



# INDIANA UNIVERSITY

## TRANSPORTATION RESEARCH CENTER

School of Public and Environmental Affairs  
222 West Second Street  
Bloomington, Indiana 47403-1501  
(812) 855-3908 Fax: (812) 855-3537

## ON-SITE AIR BAG INVESTIGATION

CASE NUMBER - IN99-091  
LOCATION - NORTH DAKOTA  
VEHICLE - 1990 GEO STORM  
CRASH DATE - April, 1999

Submitted:

September 30, 2001

Revised Submissions:

February 27, 2002

March 6, 2002



Contract Number: DTNH22-94-D-17058

Prepared for:

U.S. Department of Transportation  
National Highway Traffic Safety Administration  
National Center for Statistics and Analysis  
Washington, D.C. 20590-0003

## **DISCLAIMERS**

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no responsibility for the contents or use thereof.

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the National Highway Traffic Safety Administration.

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.

1. <i>Report No.</i> IN99-091		2. <i>Government Accession No.</i>		3. <i>Recipient's Catalog No.</i>	
4. <i>Title and Subtitle</i> On-Site Air Bag Fatality Investigation Vehicle - 1990 Geo Storm Location - North Dakota			5. <i>Report Date:</i> 9/30/2001; 2/27/2002; 3/06/2002		
			6. <i>Performing Organization Code</i>		
7. <i>Author(s)</i> Special Crash Investigations Team #2			8. <i>Performing Organization Report No.</i> Task # 0215		
9. <i>Performing Organization Name and Address</i> Transportation Research Center Indiana University 222 West Second Street Bloomington, Indiana 47403-1501			10. <i>Work Unit No. (TRAIS)</i>		
			11. <i>Contract or Grant No.</i> DTNH22-94-D-17058		
12. <i>Sponsoring Agency Name and Address</i> U.S. Department of Transportation (NRD-32) National Highway Traffic Safety Administration National Center for Statistics and Analysis Washington, D.C. 20590-0003			13. <i>Type of Report and Period Covered</i> Technical Report Crash Date: April, 1999		
			14. <i>Sponsoring Agency Code</i>		
15. <i>Supplementary Notes</i> On-site air bag deployment investigation involving a 1990 Geo Storm, two-door hatchback, with manual safety belts and driver's air bag, that impacted a curb and a fire hydrant					
16. <i>Abstract</i> This report covers an on-site investigation of an air bag deployment crash that involved a 1990 Geo Storm (case vehicle) that impacted a curb and a fire hydrant. This crash is of special interest because the case vehicle's, unrestrained driver (21-year-old female) sustained critical neck and brain injuries allegedly from impacting her deploying driver air bag, resulting in her death. The case vehicle was traveling north in the northbound lane of a two-lane, undivided, city street and was approaching a four-leg, partially controlled intersection (i.e., there was one lane in both directions with parking along the east side only). A noncontact vehicle had been traveling west in the westbound lane of the intersecting, two-lane, undivided, city street and slowly pulled out into the intersection because visibility, for both vehicles, was obstructed. The case vehicle's driver overreacted and swerved sharply to the left and braked, attempting to avoid the crash. The crash occurred off the northwest corner of the intersection of the two roadways. The right front tire of the case vehicle impacted the barrier curb, causing the case vehicle's driver (only) supplemental restraint (air bag) to deploy. The case vehicle continued in a west-northwesterly direction, and its front left bumper corner impacted a fire hydrant. The narrow end engagement with the fire hydrant traveled down the case vehicle's left side and snagged on the left front wheel, causing the case vehicle to rotate approximately 100 degrees counterclockwise to final rest. The case vehicle's driver was seated with her seat track located between its middle and rearmost positions, and the vehicle was not equipped with a tilt steering wheel. She was not using her available, active, three-point, lap-and-shoulder, safety belt system and sustained, according to the interview with the front right passenger and her medical records, critical injuries which included: a moderate nonanatomic brain injury, a neck strain, a chin abrasion, a contused left upper arm, a head laceration, and a laceration to her right internal carotid artery. This carotid artery laceration {dissection} caused a massive, traumatic, right hemispheric stroke and resulted in a deep right intracerebral hemorrhage, severe brain swelling/edema, and eventually a brainstem compression which resulted in her brain death. In this contractor's opinion, this occupant's primary neck and resultant brain injuries were most likely caused by her contact with the windshield's glazing and header. The case vehicle's front right passenger (23-year-old male) was seated with his seat track located in its rearmost position and was not wearing his available, active, three-point, lap-and-shoulder, safety belt system. He sustained, according to his interview and his medical records, a left hand laceration and a nasal fracture and contusion.					
17. <i>Key Words</i> Air Bag Deployment			Motor Vehicle Traffic Crash Injury Severity		18. <i>Distribution Statement</i> General Public
19. <i>Security Classif. (of this report)</i> Unclassified		20. <i>Security Classif. (of this page)</i> Unclassified		21. <i>No. of Pages</i> 18	22. <i>Price</i> \$9,300

**TABLE OF CONTENTS**

IN99-091

Page No.

BACKGROUND . . . . .	1
SUMMARY . . . . .	1
CRASH CIRCUMSTANCES . . . . .	4
CASE VEHICLE: 1990 GEO STORM . . . . .	5
CASE VEHICLE DAMAGE . . . . .	7
AUTOMATIC RESTRAINT SYSTEM . . . . .	8
CASE VEHICLE DRIVER KINEMATICS . . . . .	9
CASE VEHICLE DRIVER INJURIES . . . . .	10
CASE VEHICLE FRONT RIGHT PASSENGER KINEMATICS . . . . .	11
CASE VEHICLE FRONT RIGHT PASSENGER INJURIES . . . . .	12
CRASH DIAGRAM . . . . .	14
SELECTED PHOTOGRAPHS	
Figure 1: Case vehicle’s northward travel path into intersection . . . . .	4
Figure 2: Northwest corner of intersection toward which case vehicle’s driver steered . . . . .	4
Figure 3: Case vehicle’s curb and fire hydrant impacts . . . . .	5
Figure 4: Case vehicle’s front left damage from left of front . . . . .	5
Figure 5: Close-up of case vehicle’s damage from narrow end engagement . . . . .	5
Figure 6: Exterior view of driver’s contact to case vehicle’s left windshield . . . . .	6
Figure 7: Exterior view of passenger’s contact to case vehicle’s windshield . . . . .	6
Figure 8: Side view of case vehicle’s collapsed steering wheel and column . . . . .	6
Figure 9: Close-up of driver’s head contact to case vehicle’s left wind- shield and sun visor areas . . . . .	7
Figure 10: Contact evidence on case vehicle’s driver knee bolster . . . . .	7
Figure 11: Close-up of damage to case vehicle’s right front wheel . . . . .	7
Figure 12: Case vehicle’s minimally deformed front viewed from right . . . . .	7
Figure 13: Close-up of damage to case vehicle’s left front wheel . . . . .	8
Figure 14: Contact evidence of case vehicle’s deployed driver air bag . . . . .	8
Figure 15: Hair and blood spray of back bottom portion of case vehicle’s driver air bag . . . . .	9

