TRANSPORTATION SCIENCES
Crash Data Research Center

Veridian Engineering
Buffalo, New York 14225

VERIDIAN REMOTE AIR BAG RELATED ADULT DRIVER FATALITY INVESTIGATION
VERIDIAN CASE NO. CA98-064
VEHICLE: 1997 TOYOTA CAMRY
LOCATION: PENNSYLVANIA
CRASH DATE: AUGUST 1997

Contract No.
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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 are 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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15. *Supplementary Notes* Remote investigation of a moderate severity frontal crash that resulted in deployment of the driver air bag system in a 1997 Toyota Camry and the death of the 53 year old female driver and her 86 year old female front right passenger.			
16. *Abstract* This remote investigation focused on the injuries, injury mechanisms, and cause of death of the 53 year old female driver and the 86 year old front right passenger of a 1997 Toyota Camry. The driver of the Camry allowed the vehicle to drift onto the right shoulder as she attempted to negotiate a left curve. The driver subsequently applied a counterclockwise steering input in a attempt to regain directional control of the vehicle. The Toyota yawed in a CCW direction across the travel lanes and impacted a median guardrail with the full frontal area. The impact resulted in deployment of the frontal driver and right passenger air bag system. The unrestrained driver was out-of-position forward against the driver air bag module at the time of deployment. Her forward position restricted the opening of the air bag module cover flaps. The air bag membrane partially deployed through the flaps and fully deployed between the module cover and the steering assembly. Consequently, the driver was impacted by the module cover and the expanding air bag membrane which resulted in bilateral rib fractures with pulmonary contusions, aortic laceration, fractured mandible, a basilar skull fracture, a brain stem laceration, and transections of the carotid arteries. She expired immediately following the crash within the vehicle. The unrestrained front right passenger was displaced forward and right by the pre-crash trajectory of the Toyota. She sustained multiple injuries of the head, face, neck, and chest that resulted from unknown sources. It was possible that her injuries may have been air bag related, however, due to the lack of available photographic interior documentation, her injury sources could not be confirmed for this remote level investigation. The front right passenger was hospitalized for 13 days prior to succumbing to her injuries.			
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BACKGROUND

This remote investigation focused on the injuries, injury mechanisms, and cause of death of the 53 year old female driver and the 86 year old front right passenger of a 1997 Toyota Camry. The driver of the Camry allowed the vehicle to drift onto the right shoulder as she attempted to negotiate a left curve. The driver subsequently applied a counterclockwise steering input in a attempt to regain directional control of the vehicle. The Toyota yawed in a CCW direction across the travel lanes and impacted a median guardrail with the full frontal area **(Figure 1)**. The impact resulted in deployment of the frontal driver and right passenger air bag system. The unrestrained driver was out-of-position forward against the driver air bag module at the time of deployment. Her forward position restricted the opening of the air bag module cover flaps. The air bag membrane partially deployed through the flaps and fully deployed between the module cover and the steering assembly. Consequently, the driver was impacted by the module cover and the expanding air bag membrane which resulted in bilateral rib fractures with pulmonary contusions, aortic laceration, fractured mandible, a basilar skull fracture, a brain stem laceration, and transections of the carotid arteries. She expired immediately following the crash within the vehicle. The unrestrained front right passenger was displaced forward and right by the pre-crash trajectory of the Toyota. She sustained multiple injuries of the head, face, neck, and chest that resulted from unknown sources. It was possible that her injuries may have been air bag related, however, due to the lack of available photographic interior documentation, her injury sources could not be confirmed for this remote level investigation. The front right passenger was hospitalized for 13 days prior to succumbing to her injuries.

Figure 1. Frontal damage to the Toyota Camry.

The August 1997 crash was identified in November 1998 by the Veridian SCI team during another on-site investigation to the Pennsylvania area. The notification was forwarded to NHTSA and a remote investigative effort was assigned in November, 1998. Due to the extended period of time between the crash and notification dates, the involved Toyota Camry was sold by the insurance company and was not available for inspection. Copies of the vehicle photographs were obtained from the insurance company for this remote level investigation. Medical records and the autopsy reports were obtained through the respective facilities. This data was reviewed, analyzed, and complied into this remote investigative effort.

