TRANSPORTATION SCIENCES
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VERIDIAN REMOTE REDESIGNED AIR BAG RELATED CHILD PASSENGER SERIOUS INJURY INVESTIGATION
VERIDIAN CASE NO. CA00-018
VEHICLE: 2000 KIA SPORTAGE
LOCATION: FLORIDA
CRASH DATE: JUNE 2000

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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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16. *Abstract* This remote crash investigation focused on the severity of injury and the injury mechanisms for a 3 year old female front right passenger of a 2000 Kia Sportage . The Kia was equipped with redesigned frontal air bags for the driver and front right passenger positions and a left knee bolster air bag. The air bag system deployed as a result of an intersection collision with a 1997 Toyota Camry. Following the initial impact, the Toyota rotated in a clockwise direction and struck the front left area of a 1997 Mitsubishi Mirage with its left rear side area. The 26 year old female driver of the Kia was not restrained by the manual belt system. She was not injured. The 3 year old child passenger of the Kia was improperly restrained by the manual belt system with the shoulder belt positioned behind her back. She was displaced forward by pre-crash braking, into the path of the deploying front right air bag. The air bag membrane expanded against her anterior neck and arms resulting in multiple abrasions. Her neck was hyper-extended by the expanding air bag which resulted in a fracture/dislocation of the odontoid process with an unspecified cord injury. She was transported by helicopter to a regional trauma center where she was admitted for 48 days and discharged ventilator dependent and quadriplegic.			
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LOCATION: FLORIDA
CRASH DATE: JUNE 2000

BACKGROUND

This remote crash investigation focused on the severity of injury and the injury mechanisms for a 3 year old female front right passenger of a 2000 Kia Sportage **(Figure 1)**. The Kia was equipped with redesigned frontal air bags for the driver and front right passenger positions and a left knee bolster air bag. The air bag system deployed as a result of an intersection collision with a 1997 Toyota Camry. Following the initial impact, the Toyota rotated in a clockwise direction and struck the front left area of a 1997 Mitsubishi Mirage with its left rear side area. The 26 year old female driver of the Kia was not restrained by the manual belt system. She was not injured. The 3 year old child passenger of the Kia was improperly restrained by the manual belt system with the shoulder belt positioned behind her back. She was displaced forward by pre-crash braking, into the path of the deploying front right air bag. The air bag membrane expanded against her anterior neck and arms resulting in multiple abrasions. Her neck was hyper-extended by the expanding air bag which resulted in a fracture/dislocation of the odontoid process with an unspecified cord injury. She was transported by helicopter to a regional trauma center where she was admitted for 48 days and discharged ventilator dependent and quadriplegic.

Figure 1. Front left view of the Kia Sportage.

The crash was identified by NHTSA and assigned to the Veridian SCI team on June 22, 2000 as a remote investigative effort.

SUMMARY

Crash Site

The crash occurred at a four-leg intersection in a commercial area during daylight hours **(Figure 2)**. The intersection consisted of a seven lane divided (curbed concrete median) arterial with designated left turn lanes for both the north and southbound travel directions. The travel lanes were delineated by broken white lane lines that terminated at a wide stop line. The intersecting street consisted of three lanes with designated left turn lanes. Traffic flow through the intersection was controlled by an overhead signal system. Marked crosswalks were present at all four legs with pedestrian signals.

Figure 2. View of the crash site from the Kia's path of travel.

Vehicle Data - 2000 Kia Sportage

The subject vehicle was a 2000 Kia Sportage, four-door, 4x2 sport utility vehicle. The Sportage was identified by vehicle identification number KNDJB7231Y56 (production number deleted). The vehicle was configured with a body on frame design and equipped with a 2.0 liter, 4-cylinder engine linked to a 4-speed automatic transmission with a center console mounted shifter, alloy wheels, and power-assisted front disc/rear drum brakes. The interior was configured with front bucket seats with reclining seat backs and a 50/50 split rear bench seat with forward folding backrests. At the time of the crash, the driver of the Kia was transporting clothing items and the rear seat back was removed to provide greater cargo space. Additional interior features included power windows, power door locks, and adjustable D-rings for the front 3-point lap and shoulder belt systems.

