TRANSPORTATION SCIENCES
CRASH RESEARCH SECTION

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CALSPAN REMOTE CHILD PASSENGER/AIR BAG FATALITY INVESTIGATION
CALSPAN CASE NO. CA97-016
LOCATION: PUERTO RICO
VEHICLE: 1996 HYUNDAI ACCENT
CRASH DATE: APRIL, 1997

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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 investigation focused on the injury mechanisms of a fatal air bag deployment crash that involved a 1996 Hyundai Accent. The Hyundai was equipped with frontal air bags for the driver and right passenger positions. The vehicle was occupied by the 20 year old female driver and a 18 month old child front right passenger. The frontal area of the Hyundai struck the back of a stopped 1986 Toyota Tercel at a signalized four-leg intersection. The minor severity impact deployed the Hyundai's frontal air bag system. The unrestrained child passenger sustained soft tissue abrasions of the anterior neck and chin with a fracture of C1/C2 and complete cord transection from contact with the mid mount air bag cover flap and the expanding air bag membrane. The child was transported to a local hospital, however she expired en route. The female driver of the Hyundai was not injured.			
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TABLE OF CONTENTS

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BACKGROUND

This remote investigation focused on the injury mechanisms of a fatal air bag deployment crash that involved a 1996 Hyundai Accent. The Hyundai was equipped with frontal air bags for the driver and front right passenger positions. The vehicle was occupied by the 20 year old female driver and a 18 month old child front right passenger. The frontal area of the Hyundai struck the back of a stopped 1986 Toyota Tercel at a signalized four-leg intersection **(Figure 1)**. The minor severity impact deployed the Hyundai's frontal air bag system. The unrestrained child passenger sustained soft tissue abrasions of the anterior neck and chin with a fracture of C1/C2 and complete cord transection from contact with the mid mount passenger air bag cover flap and the expanding air bag membrane. The child was transported to a local hospital, however she expired en route. The female driver of the Hyundai was not injured.

Figure 1. Involved Hyundai and Toyota Tercel.

The initial notification of the crash was provided to NHTSA Headquarters by the NHTSA Regional Office (Region 2 in Puerto Rico) on April 7, 1997. The case was subsequently assigned to the Calspan Special Crash Investigation Team on April 8, 1997, as a remote investigation. Data for this case was provided by the Medical Examiner.

SUMMARY

Crash Site

The crash occurred on a divided east/west arterial roadway at a four leg intersection. The arterial roadway consisted of five eastbound travel lanes, inclusive of a designated left turn lane, and four westbound lanes. Traffic flow through the intersection was controlled by an on-colors traffic signal system. The investigating officer noted that the asphalt road surface was wet due to light rain. Conditions were dark which required headlights for proper visibility. The speed limit was not reported.

Vehicle Data

The 1996 Hyundai Accent was a 3-door hatchback, powered by a 1.5 liter transverse mounted four cylinder engine linked to an automatic transmission. The seating was configured with front bucket seats with forward folding and reclining seat back supports and a rear bench seat with a folding back rest. The front bucket seat had adjustable head restraints. The Hyundai's vehicle identification number and odometer reading were not reported by the investigating officer. The driver was not the owner of the vehicle, therefore the history of the vehicle and air bag system was unknown.

Pre-Crash

The driver of the Hyundai was initially traveling in a westerly direction on the arterial roadway. She initiated a U-turn at a designated crossover to proceed in an easterly direction. The driver approached the signalized four-leg intersection on the inboard through lane (lane #4). The signal phase for east/westbound traffic flow was red. The driver of the Hyundai stated to the investigating officer that she was inattentive as she approached the intersection and failed to detect the stopped Toyota Tercel. The Tercel was stopped in the westbound lane #4 for the red signal phase.

The driver of the Hyundai apparently detected the stopped Toyota immediately prior to impact and braked the vehicle in an attempt to avoid the crash. This braking was determined by the level of contact between the bumpers of the vehicles at impact.