SUMMARY

Crash Site

This crash occurred on a four-lane divided state route in Pennsylvania during daytime hours. The travel lanes were physically separated by a median guardrail system and bordered by shoulders on the outboard edges. The northbound travel lanes were curved to the left with respect to the Toyota's path of travel and level. The viewing conditions were police reported as clear with dry environmental surfaces. The posted speed limit was 89 km/h (55 mph).

Vehicle Data

The 1997 Toyota Camry LE was a four-door sedan that was equipped with frontal air bags for the driver and right passenger positions. The police report did not list the vehicle identification number or the mileage of the vehicle. The Camry was configured with cloth trimmed front bucket seats with adjustable head restraints and a console mounted automatic transmission selector lever. Although not worn by the driver and front right passenger, the front seat belt systems consisted of continuous loop webbings with sliding latch plates and emergency locking retractors.

Crash Sequence

Pre-Crash

The driver of the 1997 Toyota Camry was traveling in a northerly direction on the outboard lane of the state route at an unknown rate of speed. As she entered the left curve, the driver allowed the vehicle to drift to the right onto the right shoulder. The investigating police officer documented 39.6 m (130.0') of rotating tire prints on the right shoulder. The driver subsequently applied a CCW steering input in an attempt to regain directional control of the Camry. As a result of the steering input, the Toyota initiated a CCW yaw across the northbound travel lanes. The officer documented an additional 36.6 m (120.0') of yaw marks that terminated at impact with the median guardrail.

Crash

The frontal area of the area of the Toyota Camry impacted the median barrier guardrail. Initial contact probably involved the front left area, however, as the vehicle crushed and continued to rotate in a CCW direction, the full frontal width of the Camry engaged against the barrier **(Figure 2)**. The available photographs that were provided by the insurance carrier supported an impact force that was within the 1 o'clock sector. The front bumper and hood face were crushed rearward with lateral left displacement of the bumper fascia which supported the lateral component of the impact force. Although an accurate crush profile could not be determined, a maximum crush range was estimated in the 25-38 cm (10-15") range. As a result of the impact, the Toyota underwent a longitudinal velocity change that was estimated at 24-32 km/h (15-20 mph). The frontal air bag system deployed during the frontal impact sequence. The investigating officer noted on his report that two sections of guardrail were damaged by the crash. Due to the barrier deflection

Figure 2. Frontal damage to the Toyota Camry.

and the prolonged engagement with the guardrail system, the frontal air bag system probably deployed late in the crash event.

Post-Crash

The Toyota rotated CCW and came to rest against the median barrier, facing in a police reported southwesterly direction. At rest, the vehicle had rotated approximately 150 degrees CCW of its initial pre-crash trajectory.

The driver of the Toyota expired immediately following the crash and was found slumped between the front seat backs with her face resting on the right rear seat cushion. She was pronounced deceased at the scene of the crash and was removed from the vehicle by paramedics. The front right passenger came to rest in an unknown attitude within the vehicle. She was reported as conscious, but disoriented at the scene of the crash. The passenger was removed from the Toyota by paramedics and transported by helicopter to a regional trauma center where she was admitted for treatment. The front right passenger expired 13 days following the crash due to multiple head injuries. The Toyota sustained disabling damage and was towed from the scene of the crash.

Vehicle Damage

Exterior

The Toyota Camry sustained moderate frontal damage that was attributed to the impact sequence with the median barrier guardrail. The initial contact probably involved the front left area, however, as the Camry crushed and continued to rotate in a CCW direction, the full frontal area engaged against the barrier and crushed to maximum engagement. The direct contact damage extended across the full width of the bumper fascia. The bumper system was displaced rearward and laterally left by the 1 o'clock direction of force. The hood face was crushed rearward. Maximum crush at bumper level was estimated at 25-38 cm (10-15") and appeared to be evenly distributed across its full width. The grille and both headlamp assemblies were damaged and separated from their frontal mounting points. **Figure 3** is an overall view of the frontal crush and lateral displacement to support the 1 o'clock direction of force.

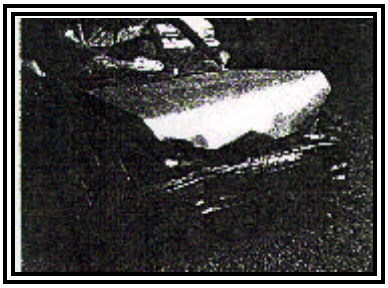

Figure 3. Guardrail damage to the Toyota Camry.

