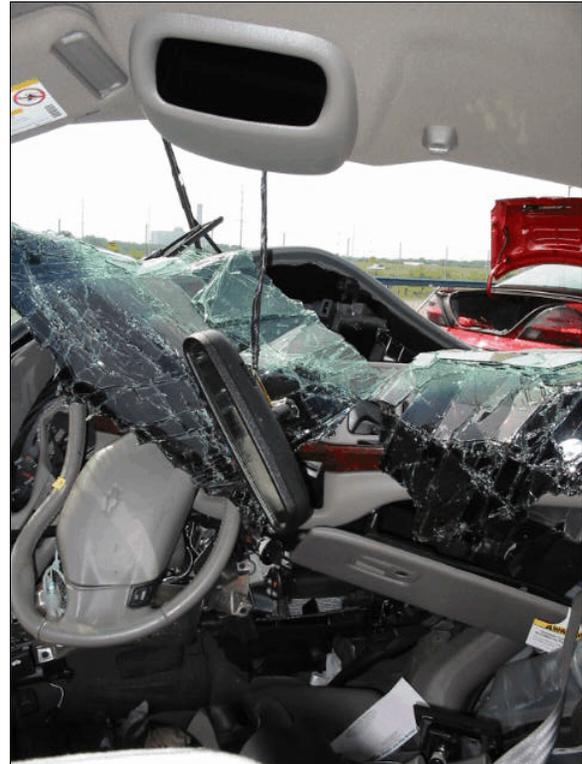


Figure 29: Case vehicle's center instrument panel area showing extensive vertical intrusion and upward roof buckling resulting from combination of left and right side impacts (case photo #49)

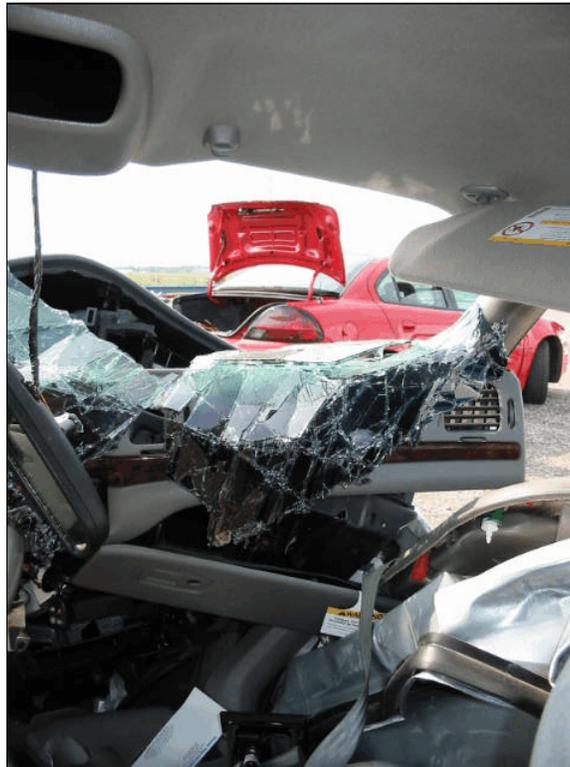


Figure 30: Case vehicle's front right passenger seating area showing lateral and vertical intrusion to right instrument panel (case photo #50)

