TRANSPORTATION SCIENCES
CRASH DATA RESEARCH CENTER

Veridian Engineering
Buffalo, New York 14225

ON-SITE FRONTAL AIR BAG NON-DEPLOYMENT/ DRIVER FATALITY INVESTIGATION

VERIDIAN CASE NO. CA02-001

VEHICLE: 2001 KIA RIO

LOCATION: MASSACHUSETTS

CRASH DATE: DECEMBER 2001

Contract No. DTNH22-01-C-17002

Prepared for:

U.S. Department of Transportation
National Highway Traffic Safety Administration
Washington, DC 20590

DISCLAIMER

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 of the involved vehicle(s) or their safety systems.

TECHNICAL REPORT STANDARD TITLE PAGE

1. *Report No.* CA02-001	2. *Government Accession No.*	3. *Recipient's Catalog No.*	
		4. Weights	
5. *Title and Subtitle* On-site Frontal Air Bag Non-Deployment/Driver Fatality Investigation Vehicle: 2001 Kia Rio Location: Massachusetts		6. *Report Date*: March 2002	
		7. *Performing Organization Code*	
8. *Author(s)* Crash Data Research Center		9. *Performing Organization Report No.*	
10. *Performing Organization Name and Address* Transportation Sciences Crash Data Research Center Veridian Engineering P.O. Box 400 Buffalo, New York 14225		11. *Work Unit No.* C00410.0000.0015	
		12. *Contract or Grant No.* DTNH22-01-C-17002	
13. *Sponsoring Agency Name and Address* U.S. Department of Transportation National Highway Traffic Safety Administration Washington, DC 20590		14. *Type of Report and Period Covered* Technical Report Crash Date: December 2001	
		15. *Sponsoring Agency Code*	

16. *Supplementary Notes*: On-site investigation of the non-deployment of the front air bags in a 2001 Kia Rio involved in a severe head-on crash.

17. *Abstract*

This on-site investigation focused on the non-deployment issues of the frontal air bag system in a 2001 Kia Rio, 4-door sedan. The Kia was involved in a severe head-on crash with a 2000 Ford F150 pick-up truck that resulted in the death of the Kia's 82 year old unrestrained female driver. The Kia was equipped with 3-point lap and shoulder belts with retractor pretensioners for the front seat occupants and redesigned frontal air bags. The pretensioners fired with the belts in the stowed position. The frontal air bags did not deploy as a result of the impact. The driver of the Kia suffered multiple thoracic and internal injuries resulting from direct contact to the windshield, steering wheel/column and knee bolster, and expired at the scene..

The investigating police officer notified the National Highway Traffic Safety Administration (NHTSA) of the crash on December 27, 2001. The NHTSA Crash Investigations Division subsequently notified the Special Crash Investigations team at Veridian Engineering of the crash on January 2, 2001 and assigned an on-site investigation. The subject vehicle was located in storage and a hold was placed by the investigating police officer pending the SCI investigation. The vehicle was inspected on January 8, 2002.

18. *Key Words* Air bag non-deployment Retractor pretensioner AIS 6 level injury Driver fatality		19. *Distribution Statement* General Public	
20. *Security Classif. (of this report)* Unclassified	21. *Security Classif. (of this page)* Unclassified	22. *No. of Pages* 11	23. *Price*

TABLE OF CONTENTS

ON-SITE FRONTAL AIR BAG NON-DEPLOYMENT/
DRIVER FATALITY INVESTIGATION
VERIDIAN CASE NO. CA02-001

VEHICLE: 2001 KIA RIO
LOCATION: MASSACHUSETTS
CRASH DATE: DECEMBER, 2001

BACKGROUND

This on-site investigation focused on the non-deployment issues of the frontal air bag system in a 2001 Kia Rio, 4-door sedan. The Kia was involved in a severe head-on crash with a 2000 Ford F150 pick-up truck that resulted in the death of the Kia's 82 year old unrestrained female driver. The Kia was equipped with 3-point lap and shoulder belts with retractor pretensioners for the front seat occupants and redesigned frontal air bags. The pretensioners fired with the belts in the stowed position. The frontal air bags did not deploy as a result of the impact. The driver of the Kia suffered multiple thoracic and internal injuries resulting from direct contact to the windshield, steering wheel/column and knee bolster, and expired at the scene.