Crash Sequence

Pre-Crash

The driver of the Kia Sportage was traveling in a southerly direction on the center lane of the divided arterial. She approached the four-leg intersection on a red signal phase. The driver of the Kia apparently failed to detect the red phase and proceeded into the intersection to continue in a southerly direction. The driver of the Toyota Camry was stopped on the northbound left turn lane. As the signal phase change to a left turn arrow for northbound traffic, the driver of the Camry accelerated into the intersection and initiated a left turn across the southbound Kia's path of travel. The driver of the Kia detected the left turning Camry and applied the brakes as indicated by pre-crash skid marks noted on the police schematic of the crash. The Mitsubishi Mirage was stopped on the westbound travel lane at the mouth of the intersection waiting for traffic to clear to initiate a right turn onto the southbound arterial.

Crash

The full frontal area of the Kia Sportage impacted the right passenger compartment area of the Toyota. Resultant directions of force were within the 11 o'clock sector for the Kia and probably within the 2 o'clock sector for the struck Toyota. The impact crushed the front bumper of the Kia to a maximum depth of approximately 15 cm (6") which resulted in a WinSMASH generated delta V of 25.5 km/h (15.8 mph) with a longitudinal component of -23.5 (-14.6 mph) and a lateral component of 8.6 km/h (5.3 mph). The damage algorithm was utilized using an estimated crush profile for the Kia Sportage. The impact induced deceleration was sufficient to deploy the Kia's frontal air bag system. The crash schematic is attached as **Figure 10**, Page 8.

The Camry rotated in a clockwise direction and deflected in a southwest direction. The left rear corner of the Camry struck the front left corner of the Mirage resulting in minor damage. The Kia Sportage rotated in a clockwise direction and came to rest within the boundaries if the intersection, facing in a northerly direction.

Post-Crash

The driver of the Kia Sportage exited the vehicle from the left front door and removed the child passenger from the vehicle. The child passenger was found by emergency personnel on the road surface adjacent to

the vehicle. The child passenger was placed on a backboard and prepared for helicopter transport to a regional trauma canter. The driver of the Kia was not reported as injured. She drove the vehicle from the scene of the crash.

Vehicle Damage

Exterior - 2000 Kia Sportage

The Kia Sportage sustained moderate frontal damage **(Figure 3)** from the intersection crash with the Toyota Camry. The direct contact damage was distributed across the full frontal width of the vehicle with minor lateral displacement to support an 11 o'clock direction of force. Maximum crush was estimated at 15 cm (6") located at the left bumper corner. The impact crushed the front bumper and hood face and displaced both front fenders laterally to the right. A crush profile was estimated at bumoer level as follows: C1= 15 cm (6"), C2= 10 cm (4"), C3= 15 cm (6"), C4= 13 cm (5"), C5= 15 cm (6"), C6= 15 cm (6"). A delta V was computed by the damage algorithm of the WinSMASH program 25.0 km/h (15.5 mph) which was sufficient to deploy the Kia's frontal air bag system. Although the damage was rated as moderate, the Kia was driven from the scene. The Collision Deformation Classification (CDC) was 11-FDEW-1.

Figure 3. Frontal damage to the Kia Sportage.

Interior - 2000 Kia Sportage

The interior of the Kia Sportage sustained minor damage that was associated with air bag deployment and occupant contact. The redesigned frontal air bags and the knee bolster air bag deployed as designed during the crash. The driver air bag module cover flaps and the mid mount passenger flap opened at the designated tear seams. The knee bolster air bag displaced the rigid bolster panel rearward from the breakaway fasteners. There was no visible intrusion into the passenger compartment. **Figure 4** is an overall view of the Kia's interior.