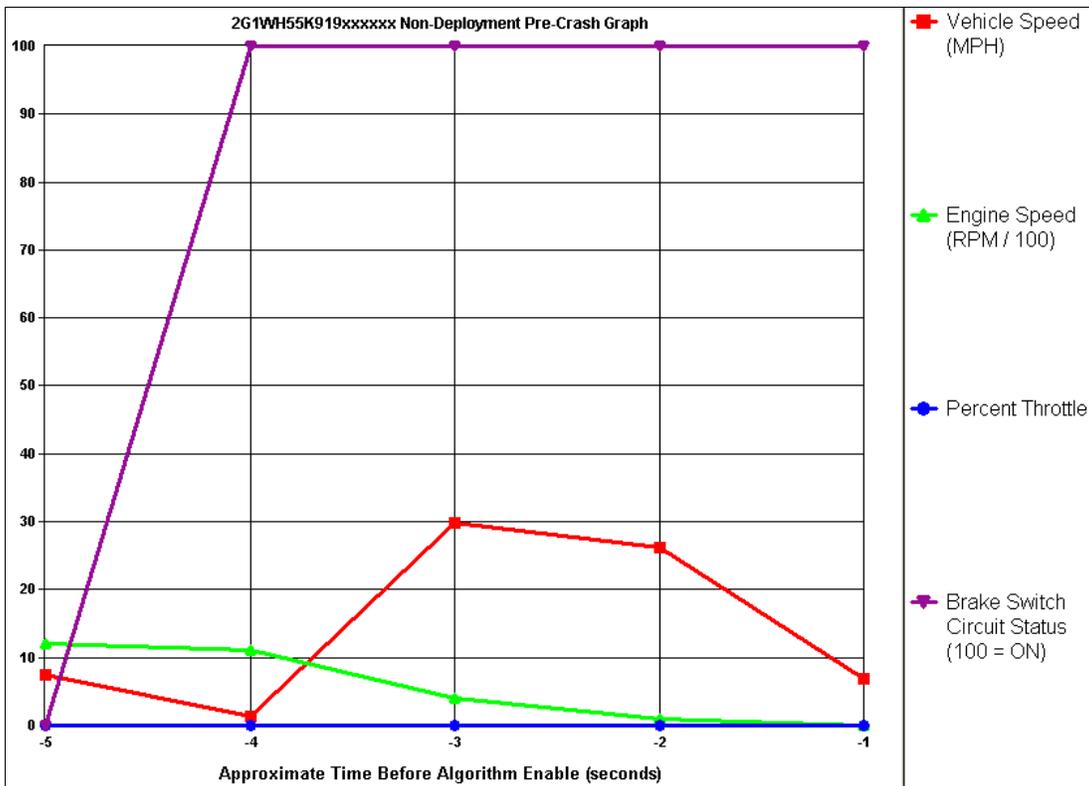


Figure 32: Case vehicle’s pre-crash speed and brake switch circuit status showing that the vehicle was most likely in a yaw [i.e., recorded speed was approximately 11 km.p.h. (7 m.p.h.)] with the driver’s foot off the accelerator when the brake was activated approximately 5 seconds prior to algorithm enable

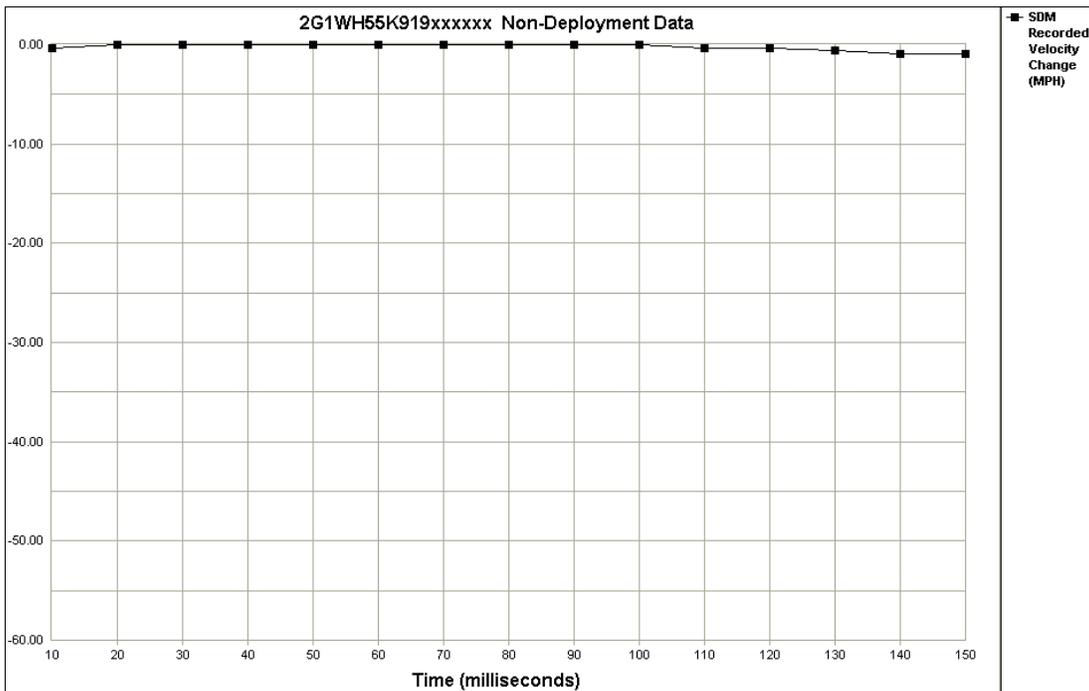


Figure 33: The case vehicle sustained a velocity change of approximately 1.5 km.p.h. (0.9 m.p.h.) during the first 150 milliseconds after the algorithm was enabled; maximum velocity change was recorded as 2.3 km.p.h. (1.4 m.p.h.) at 175 milliseconds

The following material is taken from the book: FORENSIC PATHOLOGY, 2ND EDITION by Vincent J. DiMaio, M.D., and Dominick J. DiMaio, M.D., CRC Press, Boca Raton, Florida, 2001; Chapter Six: Trauma to the Skull and Brain: Craniocerebral Injuries, *Impact Injuries*, pages 147, 166-168, and 169-172.