All four doors remained closed during the crash and appeared to be fully operational post-crash. The windshield was fractured by the deployment of the front right air bag and possible occupant contact as noted by the investigating officer. All side glazing and the backlight were intact with the exception of the left front door window. It was unknown if this window was down at the time of the crash or fractured by emergency personnel to gain access to the vehicle. The Collision Deformation Classification (CDC) for this guardrail event is 01-FDEW-2.

Interior

The interior damage consisted of deployment of the frontal air bag system and possible occupant contact. The driver was out-of-position forward at the time of deployment. Her forward position restricted the opening of the driver air bag module cover flaps. As the air bag membrane began to expand, the bag partially deployed from the flaps and fully expanded between the module cover and the steering wheel rim. This expansion resulted in separation of the module cover from the vehicle. The right aspect of the windshield was fractured by the deployment of the front right passenger air bag and probable module cover flap contact. Due to the limited vehicle photographs, additional interior damage could not be identified.

Frontal Air Bag System

The Toyota Camry was equipped with a first generation frontal air bag system for the driver and right passenger positions. The system consisted of a single point air bag sensor and control module that was located at the forward aspect of the center console, the steering wheel mounted driver module, the top mounted passenger module, and an instrument panel mounted indicator lamp. The "Holmatro Rescuer's Guide to Vehicle Safety Systems" listed the availability of front seat belt retractor pretensioners and seat mounted side impact air bags. It was unknown if this vehicle was equipped with these additional safety features. **Figure 4** is a view of the deployed air bag system.

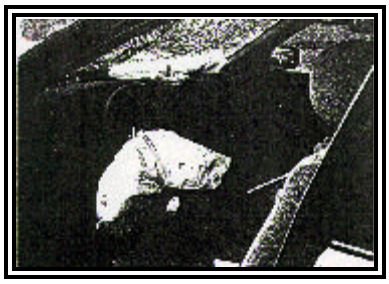

Figure 4. Deployed frontal air bag system.

The driver air bag membrane partially deployed through the H-configuration module cover flaps and fully expanded from between the module cover and the steering assembly **Figure 4**. This anomaly resulted from the forward positioned driver who restricted the normal deployment of the driver module. The driver bag was vented by two ports noted in **Figure 4**. Due to the remote nature of this investigation, it was unknown if further damage occurred to the driver air bag.

The front right passenger air bag was housed in the top of the right instrument panel and concealed by a single cover flap that was hinged at the forward aspect of the flap. The right windshield was severely fractured from probable contact by the air bag module cover flap and subsequent expansion/displacement of the air bag membrane by the unrestrained passenger. Again, damage to the front right air bag was not known due to the lack of adequate photographs.

Driver Demographics

Age/Sex:	53 year old female
Height:	167.6 cm (66.0")
Weight:	72.6 kg (160.0 lb)
Manual Restraint Usage:	None, 3-point lap and shoulder belt system was available
Usage Source:	Police report
Type of Medical Treatment:	None, expired at the scene of the crash

Driver Injuries

Injury	Severity (AIS 90/ Update 98	Injury Source
Partial ventral distraction of the pons from the brain stem with widespread focal subarachnoid hemorrhage of all aspects of the cerebral hemispheres	Maximum (140212.6,8)	Air bag and module cover flap (bag membrane appeared captured within the module cover)
Gaping basilar skull fracture extending from the from the petrous portions of both temporal bones across the floor of each middle fossa and the anterior sella turcica. The dura was lifted off the bone and focally torn in opposition to this fracture site.	Serious (150206.4,8)	Air bag and module cover flap (bag membrane appeared captured within the module cover)
Carotid arteries are torn within their syphons in the fractured base of the skull	Critical (121002.5,1; 121002.5,2)	Air bag and module cover flap (bag membrane appeared captured within the module cover)
Bilateral fractures of ribs 1-7 anteriorly and laterally with bilateral pulmonary contusions	Critical (450266.5,3)	Air bag and module cover flap (bag membrane appeared captured within the module cover)
Near complete circumferential dissection of the aorta of almost all layers of its walls sparing only the adventitia and a 1 cm laceration of the anterior mid-descending thoracic aorta with 1 liter of blood in the left chest cavity	Severe (420208.4,4)	Air bag and module cover flap (bag membrane appeared captured within the module cover)
Laceration of the pericardium	Moderate (441602.2,4)	Air bag and module cover flap (bag membrane appeared captured within the module cover)