Figure 4. Overall view of the frontal air bag system and the Kia's interior.

The driver's knees probably contacted the knee bolster cover as it was displaced rearward by the expanding air bag. A scuff mark was visible on the upper left corner of the bolster cover. There was no bending of the steering wheel rim or apparent compression of the energy absorbing steering column. The non-tethered air bag did not display evidence of contact.

Figure 5. Partial separation of the right front lap belt energy management loop.

The front right child passenger was involved with the deploying redesigned passenger air bag, however, the available images did not

yield evidence of contact (i.e., tissue transfers). Blood stains were present on the inboard aspect of the seat back, above the seat belt buckle assembly. The lap belt segment of the front right 3-point belt system was equipped with an energy management loop. The loop was concealed within a vinyl sleeve above the outboard anchorage. The top row of stitching was partially separated **(Figure 5)** which indicated a load was placed on the manual belt system. This probably occurred during the air bag induced upward and rearward trajectory of the child passenger.

Principal Other Vehicles

There was no photographic documentation of the Toyota Camry or the Mitsubishi Mirage. The PAR noted that the Camry sustained disabling damage and was towed from the scene while the Mitsubishi sustained a police reported damage value of $500 and was driven from the scene.

Frontal Air Bag System - Kia Sportage

The 2000 Kia Sportage's air bag system consisted of a center console mounted single point sensing and control module, the steering wheel mounted driver air bag, a mid mount front right passenger air bag, the knee bolster air bag, and an instrument panel mounted indicator lamp. The front driver and passenger air bags were redesigned. The frontal air bag system deployed as a result of the frontal impact against the side surface of the Toyota Camry.

The driver air bag deployed from the steering wheel module. Based on the available photographs, the driver air bag was not tethered and there was no evidence of damage or driver contact to the bag membrane.

The knee bolster air bag deployed from behind the rigid plastic knee bolster panel, displacing the panel rearward toward the driver. The bolster panel released at the designated breakaway fastener locations during deployment. A probable knee scuff mark was visible on the upper left aspect of the bolster panel. **Figure 6** is a view of the deployed knee bolster air bag.

Figure 6. Deployed knee bolster air bag.

The redesigned front right passenger air bag deployed from a mid mount module that was concealed by a single cover flap **(Figure 7)**. The flap opened in a upward direction toward the windshield. The front right passenger air bag membrane was non-tethered. There was no damage or contact evidence visible in the provided photographs.

Figure 7. Deployed mid mount front right passenger air bag.

Human Demographics

Driver - Kia Sportage

Age/Sex:	26 year old female
Height:	Not reported
Weight:	Not reported
Manual Restraint Usage:	None
Usage Source:	Vehicle inspection
Seat Track Position:	Mid track
Type of Medical Treatment:	None, not reported as injured

Driver Injuries

Injury	Injury Severity (AIS 90/Update 98)	Injury Source
Not injured	N/A	N/A

Driver Kinematics

The driver of the Kia Sportage was seated in a presumed mid track positioned based on the available photographs. She was not restrained by the manual belt system. The driver's side energy management loop was intact within the vinyl sleeve. At impact, the driver initiated a forward and lateral left trajectory as she responded to the 11 o'clock impact force **(Figure 8)**. She probably loaded the deployed redesigned driver and knee bolster air bag systems which protected her from contact with frontal components and possible injury.

Figure 8. Profile view of the driver's trajectory.