TABLE OF CONTENTS (CONTINUED)

IN99-091

	<u>Page No.</u>
SELECTED PHOTOGRAPHS (Continued)	
Figure 16: Contact evidence of case vehicle's center instrument panel . . . . .	12
Figure 17: Contact evidence to case vehicle's lower right instrument panel . . .	12
VASCULAR INJURIES . . . . .	15
SELECTED ANATOMICAL DIAGRAMS . . . . .	16
Figure 18: Major branches of the right common carotid and right subclavian arteries . . . . .	16
Figure 19: Arteries that supply blood to the brain . . . . .	17
MEDICAL TERMS . . . . .	18

This on-site investigation was brought to NHTSA's attention on November 23, 1999 by a private consultant. This crash involved a 1990 Geo Storm (case vehicle), a curb, and a fire hydrant. The crash occurred in April, 1999, at 2:45 p.m., in North Dakota and was investigated by the applicable city police department. This crash is of special interest because the case vehicle's, unrestrained driver [21-year-old White (non-Hispanic) female] sustained critical neck and brain injuries allegedly from impacting her deploying driver air bag, resulting in her death. This contractor inspected the scene and case vehicle on December 1, 1999. This contractor interviewed the front right passenger in the case vehicle on December 3, 1999. This report is based on the Police Crash Report, interviews with the investigating officers and the case vehicle's front right passenger, scene and vehicle inspections, occupant kinematic principles, occupant medical records, and this contractor's evaluation of the evidence.

## SUMMARY

The case vehicle was traveling north in the northbound lane of a two-lane, undivided, city street and was approaching a four-leg, partially controlled intersection, intending to continue traveling north (i.e., there was one lane in both directions with parking along the east side only). A noncontact vehicle had been traveling west in the westbound lane of the intersecting, two-lane, undivided, city street and yielded (i.e., slowed down or came to a stop) at the intersection. The noncontact vehicle slowly pulled out into the intersection, intending to continue in its westward path of travel. Because of parked vehicles along the east side of the north-south roadway, the visibility for both the case vehicle and the noncontact vehicle was obstructed. The case vehicle's driver overreacted and swerved sharply to the left and braked, attempting to avoid the crash. The crash occurred off the northwest corner of the intersection of the two roadways (see **CRASH DIAGRAM** below).

The right front tire of the case vehicle impacted the barrier curb [11.4 centimeters high (4.5 inches)], causing the case vehicle's driver (only) supplemental restraint (air bag) to deploy. The case vehicle continued in a west-northwesterly direction, and its front left bumper corner impacted a fire hydrant. The narrow end engagement with the fire hydrant traveled down the case vehicle's left side and snagged on the left front wheel, causing the case vehicle to rotate approximately 100 degrees counterclockwise. The case vehicle came to rest on the sidewalk, off the northwest corner of the intersection, heading in a southwesterly direction.

The 1990 Geo Storm was a front wheel drive, two-door hatchback (VIN: J81RF236XL7-----). The case vehicle was not equipped with anti-lock brakes. Based on the vehicle inspection, the CDCs for the case vehicle were determined to be: **12-FRWN-3 (0 degrees)** and **12-FLEE-5 (0 degrees)**. No reconstruction program was used on any of the case vehicle's impacts because the collision conditions (i.e., tire impact and sideswipe-type impact) were beyond the scope of the WinSMASH reconstruction program; however, this contractor's visually estimated Delta V for the curb impact is between 11 km.p.h. (7 m.p.h.) and 18 km.p.h. (11 m.p.h.). This contractor's visually estimated Delta V for the fire hydrant impact is between 16 km.p.h. (10 m.p.h.) and 22.5 km.p.h. (14 m.p.h.). The case vehicle was towed due to damage.

The case vehicle's initial contact with the curb involved the front right tire, causing the rim to be deformed and the wheelbase to be shortened. The case vehicle's initial contact with the fire hydrant was to the front left bumper corner. Direct damage began at the front left bumper corner and extended inward, a measured distance of 15 centimeters (5.9 inches), along the front bumper. The case vehicle's left EAD (i.e., Energy Absorption Device) on the front bumper was fully stroked a measured distance of 4.5 centimeters (1.8 inches). The crush to the case vehicle's bumper was approximately 4 centimeters (1.6 inches). The case vehicle's narrow corner engagement with the fire hydrant continued down the left side directly contacting and subsequently snagging and deforming (i.e., rim bent) the left front wheel. The length of direct contact extended a measured distance of 93 centimeters (36.6 inches) down the left side. The wheel base on the left side was shortened 17 centimeters (6.7 inches) while the right side was shortened 4 centimeters (1.6 inches). The case vehicle's front bumper, bumper fascia, grille, hood, left headlight and turn signal assemblies, and left fender were directly damaged and crushed rearward. The front right tire had been deflated during the curb impact, and the front left tire was deflated from impacting the fire hydrant.

The case vehicle's driver air bag was located in the steering wheel hub. An inspection of the air bag module's cover flaps and air bag revealed that the cover flaps opened at the designated tear points, and there was no evidence of damage during the deployment to the air bag or the cover flaps. The driver's air bag was designed with six tethers, each 5 centimeters (2.0 inches) wide, located at the 1, 3, 5, 7, 9, and 11 o'clock positions, respectively. The driver's air bag had two vent ports, approximately 4.5 centimeters (1.8 inches) in diameter, located at the 10 and 2 o'clock positions. The deployed driver's air bag was round with diameter 60 centimeters (23.6 inches). The examination of the air bag revealed there were a few scattered blood spots on the front surface near the center and 7 o'clock positions. In addition, there was a 27 x 10 centimeter (10.6 x 3.9 inch) area of contact evidence (i.e., blood with small hairs) readily apparent to the very bottom back surface of the driver's air bag, in the 5-8 o'clock area. It should be noted that because of the left steering maneuver, the top of the steering wheel was inverted at time of deployment. It should be noted that, according to the front right passenger, the case vehicle had been involved in a previous crash, but he had no knowledge about the crash or if the air bag deployed in that crash.

The inspection of the case vehicle's interior revealed that there was evidence of occupant contact to the windshield's glazing from both the driver and front right passenger. In addition, the case vehicle's driver loaded the steering wheel and contacted the sun visor and the knee bolster to the left of the steering column. The front right passenger contacted, in addition to the windshield's glazing, the right and center instrument panel and the rearview mirror. There was no readily visible evidence of intrusion to the case vehicle's interior.

Immediately prior to the crash the case vehicle's driver [170 centimeters and 64 kilograms (67 inches, 140 pounds)] was seated in an upright posture with her back against the seat back, her left foot on the floor, her right foot on the brake, and both hands on the steering wheel. Her seat track was located between its middle and rearmost positions, the seat back was upright, and the vehicle was not equipped with a tilt steering wheel.

The case vehicle's driver was not using her available, active, three-point, lap-and-shoulder, safety belt system. Furthermore, there was no evidence of belt pattern bruising and/or abrasions to the driver's body. The inspection of the driver's seat belt webbing, "D"-ring, and latch plate showed some evidence of loading; however as indicated above, the case vehicle had been involved in a crash previous to this owner/driver purchasing the case vehicle.