The investigating office notified the National Highway Traffic Safety Administration (NHTSA) of the crash on December 27, 2001. The NHTSA Crash Investigations Division subsequently notified the Special Crash Investigations team at Veridian Engineering of the crash on January 2, 2001 and assigned an on-site investigation. The subject vehicle was located in storage and a hold was placed by the investigating police officer pending the SCI investigation. The vehicle was inspected on January 8, 2002.

SUMMARY

Crash Site

This two-vehicle crash occurred during the afternoon hours in December, 2001. At the time of the crash, it was daylight and the weather was not a factor. The asphalt road surface was dry. The crash occurred in the southbound lane of a two-lane north/south road in a commercial area of the city. Small businesses bordered both sides of the roadway. The crash occurred on a straight section of the road, relative to the Kia's northbound travel direction. The southbound Ford had just exited a left curve as it approached the point of impact. **Figure 1** is an on-scene police photo looking northward, depicting the vehicles at final rest. The posted speed limit was 64 km/h (40 mph).

Figure 1: Final rest position of the vehicles looking northward.

Pre-Crash

The 2001 Kia Rio was northbound driven by an 82 year old female with a height 165 cm (65 in) and a weight of 64 kg (140 lb). The driver was a right arm amputee due to cancer approximately 36 years ago (1965). Her son reported she was in good health and remained independent. The driver did complain to her family of sporadic chest pains approximately one week prior to the crash, however, she did not seek medical attention. Due to her amputation, her vehicle was equipped with a spinner knob mounted to the 8 o'clock sector of the steering wheel rim, **Figure 2**. The spinner knob was installed by the driver's son. The driver had become accustomed to, and was experienced, driving in this manner. The investigating officer indicated her driver's license was restricted to operating a vehicle in this manner. It should be noted, this knob did not interfere with the air bag module cover. Further, the driver nor her family sought to have the air bag disconnected. This has been confirmed through the Kia dealership and the NHTSA.

Figure 2: View of the spinner knob and deformed steering wheel rim.

The northbound Kia was followed by a trailing witness that estimated the vehicle's speed at approximately 56 km/h (35 mph). The witness recalled the driver was seated in an upright posture and allowed the vehicle to drift left of center directly into the path of the southbound 2000 Ford F150 pick-up truck. The Ford was driven by a 47 year old restrained male. The witness indicated the Kia driver remained upright until impact and that no brakes were applied.

Crash

The full frontal area of the Kia impacted the front of the Ford in a head-on impact configuration resulting in severe frontal crush to the Kia. The force of the impact reversed the Kia's northward momentum and caused the vehicle to rotate counterclockwise approximately 150 degrees, as it slid southward to rest. The Kia came to rest facing southwest straddling the centerline of the road 3.3 m (10.8 ft) south of impact. The delta V of the Kia Rio calculated by the Damage algorithm of the WINSMASH model was 59.0 km/h (36.7 mph). The Kia's seat belt pretensioners fired as a result of the impact, however, the air bag system did not deploy.

The impact deflected the southbound Ford approximately 30 degrees to the west. The Ford came to rest facing southwest along the west shoulder of the road 7.5 m (24.5 ft) south of the impact. The force of the impact caused the deployment of the frontal air bag system in the Ford. The Collision Deformation Classifications (CDC's) were 12-FDEW-3 and 12-FYEW-3 for the Kia and Ford, respectively.