Front Right Passenger Demographics

Age/Sex:	3 year old female
Height:	119.4 cm (47.0")
Weight:	20 kg (44 lb)
Manual Restraint Usage:	Improper use of the 3-point lap and shoulder belt system, shoulder belt positioned behind back
Usage Source:	Injury sources, belt loading
Seat Track Position:	Full forward
Mode of Transport From Scene:	Helicopter to a regional trauma center
Medical Treatment:	Hospitalized for 48 days, 16 hours
Outcome:	Ventilator dependent with quadriplegia

Front Right Child Passenger Injuries

Injury	*Injury Severity (AIS 90/Update 98)*	*Injury Source*
Fracture/dislocation of the odontoid process with unspecified cord injury that resulted in quadriplegia	Severe (640218.4,6)	Expanding front right passenger air bag
Bilateral lower lobe pulmonary contusions	Severe (441410.4,3)	Expanding front right passenger air bag
Wide band (6-7 cm in width) abrasion of the anterior neck	Minor (390202.1,5)	Expanding front right passenger air bag
Abrasion of the epigastric area (upper mid aspect of the abdomen)	Minor (590202.1,7)	Expanding front right passenger air bag
Multiple abrasions of the upper extremities that include the following: - 5x5 cm abrasion of the left anterior forearm - 7x5 cm abrasion of the left lateral forearm - 8x8 cm abrasion of the anterior right lateral forearm - 2x3 cm abrasion of the dorsal right hand at base of thumb	Minor (790202.1,3)	Expanding front right passenger air bag
3 cm linear abrasion of the anterior surface of the thigh	Minor (890202.1,2)	Lap belt webbing (probable)

* Source of injury - verbal translation from hospital

Front Right Passenger Kinematics

The front right child passenger was seated in a presumed upright attitude with the seat track adjusted to a forward position. The child was probably forward on the seat cushion to allow her lower legs to extend over the leading edge of the cushion. She was improperly restrained by the manual 3-point lap and shoulder belt system. There was no loading evidence or air bag membrane transfers on the shoulder belt aspect of the system, therefore the shoulder belt was probably positioned behind the back of the child passenger. The energy management loop that was incorporated into the outboard aspect of the lap belt webbing was partially separated within the vinyl sleeve. This load induced separation supported the use of the lap belt.

Figure 9. Profile view of the child passenger's seat track position and the deployed front right air bag.

The improper use of the 3-point lap and shoulder belt system allowed the child's head and torso to move forward as a result of pre-crash braking. At impact, the child was in a close proximity the mid mount passenger air bag module with her arms extended in a forward direction. The 11 o'clock direction of force impact deployed the redesigned frontal air bag system. The top hinged cover flap did not contact the child, however, the expanding air bag membrane contacted the child's arms resulting in multiple abrasions of the right hand, bilateral forearms, and upper arms. This bag interaction displaced her arms outward which allowed the expanding air bag to contact the child under the chin, abrading her anterior neck. Continued expansion of the non-tethered air bag rotated the child's head rearward and hyper-extended the neck. The hyper-extension resulted in a fracture/dislocation of the odontoid process with an unspecified cord contusion. **Figure 9** is a profile view of the child passenger's seat track position and the rearward excursion of the air bag.

The expansion of the redesigned passenger air bag contacted the child passenger in the upper abdomen resulting in a wide band abrasion of the epigastric area with underlying bilateral pulmonary contusions. The air bag lifted the child vertically as it displaced the child rearward. This motion allowed the child to load the lap belt in a vertical direction. The belt probably slid onto her thighs as evidenced by a 3 cm linear abrasion of the anterior left thigh. This vertical loading force on the lap belt produced a partial separation of the energy management loop that was incorporated into the outboard aspect of the lap belt.

The child came to rest slumped in the right front seat. The driver of the vehicle unbuckled the manual belt system and removed the child passenger from the Kia. She was found by rescue personnel outside the vehicle. Several blood stains were noted to the inboard aspect of the lower seat back support and the outboard aspects of the seat cushion, forward of the bight.

The child was immobilized at the scene, placed on a backboard and transported by helicopter to a regional trauma center where she was admitted for a period of 48 days prior to discharge to her residence. Her cervical injuries resulted in quadriplegia and she was ventilator dependent.