The case vehicle's driver steered sharply to the left and braked, attempting to avoid the crash. As a result of these attempted avoidance maneuvers and the nonuse of her available safety belts, the case vehicle driver most likely moved slightly forward and to her right just prior to impact. The case vehicle's impact with the curb enabled the case vehicle's driver to continue forward and slightly upward toward the 0 degree Direction of Principal Force as the case vehicle jumped the curb. The deploying air bag contacted the driver's chest, neck, and face, halting her forward movement and pushing her backwards toward her seat back as the case vehicle continued forward approximately 5 meters (16.4 feet). The case vehicle's impact and rapid deceleration with the fire hydrant reversed the driver's backward movement, causing the driver to move forward and upward as the case vehicle decelerated. The driver's chest loaded the steering wheel, collapsing the steering column's shear capsules, as the driver's air bag was deflating. When the case vehicle's left front wheel impacted the fire hydrant, the case vehicle reached maximum engagement and began its approximate 100 degrees counterclockwise rotation toward its final rest position. As the case vehicle reach maximum engagement, the driver continued forward, upward, and slightly leftward, contacting the upper portion of the windshield's glazing with her face and the sun visor with her scalp. As the vehicle continued to rotate counterclockwise, the driver rebounded backwards towards the interior surface of the driver's door and eventually into her seat back. Based on the available information, at final rest the driver was semi-conscious and laying back in her seat.

The driver was transported by ambulance to the hospital. She was initially thought to have sustained only a moderate head injury. She was treated and was in the process of dressing to be released when she had a sudden onset of neurologic deficit. Although the case vehicle's driver was subsequently hospitalized, she was declared brain dead two days post-crash. According to her medical records and the interview with her boyfriend (i.e., front right passenger), the injuries sustained by the case vehicle's driver included: a moderate nonanatomic brain injury, a cervical neck strain, an abrasion to her left chin, a contusion to her left upper arm, a laceration to the top of her head, and a laceration to her right internal carotid artery. This carotid artery laceration {dissection} caused a massive, traumatic, right hemispheric stroke and resulted in a deep right intracerebral hemorrhage, severe brain swelling/edema, and eventually a brainstem compression which resulted in her brain death. In this contractor's opinion, this occupant's primary neck and resultant brain injuries were most likely caused by her contact with the windshield's glazing and header. The clinically observed consequences (i.e., neurologic deficits) of the traumatic lesion to the driver's right internal carotid artery were not present until approximately 4½ hours post-crash.

The case vehicle's front right passenger [23-year-old, White (non-Hispanic) male; 185 centimeters and 100 kilograms (73 inches, 220 pounds)] was seated in an essentially upright posture with his back arched forward away from the seat back, his feet on the floor, and both arms



outstretched bracing for the crash. His seat track was located in its rearmost position, and the seat back slightly reclined.

The case vehicle's front right passenger was not wearing his available, active, three-point, lap-and-shoulder, safety belt system. The front right passenger was transported by ambulance to the hospital. He sustained minor injuries and was treated and released. The injuries sustained by the case vehicle's front right passenger included: a left hand laceration and a nasal fracture and contusion.

**CRASH CIRCUMSTANCES**

The case vehicle was traveling north in the northbound lane of a two-lane, undivided, city street and was approaching a four-leg, partially controlled intersection (**Figure 1**), intending to continue traveling north (i.e., there was one lane in both directions with parking along the east side only). A noncontact vehicle had been traveling west in the westbound lane of the intersecting, two-lane, undivided, city street and yielded (i.e., slowed down or came to a stop) at the intersection. The noncontact vehicle slowly pulled out into the intersection, intending to continue in its westward path of travel. Because of parked vehicles along the east side of the north-south roadway, the visibility for both the case vehicle and the noncontact vehicle was obstructed. The case vehicle's driver overreacted and swerved sharply to the left successfully evading the noncontact vehicle; however, the case vehicle was now rapidly traveling toward the northwest corner of the intersection and in response the driver braked, attempting to avoid the crash (**Figure 2**). The crash occurred off the northwest corner of the intersection of the two roadways (see **CRASH DIAGRAM** below).



**Figure 1:** Case vehicle's northward travel path into four-leg intersection; Note: fire hydrant on left and white car (i.e., approximate position of noncontact vehicle) approaching from east leg (case photo #01)



**Figure 2:** Northwest corner of intersection toward which case vehicle's driver steered sharply in response to encroaching noncontact vehicle (case photo #03)

The north/south city roadway was straight and level at the area of impact (**Figure 1**). The pavement was bituminous, and the width on the south leg of the intersection was 9.6 meters (31.5 feet), with legal parking on the east side only. The north leg of the intersection was 12.2 meters (40.0 feet) wide, with legal parking along both the east and west sides. The shoulders for the

north/south roadway were improved (i.e., concrete), and the roadway (i.e., both on the north and south legs) was bordered by 13 centimeter (5.1 inch) high concrete barrier curbs. No pavement markings were present. The estimated coefficient of friction for the roadway was 0.70%. The north and south legs were uncontrolled. The east and west legs had regulatory **YIELD** signs present (Manual on Uniform Traffic Control Devices, R1-2). The legal speed limit for the north/south roadway was 40 km.p.h. (25 m.p.h.). At the time of the crash the light condition was daylight, the atmospheric condition was clear, and the road pavement was dry. Traffic density was light, and the site of the crash was urban residential.

The right front tire of the case vehicle impacted the barrier curb [11.4 centimeters high (4.5 inches)–**Figure 3**], causing the case vehicle's driver (only) supplemental restraint (air bag) to deploy. The case vehicle continued in a west-northwesterly direction, and its front left bumper corner (**Figure 4**) impacted a fire hydrant (**Figure 3**). The narrow end engagement with the fire hydrant traveled down the case vehicle's left side and snagged on the left front wheel (**Figure 5**), causing the case vehicle to rotate approximately 100 degrees counterclockwise. The case vehicle came to rest on the sidewalk, off the northwest corner of the intersection, heading in a southwesterly direction.

### CASE VEHICLE

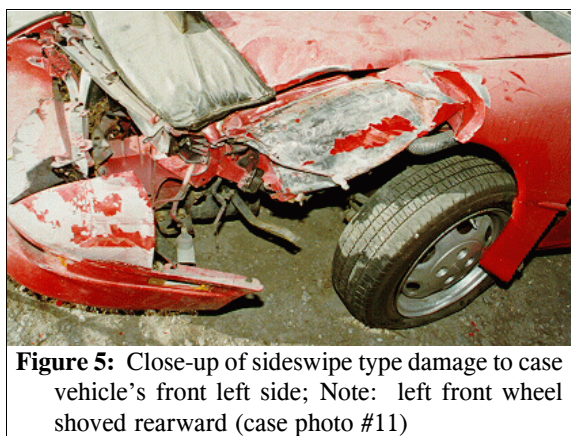
The 1990 Geo Storm was a front wheel drive, four-passenger, two-door hatchback (VIN: J81RF236XL7-----) equipped with a 1.6L, L-4 engine and an automatic transmission. Braking was achieved by a power-assisted, front disc and rear drum system. The case vehicle was not equipped with anti-lock brakes. The case vehicle's wheelbase was 245 centimeters (96.5 inches), and the odometer reading at inspection was 166,348 kilometers (103,364 miles).