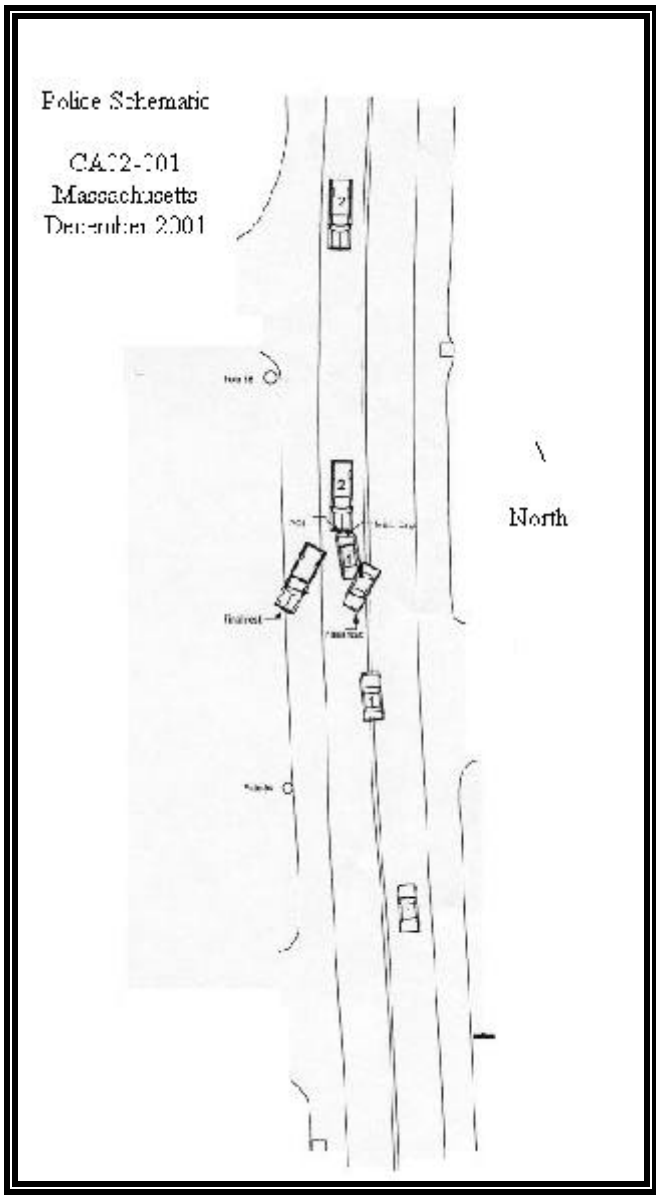

Figure 3: Police Crash Schematic

Post-Crash

The police and ambulance personnel responded to the scene. Initial observations of the police indicated the driver of the Kia was seated almost full forward. She was forward and entwined with the steering wheel. Her head had contacted the windshield. The on-scene responders moved the seat rearward and reclined the seat back as they attempted to render aid. First aid efforts proved unsuccessful due to the severity of the injuries and the driver was pronounced deceased at the scene. The driver of the Ford was transported to a local hospital. He reportedly sustained seat belt related contusions and a right lung contusion.

2001 KIA RIO

The 2001 Kia Rio was identified by the Vehicle Identification Number (VIN): KNADC123616 (production sequence deleted). The 4-door sedan was equipped with a 1.5 liter, I4 engine linked to a 4-speed automatic transmission. The vehicle was manufactured on 3/28/01 and was purchased new by the driver on July 20, 2001. The odometer read 8,357 km (5,193 miles).

Figure 4: Front view of the Kia.

Exterior Damage

Figures 4 through 6 are the front, left side and right front views of the Kia, respectively. The vehicle sustained severe frontal damage that extended across the entire 123 cm (48 in) undeformed frontal end width. The impact had displaced the bumper fascia, foam backer and bumper reinforcement bar from the vehicle. The displacement of these components exposed the upper and lower radiator supports and the vehicle's forward sub-frame. The longitudinal extent of crush along the upper radiator support was greater in magnitude than the crush along the lower support indicative of an underride. Crush profiles along both elevations were documented. The average residual crush profile across the frontal plane of the Kia was as follows: C1=58 cm (23 in), C2=63 cm (25 in), C3=58 cm (23 in), C4=58 cm (23 in), C5=51 cm (20 in), C6=30 cm (12 in). The delta V of the Kia Rio calculated by the Damage algorithm of the WINSMASH model was 59.0 km/h (36.7 mph). The longitudinal and lateral delta V components were -58.1 km/h (-36.1 mph) and -10.2 km/h (-6.4 mph), respectively. The PDOF was within the 12 o'clock sector estimated at 10 to15 degrees. The magnitude of crush was biased to the left side of the vehicle. The left wheelbase was foreshortened 12.7 cm (5.0 in). The right wheelbase was unchanged The left front corner of the was roof buckled.