Acceleration or deceleration injuries are due to sudden movement of the head the instant after injury, with resultant production of intracranial pressure gradients and the subjecting of the brain to both shearing and tensile forces. Two types of injuries are typically produced: (1) **Subdural hematomas** and (2) **Diffuse axonal injury**.

Subdural hematomas are secondary to tearing of the subdural bridging veins; diffuse axonal injury is secondary to injury to the axons. While acceleration or deceleration injuries are associated with impact, theoretically, impact is not necessary for the production of these injuries, just sudden angular rotation of the head. In situations encountered by forensic pathologists, however, acceleration or deceleration injuries of the brain involve impact.

Diffuse Axonal Injury

Immediate prolonged coma unaccompanied by an intracranial mass lesion occurs in almost half of patients with severe head injuries. The etiology of this coma and the cause of death in fatal cases is diffuse axonal injury (DAI). Diffuse axonal injury results from the effects of head motion on the brain. It is caused by sudden acceleration or deceleration of the head. While, theoretically, impaction of the head against a hard object is not necessary, in reality, brain injury in humans requires contact, not just acceleration or deceleration. For all practical purposes, it is the impact that starts the acceleration or deceleration injury to the brain.

Diffuse axonal injury is a continuum, varying from mild brain injury and dysfunction to severe irreversible dysfunction and injury, and even death. The severity of injury is determined by the amount of acceleration or deceleration of the brain, the time span over which it occurs, and the direction of movement. Experiments have shown that only motion in the coronal⁵ plane causes severe injuries. Sagittal⁶ head movement produces diffuse axonal injury of mild, or at most, moderate type.

At low levels of acceleration or deceleration, there is no anatomical disruption of the axons, only physiological dysfunction. This may lead to either complete recovery of an axon or its degeneration. As the physical force increases, there will be a progressive increase in the extent of irreversible physiological injury to axons (thus making it more likely that they will subsequently undergo degeneration) plus an increase in the amount of immediate structural disruption of axons (transaction) with immediate cessation of all activities.

The term **diffuse axonal injury** (DAI) is used clinically to characterize a condition of diffuse injury of the axons of the brain associated with immediate unconsciousness and coma longer than 6 hours of duration. In mild DAI, there is coma of 6-24 hours; in

⁵ Motion that is along the coronal plane [i.e., side-to-side (e.g., right-to-left, left-to-right)].

⁶ Motion that is along the midsagittal (median) plane [i.e., anterior to posterior (front-to-back), posterior to anterior (back-to-front)].

moderate DAI, coma of more than 24 hours without prominent clinical signs of brain stem dysfunction; and, in severe DAI, coma of more than 24 hours with brain stem signs. Severe DAI usually results in severe disability or death. Axonal injury of a greater or lesser degree is the pathological lesion common to all three forms of DAI.

With mild DAI, the injury is predominately physiological. Some axons, however, may show immediate physical disruption with cessation of functions. In other axons, the physiological disruption will eventually lead to degeneration. As the acceleration or deceleration force increases, the proportion in each category changes, until, with severe DAI, the predominant injury is shearing of axons and immediate cessation of functioning. In severe DAI, there is mechanical disruption of the axons in the white matter of the cerebral hemispheres, the corpus callosum, and upper brain stem. Focal hemorrhages are usually grossly visible in the corpus callosum and dorsolateral quadrant of the rostral brain stem. Occasionally, laceration or even transection of the corpus callosum can occur. Gliding contusions of the gray matter of the cerebral hemispheres and hippocampi may be present.

In diffuse axonal injury, experiments have revealed that it is not only the magnitude of acceleration that produces the injury, but the time over which the acceleration occurs. Severe angular accelerations over a short period result in subdural hematomas; acceleration over a long period, diffuse axonal injury. This agrees with the observation that diffuse axonal injury is more common in vehicular accidents, where the time of impact may be prolonged due to absorbing materials, but rare in falls, where there is no absorption of impact.