**Figure 3:** Case vehicle traveled off northwest corner of four-leg intersection striking first the curb (near tape measure) with its right front wheel and then the fire hydrant (case photo #04)



**Figure 4:** Case vehicle's front left damage viewed from left of front showing deformation from fire hydrant impact; Note: head contacts to windshield (case photo #09)



**Figure 5:** Close-up of sideswipe type damage to case vehicle's front left side; Note: left front wheel shoved rearward (case photo #11)

Inspection of the vehicle's interior revealed adjustable front bucket seats with folding backs and integral head restraints; a non-adjustable back bench seat with separate backs and without head restraints; continuous loop, three-point, lap-and-shoulder, safety belt systems at the front and back positions. The front seat belt systems were not equipped with manually operated height adjusters for the "D"-rings. The vehicle was equipped with a knee bolster for the driver, and it showed evidence of contact. Automatic restraint was provided by a Supplemental Restraint System (SRS) that consisted of a frontal air bag for only the driver's seating position. The driver's air bag deployed as a result of the case vehicle's frontal impact with the curb.



**Figure 6:** Exterior view of driver's contact to case vehicle's upper left windshield (case photo #14)



**Figure 7:** Exterior view of front right passenger's contact to case vehicle's right center windshield (case photo #19)

The inspection of the case vehicle's interior revealed a spider web crack on the left side of the windshield's glazing (**Figure 6**) from the driver's head and a crack on the passenger side (**Figure 7**) from contact by the front right passenger (also **Figure 4** above). In addition, the case vehicle's driver loaded the steering wheel causing the energy absorbing steering column to show significant evidence of compression (**Figure 8**). The shear capsules had become completely separated with the separation measured at 3.5 centimeters (1.4 inches). The bottom half of the steering wheel rim had blood splatter over it. Furthermore, the driver contacted the sun visor (**Figure 9** below) and the knee bolster—to the left of the steering column, was scuffed and deformed (**Figure 10** below). The front right passenger contacted, in addition to the windshield's glazing, the right and center instrument panel (i.e., deformed and scuffed) and the rearview mirror. The roof near the left side rail showed what appeared to be a mucous smear. There was no readily visible evidence of intrusion to the case vehicle's interior.



**Figure 8:** Side view of case vehicle's steering wheel and column pushed forward into instrument panel from driver loading (case photo #29)



**Figure 9:** Close-up of case vehicle's front left header area showing driver's head strike to windshield, header, and sun visor; Note: hair hanging down (case photo #30)



**Figure 10:** Contact evidence on case vehicle's driver knee bolster, left of steering column (case photo #23)



**Figure 11:** Close-up view of case vehicle's right front wheel showing rim and tire damage from curb impact (case photo #18)



**Figure 12:** Case vehicle's minimally deformed front viewed along front reference line from right (case photo #20)

## CASE VEHICLE DAMAGE

The case vehicle's initial contact with the curb involved the front right tire, causing the rim to be deformed (**Figure 11**) and the wheelbase to be shortened. The case vehicle's initial contact with the fire hydrant was to the front left bumper corner (**Figure 12**). Direct damage began at the front left bumper corner (**Figure 4** above) and extended inward, a measured distance of 15 centimeters (5.9 inches), along the front bumper. The case vehicle's left EAD (i.e., Energy Absorption Device) on the front bumper was fully stroked a measured distance of 4.5 centimeters (1.8 inches). The crush to the case vehicle's bumper was approximately 4 centimeters (1.6 inches). The case vehicle's narrow corner engagement with the fire hydrant continued down the left side directly contacting and subsequently snagging and deforming (i.e., rim bent) the left front wheel (**Figure 13** below). The length of direct contact extended a measured distance of 93

centimeters (36.6 inches) down the left side. The wheel base on the left side was shortened 17 centimeters (6.7 inches) while the right side was shortened 4 centimeters (1.6 inches). The case vehicle's front bumper, bumper fascia, grille, hood, left headlight and turn signal assemblies, and left fender were directly damaged and crushed rearward. The front right tire had been deflated during the curb impact (**Figure 11** above), and the front left tire was deflated from impacting the fire hydrant (**Figure 13**).

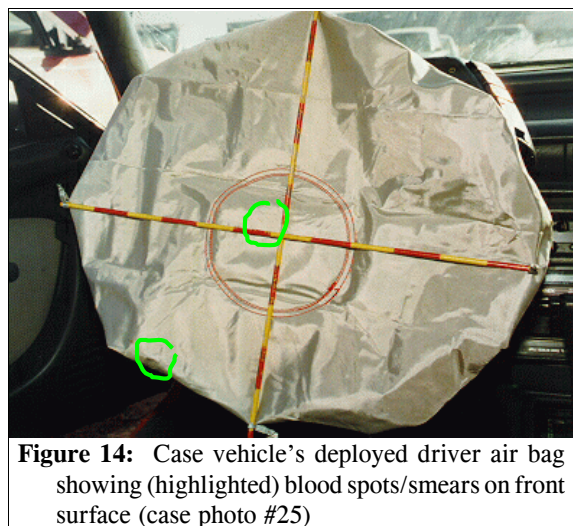


**Figure 13:** Close-up of case vehicle's left front wheel, viewed from rear of left, showing rim damage from fire hydrant impact (case photo #13)

Based on the vehicle inspection, the CDCs for the case vehicle were determined to be: **12-FRWN-3 (0 degrees)** and **12-FLEE-5 (0 degrees)**. No reconstruction program was used on any of the case vehicle's impacts because the collision conditions (i.e., tire impact and sideswipe-type impact) were beyond the scope of the WinSMASH reconstruction program; however, this contractor's visually estimated Delta V for the curb impact is between 11 km.p.h. (7 m.p.h.) and 18 km.p.h. (11 m.p.h.). This contractor's visually estimated Delta V for the fire hydrant impact is between 16 km.p.h. (10 m.p.h.) and 22.5 km.p.h. (14 m.p.h.). The case vehicle was towed due to damage.