Figure 5: Left side view of the Kia.

Figure 6: Right front view of the Kia.

2000 FORD F150 PICK-UP TRUCK

The Ford F150 XLT pick-up was identified by the Vehicle Identification Number (VIN): 1FTRX18LXYN (production sequence deleted). The 4-wheel drive, 4-door truck was configured with a super cab and had a 352.6 cm (138.8 in) wheelbase. The power train consisted of a 5.4 liter/V8 engine linked to a 4-speed automatic transmission. The date of manufacture was 02/00. The electronic odometer could not be read at the inspection.

Exterior Damage

Figures 7 and 8 are the front and left side views of the Ford, respectively. The front of the Ford sustained 106.0 cm (41.7 in) of direct contact damage that began 26.1 cm (10.3 in) right of center and extended to the left front bumper corner. The residual crush profile measured along the front bumper was as follows: C1=71 cm (28 in), C2=53 cm (21 in), C3=36 cm (14 in), C4=28 cm (11 in), C5=19 cm (7.5 in), C6=10 cm (4 in). The left wheelbase was foreshortened 31.2 cm (12.3 in). The driver's door was jammed shut by the force of the impact and forced open by the emergency responders. Contact between the forward aspect of the rear bed and back of the cab was noted. The delta V of the Ford calculated by the Damage algorithm of the WINSMASH model was 34.0 km/h (21.1 mph). The longitudinal and lateral delta V components were -33.5 km/h (-20.8 mph) and 5.9 km/h (3.7 mph), respectively.

Figure 8: Front view of the Ford.

Figure 7: Left side view of the Ford.

2001 KIA RIO INTERIOR DAMAGE

Figure 9 is an overall view of the Kia's forward interior. The vehicle's interior sustained moderate damage and intrusion consistent with the exterior forces of the crash. Four specific points of occupant contact were noted. The driver's head contacted the windshield directly forward of the steering assembly and her chest contacted and deformed the lower half of the steering wheel rim. The left knee contacted the left outboard aspect of the bolster panel and her right knee contacted the steering column assembly immediately right of the adjustment lever. (This contact is hidden by the lower steering wheel rim in Figure 9).

The driver's foot well intrusion was an estimated 15 to 20 cm (6 to 8 in). The lower aspect of the steering column intruded rearward into the driver's space causing the column to rotate to a more vertical orientation. There was no displacement of the steering column's shear capsules. The center instrument panel intrusion was approximately 6.4 cm (2.5 in). The glove box was displaced from its mounted position and was found in the back seat. The intrusion of the metal support bracket behind the glove box measured approximately 8.3 cm (3.3 in).

Figure 9: View of the front interior.

MANUAL RESTRAINT SYSTEM

The front seat belt systems in the Kia were 3-point lap and shoulder belts with a continuous loop webbing and a sliding latch plate. The inertia-activated emergency locking retractors were located in the base of the B-pillars. The retractors were equipped with pretensioners. Both front restraints were in the stowed position and were locked in place by the fired pretensioners. Both seat belt webbings were taut and could not be extended from their respective retractors..

SUPPLEMENTAL RESTRAINT SYSTEM

The Supplemental Restraint System in the Kia consisted of redesigned driver and front right passenger air bags. The air bags did not deploy as a result of the crash. The driver air bag was located in the center hub of the 4-spoke steering wheel rim. The front right passenger was a mid-mount design located in the right aspect of the instrument panel.