Crash

The frontal area of the Hyundai Accent impacted the rear of the Toyota Tercel in a slightly off-set configuration involving the left two-thirds of the frontal plane of the Hyundai **(Figure 2)** against the right two-thirds of the Tercel. The pre-crash braking action by the driver of the Hyundai compressed the front suspension of the vehicle. This allowed the front bumper fascia of the Hyundai to impact the Tercel's Class I trailer hitch and the exhaust tailpipe. Both of these components extended below the level of the Tercel's bumper. The trailer hitch deformed the Hyundai's bumper fascia left of center below the inboard aspect of the left headlight assembly. The tailpipe of the Tercel produced a semi-circular gouge to the plate that was affixed to the front license plate mounts (front license plate was not required). The impact crushed the energy absorbing front bumper of the Hyundai which allowed the hood face to engage against the bumper of the Tercel. Minor damage resulted to the involved vehicles. Resultant directions of force were 12 o'clock for the Hyundai and 06 o'clock for the struck Toyota. The Hyundai underwent a longitudinal deceleration that was sufficient to deploy the vehicle's frontal air bag system. Velocity changes were estimated at 13-16 km/h (8-10 mph) for both vehicles. The

Figure 2. Frontal damage to the Hyundai Accent.

Post-Crash

The child passenger of the Hyundai came to rest in an unknown attitude within the vehicle. She was subsequently removed from the Hyundai and transported to a local hospital where she expired en route. An autopsy was performed which identified the injuries for this investigation.

VEHICLE DAMAGE

Hyundai - Exterior

The Hyundai sustained minor frontal damage as a result of its impact with the rear of the Toyota Tercel. The front bumper of the Hyundai partially underrode the rear bumper of the Tercel. Residual crush was minimal as the energy absorbing bumper system appeared to have rebounded following the impact. The direct contact damage began approximately 25 cm (10") right of center and extended to the left bumper

Hyundai - Exterior continued

corner. Superficial transfers were evident across the left two-thirds of the frontal plane. The tailpipe of the Tercel penetrated the front dealer plate that was fastened to the center license plate mounting system. The trailer hitch of the Tercel deformed the Hyundai's front bumper fascia directly below the inboard aspect of the left headlamp assembly **(Figure 3)**. The hood face of the Hyundai engaged against the rear bumper of the Tercel which buckled the forward aspect of the hood. In addition, the left turn signal assembly was displaced from its fender mount. The Collision Deformation Classification (CDC) for this impact was 12-FYEW-1.

Figure 3. Contact damage to the front bumper fascia.

Figure 4. Rear impact damage to the Toyota.

Toyota - Exterior

The Toyota Tercel sustained minor damage to the rear of the vehicle. Although the available photographs failed to document a crush depth, minimal displacement of the bumper probably occurred. The tongue of the center mounted trailer hitch was deformed in a downward direction **(Figure 4)** from contact with the Hyundai. The tailpipe, however, did not appear to be displaced. The CDC for this damage pattern was 06-BZLW-1.

AUTOMATIC RESTRAINT SYSTEM

Hyundai

The Hyundai was equipped with frontal air bags for the driver and front right passenger positions. The system did deploy as a result of the front-to-rear impact sequence with the Toyota Tercel. The system consisted of a conventionally mounted driver air bag module assembly that was contained within the 4-spoke steering wheel rim and a mid mount passenger air bag module.

Figure 5. Deployed driver air bag and adjusted seat track position.

The driver air bag deployed from an H-configuration module assembly. Base on previous investigations, the upper cover flap was 12.1 cm (4.75") in width at the tear seam and 7.6 cm (3.0") in height. The lower cover flap maintained the same width, however, the height was 5.7 cm (2.25"). The driver bag was approximately 66.0 cm (26.0") in diameter in its deflated state and was vented by two 2.5 cm (1.0") diameter ports located at the 10 and 2 o'clock positions. The bag was tethered by two wide band internal straps. The deployed driver air bag is shown in **Figure 5**.

The passenger air bag in the Hyundai Accent was mounted in a mid mount configuration in the right instrument panel. The single cover flap was hinged at the top surface and opened at the designated side and bottom tear seams. Again, based on previous investigations, the vinyl cover flap was 15.2 cm (6.0") in height and 35.3 cm (13.9") in width. The on-scene police photographs documented a faint horizontal transfer to the leading edge of the cover flap that appeared to be tissue. The transfer extended across the right two-thirds of the leading edge **(Figure 6)**. This transfer resulted from contact against the chin and right arm of the child passenger. Additional faint vertically oriented scuffs were present of the mid aspect of the cover flap at the apex of the contour. These scuff marks were related to the extended arms of the child passenger.

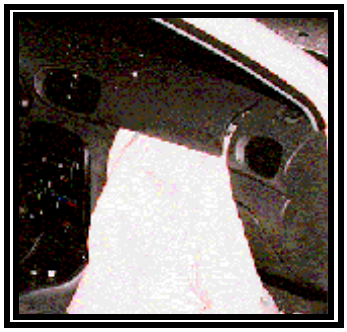

Figure 6. Deployed front right air bag with tissue transfer on the leading edge of the cover flap.