#### AUTOMATIC RESTRAINT SYSTEM

The case vehicle was equipped with a Supplemental Restraint System (SRS) that consisted of a frontal air bag at the driver (only) position. The driver's air bag deployed as a result of the right front tire impact with the curb. The case vehicle's driver air bag was located in the steering wheel hub. An inspection of the air bag module's cover flaps and air bag revealed that the cover flaps opened at the designated tear points, and there was no evidence of damage during the deployment to the air bag or the cover flaps. The driver's air bag was designed with six tethers, each 5 centimeters (2.0 inches) wide, located at the 1, 3, 5, 7, 9, and 11 o'clock positions, respectively. The driver's air bag had two vent ports, approximately 4.5 centimeters (1.8 inches) in diameter, located at the 10 and 2 o'clock positions. The deployed driver's air bag was round with diameter 60 centimeters (23.6 inches). The examination of the air bag revealed there were a few scattered blood spots on the front surface near the center and 7 o'clock positions (**Figure 14**). In addition, there was a 27 x 10 centimeter (10.6 x 3.9 inch) area of contact evidence (i.e., blood with small, very short, dark



**Figure 14:** Case vehicle's deployed driver air bag showing (highlighted) blood spots/smears on front surface (case photo #25)

hairs) readily apparent to the very bottom back surface of the driver's air bag, in the 5-8 o'clock area (**Figure 15**). Furthermore there were two blood spots on the backside around the 3 o'clock area. It should be noted that because of the left steering maneuver, the top of the steering wheel was inverted at time of deployment. It should also be noted that the case vehicle had been involved in a previous crash, but it is unknown if the air bag deployed in that crash.



**Figure 15:** Case vehicle's deployed driver air bag showing hair and blood spray from driver towards bottom of air bag; Note: steering wheel inverted at time of deployment (case photo #26)

### **CASE VEHICLE DRIVER KINEMATICS**

Immediately prior to the crash the case vehicle's driver [21-year-old White (non-Hispanic) female; 170 centimeters and 64 kilograms (67 inches, 140 pounds)] was seated in an upright posture with her back against the seat back, her left foot on the floor, her right foot on the brake, and both hands on the steering wheel. Her seat track was located between its middle and rearmost positions, the seat back was upright, and the vehicle was not equipped with a tilt steering wheel.

The case vehicle's driver was not using her available, active, three-point, lap-and-shoulder, safety belt system. Furthermore, there was no evidence of belt pattern bruising and/or abrasions to the driver's body. The inspection of the driver's seat belt webbing, "D"-ring, and latch plate showed some evidence of loading; however as indicated above, the case vehicle had been involved in a crash previous to this owner/driver purchasing the case vehicle.

The case vehicle's driver steered sharply to the left and braked, attempting to avoid the crash. As a result of these attempted avoidance maneuvers and the nonuse of her available safety belts, the case vehicle driver most likely moved slightly forward and to her right just prior to impact. The case vehicle's impact with the curb enabled the case vehicle's driver to continue forward and slightly upward toward the 0 degree Direction of Principal Force as the case vehicle jumped the curb. The deploying air bag contacted the driver's chest, neck, and face, halting her forward movement and pushing her backwards toward her seat back as the case vehicle continued forward approximately 5 meters (16.4 feet). The case vehicle's impact and rapid deceleration with the fire hydrant reversed the driver's backward movement, causing the driver to move forward and upward as the case vehicle decelerated. The driver's chest loaded the steering wheel (**Figure 8** above), collapsing the steering column's shear capsules, as the driver's air bag was deflating. When the case vehicle's left front wheel impacted the fire hydrant, the case vehicle reached maximum engagement and began its approximate 100 degrees counterclockwise rotation toward its final rest position. As the case vehicle reached maximum engagement, the driver continued forward, upward, and slightly leftward, contacting the upper portion of the windshield's glazing with her face and the sun visor with her scalp (**Figures 6 and 9** above). As the vehicle continued to rotate counterclockwise, the driver rebounded backwards towards the interior surface of the driver's door and eventually into her seat back. Based on the available information, at final rest the driver was semi-conscious and laying back in her seat.

The driver was transported by ambulance to the hospital. She was initially thought to have sustained only a moderate head injury. She was treated and was in the process of dressing to be released when she had a sudden onset of neurologic deficit; see material on **VASCULAR INJURIES** below. Although the case vehicle’s driver was subsequently hospitalized, she was declared brain dead two days post-crash. According to her medical records and the interview with her boyfriend (i.e., front right passenger), the injuries sustained by the case vehicle’s driver included: a moderate nonanatomic brain injury, a cervical neck strain, an abrasion to her left chin, a contusion to her left upper arm, a laceration to the top of her head, and a laceration to her right internal carotid artery. This carotid artery laceration {dissection} caused a massive, traumatic, right hemispheric stroke and resulted in a deep right intracerebral hemorrhage, severe brain swelling/edema, and eventually a brainstem compression which resulted in her brain death; see **SELECTED ANATOMICAL DIAGRAMS and MEDICAL TERMS\*** at the end of this report. In this contractor’s opinion, this occupant’s primary neck and resultant brain injuries were most likely caused by her contact with the windshield’s glazing and header. The clinically observed consequences (i.e., neurologic deficits) of the traumatic lesion to the driver’s right internal carotid artery were not present until approximately 4½ hours post-crash.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1	Laceration {dissection*} right internal carotid artery near its origin with neurologic deficit <sup>1</sup> and thrombosis, complete occlusion, infarction, and ischemic stroke that involved the complete internal carotid artery distribution system (i.e., in right cerebral hemisphere of brain) <b>and</b> resulted in: (2-4)	320214.5 critical	Front left windshield’s glazing, header, and sun visor <sup>2</sup>	Probable	Hospitalization records
2	Compression of the brain stem, specifically right transtentorial (uncal) herniation	140202.5 critical	Front left windshield’s glazing, header, and sun visor	Probable	Hospitalization records

<sup>1</sup> This occupant subsequently (approximately 4 hours and 25 minutes post-crash) had a stroke resulting in an abrupt left hemiparesis, a right gaze (i.e., deviation of both eyes to the same side), unequal pupils, and possibly a visual field deficit (i.e., blurred vision). These neurologic deficits resulted from a traumatic injury to her neck rather than her brain.

<sup>2</sup> The deploying driver’s air bag was considered as the injury source for this lesion; however, in this contractor’s opinion, this occupant’s primary neck and resultant brain injuries were most likely caused by her contact with the windshield’s header and glazing. As the materials in the Vascular Injuries section below indicate, this lesion is associated with cervical hyperextension and, although, this occupant may have sustained some degree of hyperextension as a result of her interaction with the deploying air bag, it is almost certain that cervical hyperextension resulted when the top of this occupant’s head struck the windshield’s header and/or sun visor. Furthermore, when the case vehicle reached maximum engagement and began to rotate counterclockwise, a strong probability exists that the driver’s cervical region sustained rotation forces as well. Therefore, with near certain hyperextension, and probably cervical rotation, resulting from the windshield area contact, this contractor’s conclusion is that the most likely injury source is the windshield’s header and glazing.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
3	Hemorrhage, intracerebral, deep within right hemisphere centered in region of right basal ganglia and right caudate nucleus and near the area of the right middle cerebral artery; size not further specified	140638.4 severe	Front left windshield's glazing, header, and sun visor	Probable	Hospitalization records
4	Swelling/edema of brain with midline shift, right to left, of ventricular system and increased effacement of sulci and obliteration of basilar cisterns; right lateral ventricle was essentially completely effaced	140666.5 critical	Front left windshield's glazing, header, and sun visor	Probable	Hospitalization records
5	Nonanatomic brain injury with loss of consciousness of short, unknown time and amnesia for event without neurologic deficit <sup>1</sup>	160410.2 moderate	Front left windshield's glazing, header, and sun visor	Possible	Emergency room records
6	Strain, cervical, soft tissues of neck	640278.1 minor	Front left windshield's glazing, header, and sun visor <sup>2</sup>	Probable	Emergency room records
7	Abrasion, small, left chin	290202.1 minor	Air bag, driver's	Possible	Emergency room records
8	Contusion left lateral distal arm above supracondylar region	790402.1 minor	Side interior door surface, driver's	Probable	Emergency room records
9	Laceration {cut} on top left side of head	190600.1 minor	Front left windshield's header	Certain	Interviewee (other occupant)

#### CASE VEHICLE FRONT RIGHT PASSENGER KINEMATICS

The case vehicle's front right passenger [23-year-old, White (non-Hispanic) male; 185 centimeters and 100 kilograms (73 inches, 220 pounds)] was seated in an essentially upright posture with his back arched forward away from the seat back, his feet on the floor, and both arms outstretched bracing for the crash. His seat track was located in its rearmost position, and the seat back slightly reclined.