Injury	Severity (AIS 90/ Update 98	Injury Source
Fracture of the right clavicle	Moderate (752200.2,1)	Air bag and module cover flap (bag membrane appeared captured within the module cover)
Complete traumatic separation of the left clavicle of its medial end from the manubrium sterni and underlying first rib	Moderate (751230.2,2)	Air bag and module cover flap (bag membrane appeared captured within the module cover)
12.7 cm gaping abraded laceration overlying the fracture of the jaw that involves the subcutaneous adipose tissue, platysma, and superficial aspects of the left sternocleidomastoid muscle	Moderate (290604.2,8; 290202.1,8)	Air bag and module cover flap (bag membrane appeared captured within the module cover)
Mandible is fractured and fragmented anteriorly on the left	Moderate (250610.2,2)	Air bag and module cover flap (bag membrane appeared captured within the module cover)
Right anterior upper incisor No. 8 was traumatically extracted	Minor (251406.1,8)	Air bag and module cover flap (bag membrane appeared captured within the module cover)
1.3 cm abrasion of the left earlobe	Minor (290202.1,2)	Air bag membrane
Abrasion of the left scalp behind the left ear	Minor (190202.1,2)	Air bag membrane
Scattered superficial contusions and abrasions over the central chest	Minor (490402.1,4; 490202.1,4)	Air bag and module cover flap (bag membrane appeared captured within the module cover)
10x5 cm irregular abrasions over the antero-medial aspect of the left upper arm	Minor (790202.1,2)	Air bag and module cover flap (bag membrane appeared captured within the module cover)

Injury	Severity (AIS 90/ Update 98	Injury Source
Superficial abrasions of the right upper and central abdomen	Minor (590202.1,7)	Air bag and module cover flap (bag membrane appeared captured within the module cover)
1.9cm flapped laceration (avulsion) of the right knee	Minor (890802.1,1)	Knee bolster (probable)

**Source of Injury Data - Autopsy report*

Driver Kinematics

The driver of the Toyota Camry was seated in a presumed upright posture with her seat adjusted to a mid track position. The investigating officer observed the driver at rest (deceased) within the vehicle slumped between the front seats, unrestrained. Based on the anomaly of the driver air bag membrane that was partially captured between the air bag module cover flap, and fully deployed from behind the module cover, the driver was out-of-position forward at the time of deployment. Her forward position probably resulted from a combination of the pre-crash CCW yawing of the vehicle and the presumed late deployment of the frontal air bag system following the guardrail impact sequence. Additionally, toxicology results noted in the police report identified sertraline, phentermine, and phenylpropanolamie in the driver's blood. The toxicologist stated to the investigating officer "that these compounds were in sufficient concentration to render the driver impaired in judgement, perception, alertness, coordination, and response time". It was unknown if these substances contributed to the causation of this crash.

The unrestrained driver initiated a forward trajectory in response to the frontal impact force. This trajectory, combined with her pre-crash motion, placed her upper torso against the driver air bag module. As the air bag deployed, the driver's forward position restricted the H-configuration cover flaps from opening. The air bag membrane began to deploy from the flaps, however, a small portion of the bag became captured between the flaps. The continued expansion of the bag separated the entire module cover from the steering assembly **(Figure 5)**. As a result, the driver sustained a punch-out loading force to the chest that resulted in bilateral 1-7 rib fractures with pulmonary contusions, a fracture of the right clavicle, complete separation of the left clavicle, lacerations of the aorta and pericardium, and multiple abrasions and contusion of the chest and upper abdomen. The continued expansion of the air bag membrane resulted in contact to the driver face. She sustained abrasions over the mandible, a fracture of the left mandible, a dislocated tooth, and a gaping laceration of the subcutaneous tissue overlying the fracture site.

Figure 5. Separated module cover and deployed driver air bag.

The continued expansion of the air bag membrane hyperextended the driver's neck as it wrapped around her face as evidenced by a left ear laceration and scalp abrasions. The hyperextension resulted in a gaping basilar skull fracture, a partial distraction of the pons from the brain stem, and tears of the carotid arteries.

The driver's left knee probably impacted the knee bolster which resulted in a 1.9 cm flapped laceration over the knee.