The design of the air bag system consisted of the driver air bag module and clock spring, the front right passenger air bag module, an instrument cluster indicator lamp, associated wiring, and an Air Bag Diagnostic Unit (ADU). The ADU consisted of a processor, memory, auxiliary power supply, and the crash and safing sensors. The ADU was located under the center electronic stack and is depicted in **Figure 10**. The processor performed a diagnostic test of the system upon each key-cycle and also initiated the deployment upon crash recognition. The seat belt pretensioners were incorporated in the SRS design and were also deployed by the ADU. Reportedly, the Kia had been taken back to the dealer three times for routine service. This routine service was not related to the air bag system. No fault codes were ever reported during those service requests.

Figure 10: View of the Air Bag Diagnostic Unit.

The ADU was manufactured by Hyundai Electronics and was identified by the following manufacture's nomenclature:

0 K32B 67 7F0
Part # G13019
Serial # B3EBAM3LAA0966

Technical representatives of Kia Motors inspected the vehicle 2 days following the SCI investigation in order to download any fault codes stored within the ADU. The process involved attaching a proprietary scan tool to the vehicle's J1962 Data Link Connector (DLC) located in the left aspect of the engine compartment and communicating with the ADU. Reportedly, the electrical wiring supplying power and continuity between the DLC and to the ADU had been compromised as a result of the collision damage. The technician was able to restore power remotely via jumper wires, however, communication between the scan tool and the ADU could not be established. It was theorized that additional hidden damage to the wiring harness was damaged, thus preventing communication.

On January 14, 2001, the subject Kia Rio was reinspected by the SCI investigator and Kia representatives for the purposes of downloading any information stored within the ADU. The procedure for this inspection called for removing the subject ADU from the damaged Kia Rio and reinstalling it in an exemplar 2001 Kia Rio. The module was then read utilizing the exemplar vehicle's electrical system. The exemplar vehicle was identified by the manufacturer's VIN: KNADC123416 (production sequence deleted) and had an odometer reading of 8,012 km (4,979 miles).

The ADU was attached to the vehicle by three 5 mm fasteners and was properly mounted. The nuts were found to be properly torqued upon removal. A ground wire was properly attached to the forward right fastener and was corrosion free. The wiring harness appeared to be positively attached upon disassembly. **Figure 11** is a close-up view of the subject ADU. It was not damaged in the impact.

Figure 11: Close-up view of the subject ADU.

The subject ADU was installed in the exemplar vehicle. Upon ignition, the air bag warning lamp illuminated, as the ADU went through its standard diagnostic procedure, and then went off after approximately 6 seconds. The "off' status of the warning lamp indicated the SRS was functioning properly. The scan tool was used to access the ADU for any stored diagnostic trouble codes. There were no diagnostic trouble codes stored within the subject ADU. This indicated to the Kia Technician that the ADU was operating properly at the time of the inspection and should have been operating properly at the time of the crash. The root cause for the non-deployment of the frontal air bag system in the subject 2001 Kia Rio could not be determined.

During this second inspection, the driver air bag was removed from the subject Kia and inspected. **Figures 12-15** are a series of photographs depicting the driver air bag module and its mounting location in the center hub of the steering wheel rim. The driver air bag was identified by the following nomenclature:

Kia: 0K32A 57 K00A01 KCD M1B 1M CXH (Inflator)
Autoliv: 122903-01
B3ADAM1FF50267 KCFM1F5FAKX

The driver air bag module appeared to be undamaged. All the electrical appeared to be intact and were corrosion free. It was noted that the electrical connector attached to the inflator had contacted the hardware that attached the steering wheel rim to the steering column. Refer to **Figures 14 and 15**. Although the connector's molded insulator jacket was damaged by this contact, the electrical connection itself appeared to be intact. This contact between the inflator and steering column would have occurred in the later stages of the crash sequence and should not have affected the performance of the air bag system. It was probable the deployment sequence should have been initiated before this contact occurred.