The case vehicle's front right passenger was not wearing his available, active, three-point, lap-and-shoulder, safety belt system. Furthermore, there was no evidence of belt pattern bruising



and/or abrasions to the front right passenger's body; however, as indicated above, the case vehicle had been involved in a previous crash.

The case vehicle's driver steered sharply to the left and braked, attempting to avoid the crash. As a result of these attempted avoidance maneuvers and the nonuse of his available safety belts, the case vehicle's front right passenger most likely moved slightly forward and to his right just prior to impact. The case vehicle's impact with the curb enabled the case vehicle's front right passenger to continue forward and slightly upward toward the 0 degree Direction of Principal Force as the case vehicle jumped the curb. The passenger's bracing action momentarily prevented him from striking the right instrument panel or windshield. The case vehicle's impact and rapid deceleration with the fire hydrant caused the front right passenger to move forward off his seat cushion and slightly upward as the case vehicle decelerated. When the case vehicle's left front wheel impacted the fire hydrant, the case vehicle reached maximum engagement and began its approximate 100 degrees counterclockwise rotation toward its final rest position. As the case vehicle reach maximum engagement, the front right passenger continued forward, upward, and slightly leftward, contacting the center instrument panel (**Figure 16**) with his face, the windshield's glazing with his left hand (**Figure 7** above), and the lower portion of the right instrument panel with his left leg (**Figure 17**). As the vehicle continued to rotate counterclockwise, his left hand struck the rear view mirror knocking it off the windshield, and the front right passenger rebounded backwards into his seat back. At final rest the front right passenger was conscious, in his seat, and reached over to turn off the case vehicle's ignition, since the engine was racing.



**Figure 16:** Contact evidence on case vehicle's center instrument panel from front right passenger (case photo #35)



**Figure 17:** Contact evidence to case vehicle's lower right instrument panel from front right passenger (case photo #34)

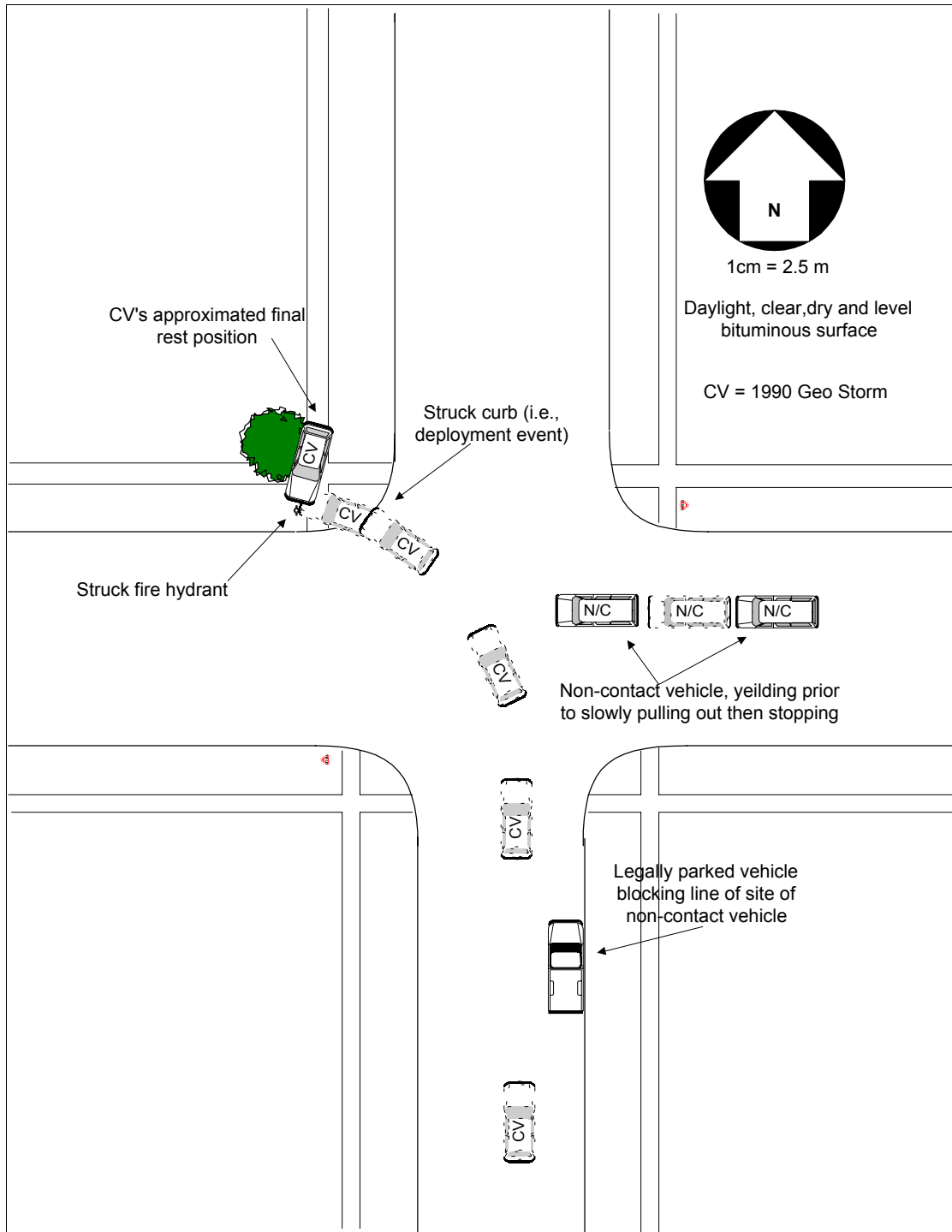
### **CASE VEHICLE FRONT RIGHT PASSENGER INJURIES**

The front right passenger was transported by ambulance to the hospital. He sustained minor injuries and was treated and released. The injuries sustained by the case vehicle's front right passenger included: a left hand laceration and a nasal fracture and contusion.