The bag was tethered by two wide band tether straps sewn to the face of the bag. The maximum rearward excursion of the bag was 50.2 cm (19.75") while the maximum excursion at the tether locations was 44.4 cm (17.5"). Both of these dimensions were documented from the mid instrument panel. The front passenger air bag was vented by two 5.7 cm (2.25") diameter ports located at the 3 and 9 o'clock positions.

The passenger air bag module of the Hyundai involved in this crash was removed from the vehicle and photographed by the medical examiner's staff **(Figure 7)**. No distinct occupant contacts (i.e., tissue transfers) were visible on the bag membrane. Two vertically oriented transfers (probable vinyl) were noted to the face of the bag centered at the horizontal mid point and over the top tether stitching. These transfers probably resulted from bag expansion against the inside surface of the module cover flap as the child passenger restricted the deployment path of the flap. The ME's staff used a yardstick as a point of reference which indicated the height of the bag was approximately 50.8 cm (20.0"). In a previous investigation, the overall dimensions of the passenger bag were 54.0 cm (21.25") vertically and 45.7 cm (18.0") in width. There was no damage (i.e., tears) to the deployed passenger air bag membrane.

Figure 7. Removed front passenger air bag.

MANUAL RESTRAINT SYSTEMS (Hyundai)

The 1996 Hyundai Accent was equipped with manual 3-point lap and shoulder belts at the four outboard seated positions. The front belt systems consisted of continuous loop webbings with a sliding latchplate that retracted onto a dual mode locking retractor located in the lower B-pillars. The upper anchorages (D-rings) were adjustable, however, the position of the D-rings were unknown. It was also unknown if the driver was restrained by the manual belt system. The investigating officer noted that the child passenger was not restrained and this was in violation of Puerto Rico traffic laws.

DRIVER DEMOGRAPHICS (Hyundai)

Age/Sex:	20 year old female
Height:	Unknown
Weight:	Unknown
Manual Restraint Usage:	Unknown
Usage Source:	Unknown
Mode of Transport From Scene:	Private vehicle
Type of Medical Treatment:	None

DRIVER INJURIES

Injury	Injury Severity (AIS 90)	Injury Mechanism
Not injured	N/A	N/A

DRIVER KINEMATICS

The driver of the 1996 Hyundai Accent was seated in a presumed normal driving posture with the seat adjusted to a mid track position. It was unknown if she was restrained by the manual belt system. At impact with the Toyota, the driver was braking in an attempt to avoid impact. This action compressed the front suspension of the Hyundai which allowed the bumper fascia to impact the trailer hitch and tailpipe of the Tercel. The impact triggered the deployment of the frontal air bag system. The driver probably contacted the deployed air bag which prevented possible contact with the steering assembly. As a result, the driver was not reported as injured.

CHILD PASSENGER DEMOGRAPHICS

Age/Sex:	18 month old female
Seated Position:	Front right of the Hyundai
Height:	86.4 cm (34.0")
Weight:	12.2 kg (27.0 lb)
Manual Restraint Use:	None, child should have been restrained in a forward facing child safety seat in the rear seat of the Hyundai
Usage Source:	Injury patterns, police investigation
Mode of Transport From Scene:	Ambulance
Type of Medical Treatment:	Expired en route to hospital

CHILD PASSENGER INJURIES

Injury	Injury Severity (AIS 90)	Injury Mechanism
Internal Transection of the spinal cord with fracture of C1/C2 and complete displacement and separation of the cranium from the spine	Maximum (640276.6,6)	Front right air bag module cover flap and the expanding air bag membrane
Intraparenchyma hemorrhage at the upper lobes of both lungs	Severe (441410.4,3)	Expanding air bag membrane
Diffuse subarachnoid hemorrhage, more prominent at the base of the brain	Serious (140466.3,6)	Front right air bag module cover flap and the expanding air bag membrane
Hemorrhage at the posterior aspect of the esophagus	Moderate (440802.2,4)	Front right air bag module cover flap and the expanding air bag membrane
Hemorrhagic infiltrate at the left renal capsule	Moderate (541610.2,2)	Expanding air bag membrane
Extensive hemorrhages of the anterior neck muscles	Minor (390402.1,5)	Front right air bag module cover flap and the expanding air bag membrane
Complete tear of the right sternocleidomastoid muscle from its insertion at the clavicle	Moderate (740400.2,1)	Front right air bag module cover flap and the expanding air bag membrane
Bilateral lacerations of the tongue (consistent with bite marks)	Minor (243402.1,8)	Self-inflicted from air bag cover flap and membrane contact
External-Soft Tissue 8x9 cm abrasion of the chin extending onto the anterior neck	Minor (290202.1,8; 390202.1,5)	Front right air bag module cover flap and the expanding air bag membrane
Multiple pinpoint abrasions of the left side of the mouth	Minor (290202.1,2)	Expansion of the front right air bag membrane
Two 1 cm contusions of the lower lip	Minor (290402.1,8)	Expansion of the front right air bag membrane
1 cm abrasion of the mid forehead	Minor (290202.1,7)	Internal object (possible)