The air bag displaced the driver upward and rearward as she rebounded from the forward impact. She came to rest between the front seat backs with her head lying in a face-down attitude on the right rear seat cushion. The driver expired immediately from the brain stem injury. Her body was subsequently removed from the vehicle and transported to the Medical Examiner's Office where an autopsy was performed.

Front Right Passenger Demographics

Age/Sex:	86 year old female
Height:	172.7 cm (68.0")
Weight:	77 kg (103 lb), weight at time of death following 13 days of hospitalization
Manual Restraint Usage:	None, 3-point lap and shoulder belt system was available
Usage Source:	Police report
Mode of Transport From Scene:	Helicopter transport
Type of Medical Treatment:	Admitted for 13 days prior to succumbing to her injuries

Front Right Passenger Injuries

Injury	Severity (AIS 90/Update 98)	Injury Sources
* Multiple contusions of the left cerebrum - 5 cm. Left anterior temporal parenchymal hemorrhagic contusion and a 2 x 2 cm. lesion to the posterior left temporal lobe - Patchy areas of left frontal contusion	Critical (140618.5,2)	Unknown
* Cerebral edema with compression of the left lateral ventricle, and increasing mass effect including midline shift to the right	Severe (140664.4,2)	Unknown

Injury	Severity (AIS 90/Update 98)	Injury Sources
* Intraventricular hemorrhage involving the atrium and occipital horn of the right lateral ventricle	Severe (140678.4,1)	Unknown
* Small left subdural hematoma	Severe (140652.4,2)	Unknown
* Predominately left subarachnoid hemorrhage with extension of blood from the Sylvian cistern	Serious (140684.3,2)	Unknown
* Diffuse subarachnoid hemorrhage in the right hemisphere with blood in the interpeduncular cistern and along the tentorium	Serious (140684.3,1)	Unknown
* Left medial orbital wall blowout fracture	Serious (251204.3,2)	Unknown
# Closed fracture of nasal bone	Minor (251002.1,4)	Unknown
* Nasal bridge contusion	Minor (290402.1,4)	Unknown
* Epistaxis	Minor (251090.1,4)	Unknown
* Left temporal scalp severely contused with significant temporalis muscle injury	Minor (190402.1,2)	Unknown
# Contusion above left eyebrow	Minor (290402.1,7)	Unknown
# Left forehead abrasion	Minor (290202.1,7)	Unknown
# Ecchymosis left eye	Minor (297402.1,2)	Unknown
# Ecchymosis right eye	Minor (297402.1,1)	Unknown
* Abrasion left cheek	Minor (290202.1,2)	Unknown
* Deep, 10 cm transverse laceration below the chin, through the platysma	Minor (290602.1,8)	Unknown
* Closed fracture of left rib, NFS	Minor (450212.1,2)	Unknown
* Right ventricular heart contusion, NFS	Minor (441002.1,4)	Unknown

Injury	Severity (AIS 90/Update 98)	Injury Sources
* Contusion to the outside of the descending aortic wall	Not codeable under AIS	Unknown
# Contusions of the right, mid, and left chest	Minor (490202.1,0)	Unknown
* Mid shaft fracture of the left clavicle, closed	Moderate (752200.2,2)	Unknown
* Abrasion over posterior shoulder/scapula	Minor (790202.1,2)	Rebound contact into the right seat back
* Large hematoma left shoulder	Minor (790402.1,2)	Unknown
* Displaced mid-shaft fracture of the right humerus	Serious (752604.3,1)	Unknown
# Abrasions over the right anterolateral mid-humerus and right elbow	Minor (790202.1,1)	Unknown
# Ecchymosis over the right mid-humerus	Minor (790402.1,1)	Unknown
# Abrasion to top, posterior right shoulder	Minor (790202.1,1)	Unknown
# 2 small lacerations to the lateral top, posterior of the right shoulder	Minor (790602.1,1)	Unknown
* Left wrist fracture, NFS	Moderate (751800.2,2)	Unknown
+ Left wrist contusion	Minor (790402.1,2)	Unknown
* Hematoma of the left flank into subcutaneous tissues	Minor (590402.1,2)	Possible console mounted transmission shifter
* Closed fracture of the left sacroiliac	Serious (852800.3,6)	Induced fracture from knee loading into the right instrument panel/glove box door