*Case Vehicle Front Right Passenger Injuries (Continued)*

IN99-091

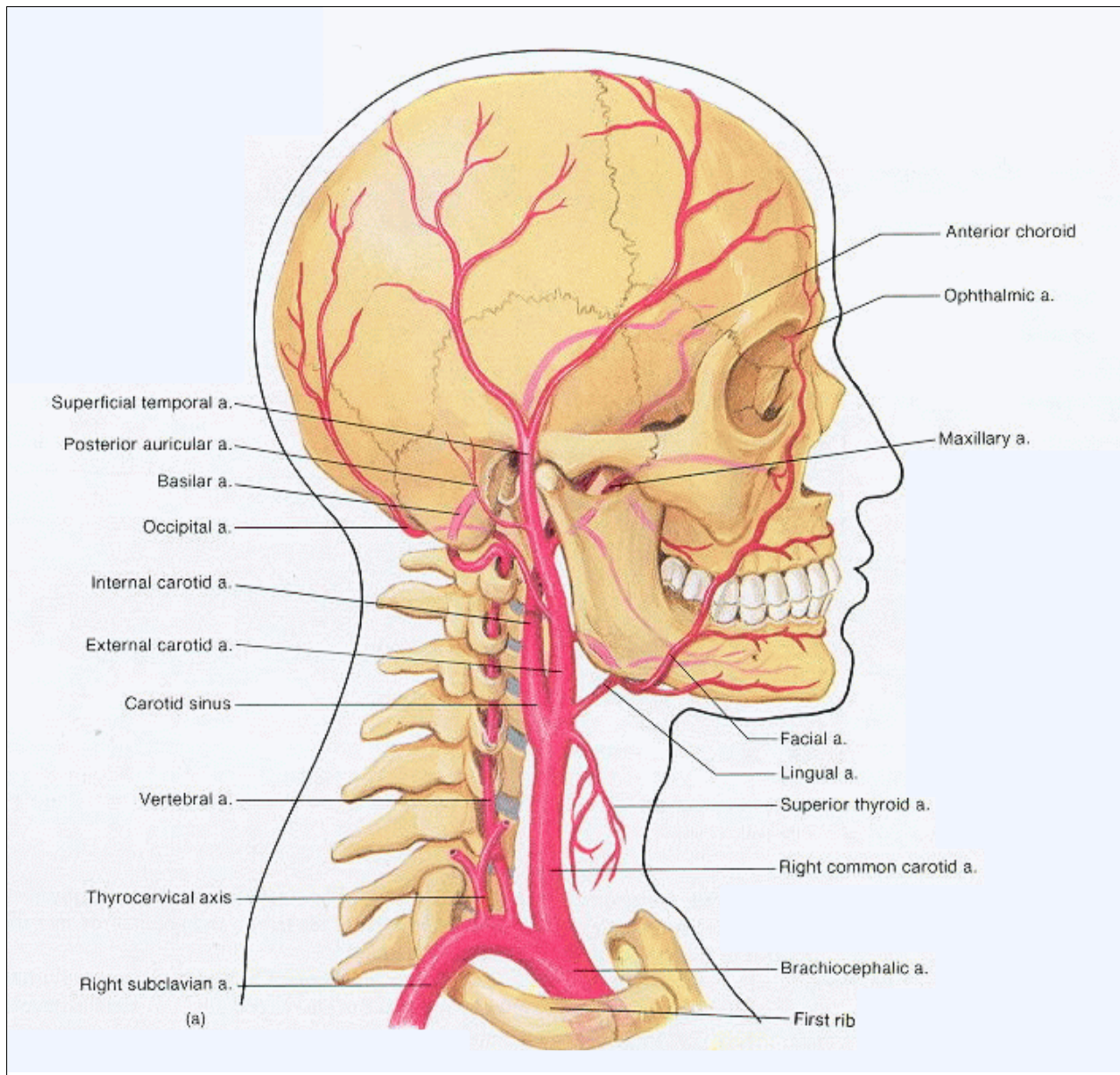
Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1	Fracture, minimal, nasal bone	251002.1 minor	Center instrument panel and below	Probable	Medical Clinic
2	Contusion {bruise} to tip of nose	290402.1 minor	Center instrument panel and below	Probable	Medical Clinic
3	Laceration {scratch} left knuckle	790602.1 minor	Front center windshield's glazing	Probable	Interviewee (same person)



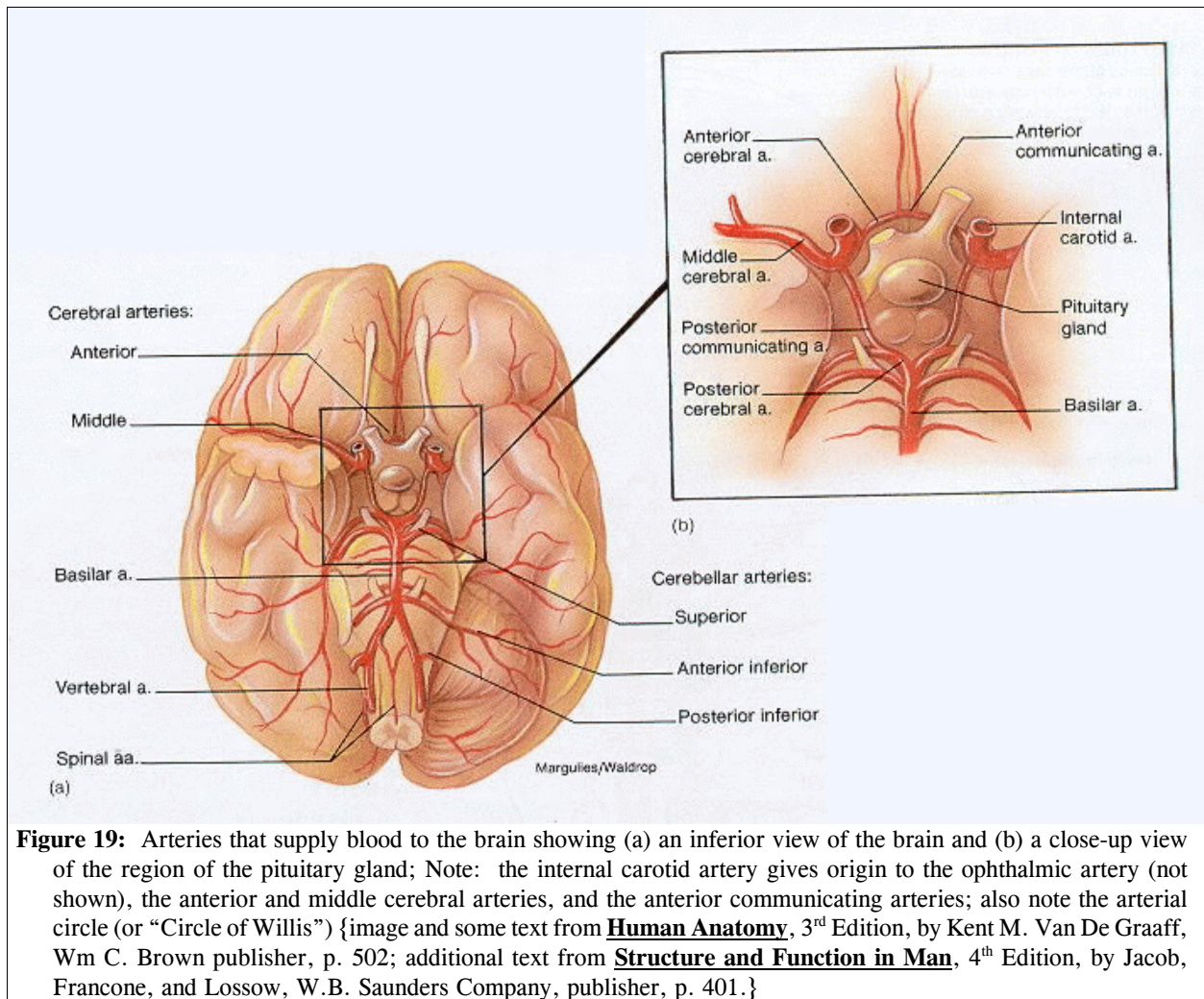
The following material is taken from the book: THE MANAGEMENT OF TRAUMA, 4<sup>th</sup> Edition, by Zuidema, Rutherford, and Ballinger, W.B. Saunders Co., Philadelphia, 1985; Chapter Eleven: The Management of Neck Injuries, by Balkany, Rutherford, Narrod, and Jafek, *Vascular Injuries*, page 371.