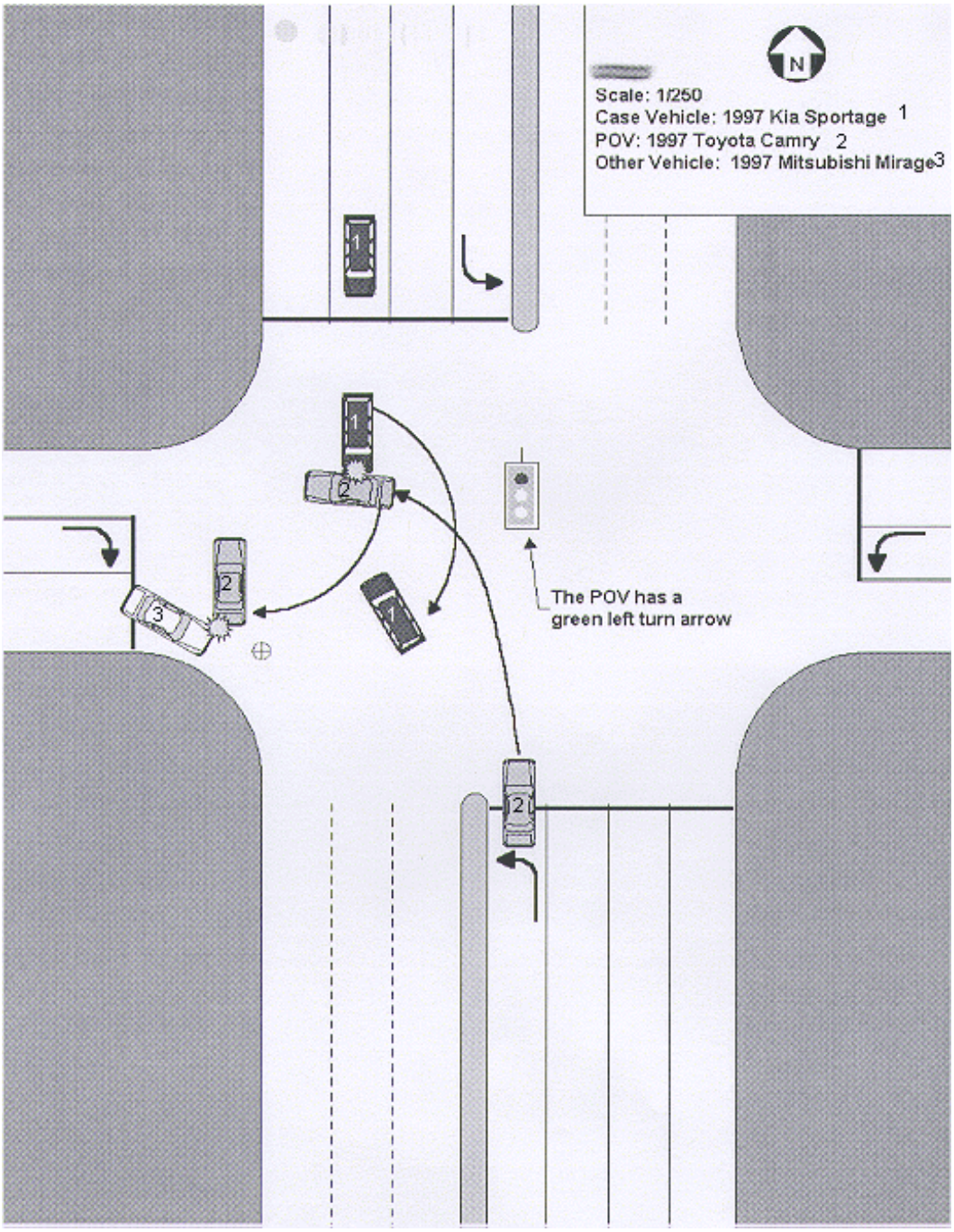

Figure 10. Crash Schematic