Injury	Injury Severity (AIS 90)	Injury Mechanism
2 cm abrasion with contusion of the left chest near the nipple	Minor (490202.1,2; 490402.1,2)	Expansion of the front right air bag membrane
5 cm abrasion over the ventral aspect of the right elbow with a 2-4 cm abrasion of the internal aspect of the elbow	Minor (790202.1,1)	Expansion of the front right air bag membrane
Abrasion of the lateral aspect of the left ring finger	Minor (790202.1,2)	Front right air bag module cover flap

**All injuries were documented in the autopsy report.*

CHILD PASSENGER KINEMATICS

The 18 month old child passenger was positioned in the front right of the Hyundai Accent. It was unknown if the child was in a seated position pre-crash or in another position, either on the seat or standing in front of the front passenger air bag module assembly. Base on the on-scene police photographs, the front right seat was positioned in a mid track position with the seat back support set to a slight recline position **(Figure 8)**. The child passenger was not wearing the manual 3-point lap and shoulder belt system. It should be noted that this child passenger should have been restrained in a forward facing child restraint in the rear seat of the vehicle.

Figure 8. Adjusted seat track position and the deployed passenger air bag.

Although not supported by physical evidence at the crash site (i.e., skid marks), the driver of the Hyundai was braking in an attempt to avoid the crash. This was determined by contact evidence to the Hyundai's bumper fascia from engagement against the trailer hitch and tailpipe of the struck Toyota Tercel. This braking would have compressed the Hyundai's front suspension to allow the fascia to engage with the low mounted components. In addition to the pre-crash braking, the low severity crash could have resulted in an elongated pulse which would have triggered the frontal air bag system late in the crash sequence. These factors would have displaced the child forward against the front right passenger air bag module at the time of deployment.

The child passenger was positioned against the front right air bag module cover with her right arm extended over her face. The left hand was also in a raised position as the air bag system deployed. The leading edge of the mid mount front right air bag module cover contacted the chin and anterior neck area of the child passenger resulting in extensive abrasion of theses areas. The ventral area of the child's right elbow was abraded from contact by the cover flap and the expanding air bag. The left corner area of the cover flap probably contacted the outboard aspect the child's left ring finger which resulted in two separate abrasions of the lateral aspect of the finger.

The chin and anterior neck contact by the cover flap and the expanding air bag membrane displaced the child passenger's head in an upward and rearward direction. This hyperextension resulted in a fracture of C1/C2 with transection of the spinal cord and complete displacement and separation of the cranium from the spine (AIS-6). In addition to the C-spine injury, the child passenger sustained extensive hemorrhages of the anterior neck muscles at the level of C1-C4, hemorrhage at the posterior aspect of the esophagus, diffuse subarachnoid hemorrhage, and a complete tear of the right sternocleidomastoid muscle from its insertion at the clavicle.

The continued expansion of the air bag membrane contacted the face and anterior chest of the child passenger. This contact sequence produced additional injury which included abrasions with contusions to the left aspect of the mouth, a 2 cm abrasion of the left chest, intraparenchymal hemorrhages of the upper lobes of both lungs, and hemorrhagic infiltrate at the left renal capsule. The child also sustained self-inflicted lacerations of the tongue which probably occurred as a result of the initial contact from the cover flap and expanding air bag against the anterior neck and chin.

The on-scene police photographs documented a substance scattered in the right passenger compartment of the vehicle. This material appeared to be light in composition, such as torn paper. It did indicate that the child passenger may have been holding an object prior to the crash and that the object was fragmented by the deploying air bag. The child passenger did sustain a 1 cm abrasion to the mid forehead which did not appear to be air bag related. This abrasion possibly resulted from contact with an object external to the air bag.

The child passenger came to rest in an unknown attitude within the vehicle. She was transported by ambulance to a local hospital where she expired en route due to the spinal cord transection.