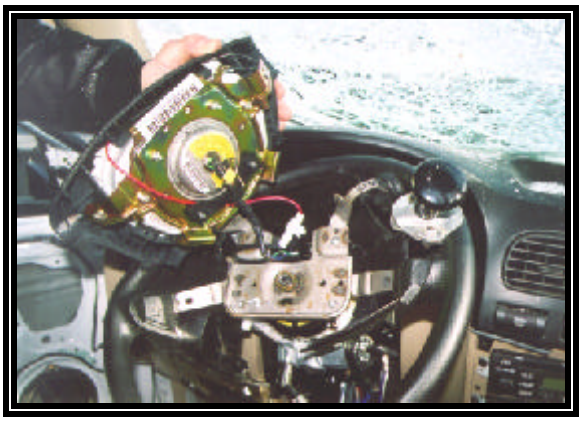

Figure 12: Driver air bag disassembly.

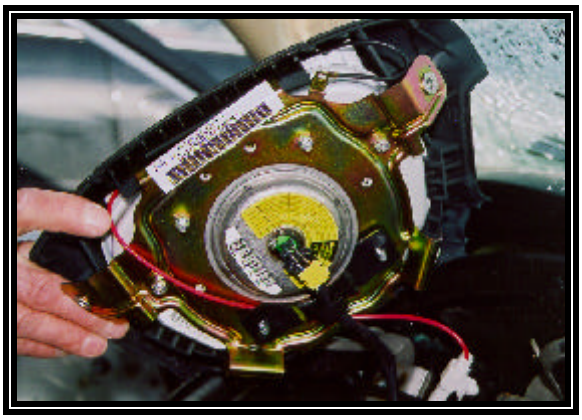

Figure 13: Drive air bag module.

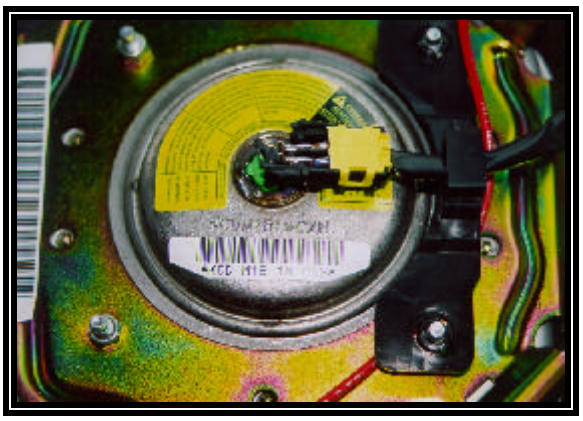

Figure 14: Close-up of inflator and electrical connection.

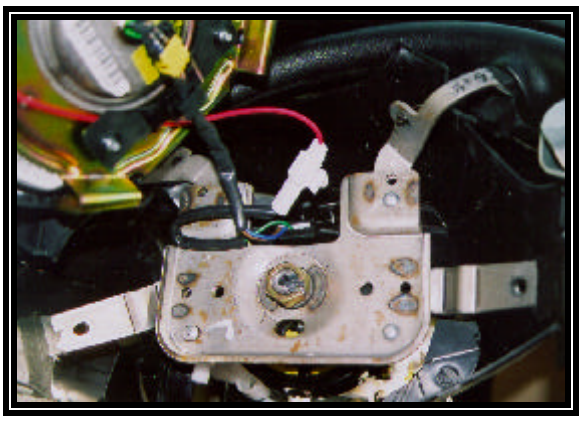

Figure 15: Close-up view of the end of the steering column.

DRIVER DEMOGRAPHICS

Age/Sex:	82 year old/Female
Height:	165 cm (65 in)
Weight:	64 kg (140 lb)
Restraint Use:	Unrestrained
Usage Source:	Observation of the first responders/SCI inspection
Medical Outcome:	Dead at the scene