Injury	Severity (AIS 90/Update 98)	Injury Sources
* Left femoral neck fracture, NFS	Serious (851812.3,2)	Induced fracture from knee loading into the right instrument panel/glove box door
# Abrasion over left anterior mid/distal thigh	Minor (890202.1,2)	Lower right instrument panel
# Abrasion over left anterior shin	Minor (890202.1,2)	Lower right instrument panel
* Open left ankle fracture - Grade II, comminuted bimalleolar fracture of the left fibula. There is an open, 8 cm laceration into the fracture site, at the left lower leg extending to the medial ankle.	Serious (851614.3,2)	Toe pan
* Dorsally dislocated tarsus of the left ankle	Minor (850299.1,2)	Toe pan
+ Right femoral neck fracture, NFS	Serious (851812.3,1)	Induced fracture from knee loading into the right instrument panel/glove box door
+ Large 15 cm, transverse laceration to the right knee, just distal to the patella	Minor (890602.1,1)	Right instrument panel/glove box door
* Open fracture of the right tibia and fibula, grade III - Non-displaced transverse fracture of the distal shaft tibia. A 30 cm. laceration of the right lower anterior extremity extends into the fracture site. - Non-displaced fracture of the right fibula	Serious (853422.3,1) Moderate (851605.2,1)	Toe pan

*Source of medical data - * Hospital discharge summary/hospital records*
 # Emergency room report
+ Medical Examiner's report

Front Right Passenger Kinematics

The front right 86 year old female passenger of the Toyota Camry was not restrained by the available 3-point lap and shoulder belt system. Her seat track was positioned to an estimated mid track position based on the available photograph of her seated position.

Due to the lack of detailed interior photographs/documentation that was available for this remote investigation **(Figure 6)**, an accurate reconstruction of the front right passenger's kinematics and injury sources could not be made with certainty. The deployment of the front right passenger air bag and the nature and location of the passenger's injuries may suggest that the deploying air bag could have been a potential source for the majority of her injuries during its initial expansion. The driver was also viewed as a possible source of injury resulting from occupant-to-occupant interaction, however, the driver did not sustain injury that was consistent with this interaction sequence. Therefore, the majority of her injuries and the injuries that contributed to her death were from unknown sources.

Figure 6. Sole image of the front right passenger air bag and occupant's seated position .

The driver and front right passenger of the Toyota Camry were both police reported as unrestrained. The driver was displaced out-of-position forward by the pre-crash trajectory of the vehicle and the frontal impact force. The front right passenger should have mirrored the trajectory of the driver provided that she was seated in a normal upright posture. Her pre-crash posture was unknown. The passenger was probably displaced out-of-position forward and to her right by the initial counterclockwise yaw of the vehicle and the frontal crash force. Although unconfirmed by recorded crash data, the frontal air bag system probably deployed late in the crash sequence.

The front right passenger sustained multiple injuries of the left face and head which suggest contact with a hard surfaced component. The right A-pillar was viewed as a potential injury source, however, for this to occur, the passenger's head would have to had been turn to the right, thus exposing her face to the right front door glazing. The provided images of the Toyota Camry showed that the right front door glazing was fully closed and not damaged.

The front right passenger's knees possibly loaded the lower right instrument panel and/or the glove box door which resulted in a 15 cm laceration over the right knee. The energy from these contacts were transmitted through the knees into the femurs which fractured the bilateral femoral heads and a closed fracture of the left sacroiliac. Her feet and ankles probably loaded against the toe pan which resulted in open fractures of the distal tibia and fibula, a dorsally dislocated tarsus of the left ankle, and an open left ankle fracture.

She was probably displaced rearward into the right seat back and B-pillar as evidenced by abrasions over the posterior aspects of the shoulders.

Medical Treatment

The front right passenger was observed in the vehicle post-crash unrestrained. She was conscious at the scene, however, she appeared disoriented. She was transported by helicopter to a regional trauma center where she was evaluated and intubated. Her Glascow Coma Score (GCS) was 10 following arrival, however, due to declining mental status, A CT was performed which revealed diffuse subarachnoid hemorrhage. She was transferred to the operating room for an emergency left temporal craniotomy and evaluation of intercerebral hematoma. Additional procedures were initiated on the day of admission to repair the multiple fractures. Her GCS declined to 6-7 and she was placed on a ventilator. She steadily declined and was extubated following a 13 day hospitalization. The passenger expired on the day of the extubation.