Equally treacherous are blunt injuries resulting in internal carotid occlusion. As documented ..., **neurological deficit is characteristically delayed in onset and rarely follows a direct blow to the neck but rather is associated with hyper extension or sharp rotation of the neck.** Hematoma in the side of the neck, Horner's syndrome, a transient ischemia attack, lucid interval, and limb paresis in an alert individual should arouse suspicion of the likelihood of this lesion and prompt arteriography.

In general, injuries to the internal carotid artery commonly present with a neurological deficit and are difficult to repair, injuries to the vertebral artery rarely cause a neurological deficit but are difficult to repair, and injuries to the common carotid and innominate arteries rarely produce neurological deficits and are easily repaired. Injuries to the subclavian arteries at the base of the neck almost never cause neurological sequelae and are easily repaired once the challenges of exposure and hemostasis have been overcome.



**Figure 18:** Arteries of the neck and head showing major branches of the right common carotid and right subclavian arteries; Note: the right internal carotid artery arises from the right common carotid artery and bifurcates at the level of the thyroid cartilage, enters the carotid canal in the skull, passes along the anterior border of the tympanic cavity, and turns medially to pierce the dural lining on the side of the sphenoid bone {image and some text from Human Anatomy, 3<sup>rd</sup> Edition, by Kent M. Van De Graaff, Wm C. Brown publisher, p. 501; additional text from Structure and Function in Man, 4<sup>th</sup> Edition, by Jacob, Francone, and Lossow, W.B. Saunders Company publisher, p. 401.}



**Figure 19:** Arteries that supply blood to the brain showing (a) an inferior view of the brain and (b) a close-up view of the region of the pituitary gland; Note: the internal carotid artery gives origin to the ophthalmic artery (not shown), the anterior and middle cerebral arteries, and the anterior communicating arteries; also note the arterial circle (or “Circle of Willis”) {image and some text from Human Anatomy, 3<sup>rd</sup> Edition, by Kent M. Van De Graaff, Wm C. Brown publisher, p. 502; additional text from Structure and Function in Man, 4<sup>th</sup> Edition, by Jacob, Francone, and Lossow, W.B. Saunders Company, publisher, p. 401.}

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

**cistern (sis'tern):** a closed space serving as a reservoir for fluid; see also *cisterna*.

**basal c.:** cisterna interpeduncularis.

**interpeduncular c.:** cisterna interpeduncularis.

**cisterna (sis-ter'na) pl. cister'nae:** a cistern -- a closed space serving as a reservoir for lymph or other body fluid, especially one of the enlarged subarachnoid spaces containing cerebrospinal fluid.

**c. basa'lis:** c. interpeduncularis.

**c. interpeduncula'ris:** interpeduncular cistern -- a dilatation of the subarachnoid space between the cerebral peduncles; called also *basal cistern*.

**dissect (di-sekt'): to cut apart, or separate; especially, the exposure of structures of a cadaver for anatomical study or to other cutting of tissues of the body.**

**dissection (di-sek'shen):** 1. the act of dissecting. 2. a part or whole of an organism prepared by dissecting.

**aortic d.:** one resulting from hemorrhage that causes longitudinal splitting of the arterial wall, producing a tear in the intima and establishing communication with the lumen; it usually affects the thoracic aorta but may also affect the abdominal aorta. Called also *dissecting aneurysm*.

**blunt d.:** dissection accomplished by separating tissues along natural cleavage lines, without cutting.

**embolism (em'ba-liz-am):** the sudden blocking of an artery by a clot or foreign material which has been brought to its site of lodgment by the blood current.

**embolus (em'bo-las) pl. emb'oli:** a mass of clotted blood or other formed elements (bubbles of air, calcium fragments, etc.) brought by the blood from another vessel and forced into a smaller one, thus obstructing the circulation.

**herniation (her'ne-a'shen):** the abnormal protrusion of an organ or other body structure through a defect or natural opening in a covering, membrane, muscle, or bone.

**tentorial h.:** downward displacement of the medially-placed cerebral structures through the tentorial notch, caused by a supratentorial mass. Pressure is exerted on underlying structures, including the brain stem. Called also *transtentorial h.*, and *uncal h.*

**transtentorial h.:** tentorial h.

**uncal h.:** tentorial h.

**infarct (in'fahrkt):** an area of coagulation necrosis in a tissue due to local ischemia resulting from obstruction of circulation to the area, most commonly by a thrombus or embolus.

**infarction (in-fahrk'shen):** 1. the formation of an infarct. 2. an infarct.

**ischemia (is-ke'me-a):** deficiency of blood in a part, usually due to functional constriction or actual obstruction of a blood vessel

**ischemic (is-kem'ik):** pertaining to, or affected with, ischemia.

**occlusion (o-kloo'zhen):** 1. the act of closure or state of being closed; an obstruction or a closing off.

**sulcus (sul'kas) pl. sul'ci (sul'si):** a groove, trench, or furrow; a general term for such a depression, especially one of those on the surface of the brain, separating the gyri. Compare *fissure*.

**thrombosis (throm-bo'sis):** the formation, development, or presence of a thrombus.

**thrombus (throm'bas):** an aggregation of blood factors, primarily platelets and fibrin with entrapment of cellular elements, frequently causing vascular obstruction at the point of its formation. Some authorities thus differentiate thrombus formation from simple coagulation or clot formation. Compare *embolism*.

According to the RANDOM HOUSE WEBSTER'S UNABRIDGED DICTIONARY, these terms are defined as follows:

**effaced (i f s'): 1. to wipe out; do away with; expunge: to efface one's unhappy memories. 2. to rub out, erase, or obliterate (outlines, traces, inscriptions, etc.)**

**stroke (strok): cerebrovascular accident. Pathology:** a blockage or hemorrhage of a blood vessel leading to the brain, causing inadequate oxygen supply and, depending on the extent and location of the abnormality, such symptoms as weakness, paralysis of parts of the body, speech difficulties, and, if severe, loss of consciousness or death.