DRIVER INJURIES

Injury	**Injury Severity (AIS 98 Update)**	**Injury Mechanism**
Abrasions about the forehead, dorsum of the nose and chin	Minor (290202.1,7) (290202.1,4) (290202.1,8)	Windshield contact
Multiple fractures of the sternum	Moderate (450804.2,4)	Steering wheel/hub contact
Multiple rib fractures, *"Bilateral anterior and posterior rib fractures involving most ribs."*	Severe (450240.4,3)	Steering wheel/hub contact
Abrasions about the right and left chest, NFS	Minor (490202.1,1) (490202.1,2)	Steering wheel/hub contact
Bilateral mid-shaft femur fractures w/ open fracture of the left femur	Serious (851814.3,1) (851814.3,2)	Knee bolster contact, indirect
Anterior contusions of the lower legs, bilaterally, (3x4 cm right and 6x10 cm left)	Minor (890402.1,1) (890402.1,2)	Knee bolster contact
Left ankle dislocation of the medial portion of the foot joint	Moderate (850210.2,2)	Intruding foot well/foot controls
Large area of laceration in the left mid back, NFS	Minor (690600.1,2)	Unknown

Extensive injury to the visceral organs, NFS	Unknown (515099.7,0)	Steering wheel/hub contact
Partial avulsion of the heart in its ventricular system, Multiple myocardial lacerations are also present	Maximum (441018.6,4) (441016.6,4)	Steering wheel/hub contact
Complete transection of the aorta	Critical (420210.5,4)	Steering wheel/hub contact
Partial avulsion of the lungs, bilaterally with tears of both mainstem bronchi and partial tears of the blood vessels	Severe (441450.4,3) Serious (442606.3,4)	Steering wheel/hub contact
Multiple tears and lacerations of the splenic capsule	Moderate (544222.2,2)	Steering wheel/hub contact
Fracture of the 1st and 2nd cervical spine with transection of the spinal cord	Maximum (640272.6,6)	Windshield contact, indirect

Note: The above noted injuries were identified in the driver's autopsy report.

DRIVER KINEMATICS AND INJURY

The unrestrained 82 year old female driver of the Kia was a right arm amputee for 36 years and controlled the vehicle via a spinner knob attached to the 8 o'clock sector of the steering wheel rim. The police reported she was seated on a pillow found in the driver's seat. The pillow measured 38 cm (15 in) square and was approximately 5 cm (2 in) thick. Her seat was adjusted to a near-forward track position consistent with her stature. A trailing witness reported the driver was seated in an upright posture up to the point of impact.

For unknown reasons, the driver allowed the Kia to drift to the left, across the center line, directly into the path of the Ford. Upon impact, the driver exhibited a forward trajectory in response to the 12 o'clock direction of the impact force. This forward translation caused the unrestrained driver to contact the vehicle's interior components directly forward of her position. The driver's lower extremities contacted and deformed the knee bolster resulting in contusions to the anterior aspect of her lower legs. The energy of this contact was transmitted through the knees into the femurs which resulted in bilateral femur fractures. The left femur was an open fracture. The intruding toe pan and/or foot controls caused a left ankle dislocation.

The driver's chest and abdomen contacted and deformed the steering wheel rim. The entire circumference of the rim was deformed forward around the center hub and air bag module (approximately 5cm (2 in)). There no was displacement of the steering column shear capsules. The contact to the steering wheel

rim/driver air bag module resulted in the multiple rib fractures, sternum fractures, partial avulsion of the lungs bilaterally and extensive traumatic injury to the visceral organs. The heart was partially avulsed and the aorta was transected as a result of the deceleration. A large area of laceration was noted to the left mid back. The source of this injury was unknown.

As the upper body regions decelerated, it was probable the driver then pitched up and over the steering wheel. The driver's head then contacted and fractured the windshield evidenced by the hair and tissue transfers at the contact point. The above noted facial abrasions resulted from this contact. The driver's unrestrained forward kinematic pattern continued to load the (now restrained) head and windshield through neck. This off-axis load exceeded the anatomical limits of the neck's structure and resulted in the fracture of the 1st and 2nd vertebra with complete transection of the spinal cord. At this time, the vehicle was near maximum engagement and probably was beginning to reverse its momentum.

Reports from the first responders indicated the driver remained in contact with, and was entwined around, the steering wheel rim. The severity of her injuries resulted in immediate death. The blunt trauma and damage to the heart precluded the ability to determine if the driver had a medical condition or myocardial infarction that would have resulted in the initial loss of vehicular control.