TRANSPORTATION SCIENCES
CRASH DATA RESEARCH CENTER

Veridian Engineering
Buffalo, NY 14225

VERIDIAN ON-SITE CHILD SAFETY SEAT CRASH INVESTIGATION
SCI TECHNICAL SUMMARY REPORT

NASS/SCI COMBO CASE NO. 00-11-134K

VEHICLE - 1994 FORD TEMPO

LOCATION - STATE OF MICHIGAN

CRASH DATE - SEPTEMBER 2000

Contract No. DTNH22-94-D-07058

Prepared for:

U.S. Department of Transportation
National Highway Traffic Safety Administration
Washington, D.C. 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 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.

TECHNICAL REPORT STANDARD TITLE PAGE

1. *Report No.* 00-11-134K	2. *Government Accession No.*	3. *Recipient's Catalog No.*	
4. *Title and Subtitle* Veridian On-Site Child Safety Seat Crash Investigation Vehicle: 1994 Ford Tempo Location: State of Michigan		5. *Report Date*: July 2001 6. *Performing Organization Code*	
7. *Author(s)* Crash Data Research Center		8. *Performing Organization Report No.*	
9. *Performing Organization Name and Address* Transportation Sciences Crash Data Research Center Veridian Engineering P.O. Box 400 Buffalo, New York 14225		10. *Work Unit No.* C01115.0310.(0000-0009) 11. *Contract or Grant No.* DTNH22-94-D-07058	
12. *Sponsoring Agency Name and Address* U.S. Department of Transportation National Highway Traffic Safety Administration Washington, D.C. 20590		13. *Type of Report and Period Covered* Technical Report Crash Date: September 2000 14. *Sponsoring Agency Code*	
15. *Supplementary Notes* On-site investigation of a run-off-road crash that resulted in the serious injury to the driver and the 18-month-old child passenger who was restrained in a child safety seat.			
16. *Abstract* This investigation focused on a single vehicle crash that involved a 1994 Ford Tempo that was occupied by a 32-year-old male driver and 18-month-old female rear passenger. The female child passenger was positioned in a forward-facing convertible child safety seat with a tray shield that was installed in the rear center position of the Tempo. The vehicle departed the roadway and struck a tree with the front center area. The computed delta-V was 58.8 km/h (36.5 mph). The driver was restrained by the automatic 2-point shoulder belt, but was not utilizing the manual lap belt. He initiated a forward trajectory in response to the frontal impact force and submarined the automatic shoulder belt. He loaded the steering wheel rim/hub, knee bolster, and contacted the rear view mirror and instrument panel with his hands. He was transported by ambulance to a local trauma center and admitted for a right eye subconjunctiva injury, multiple lip lacerations, a concussion with loss of consciousness, lateral and posterior rib fractures of the right ribs 7 and 9, a liver laceration, a gall bladder laceration, a ruptured diaphragm, and a right kidney laceration. The child passenger was not properly restrained in the child safety seat. At impact, she initiated a forward trajectory and loaded the harness straps which were improperly positioned in the lower slots. The loading caused the harness straps to pull through the plastic shell of the child safety seat which allowed additional forward travel of the child. She loaded the tray shield which fractured on the left side. Additionally, she loaded the front left seat back and rebounded rearward into the child safety seat. She was found lying in the child safety seat and was in cardiac arrest. She was revived and transported by ambulance to a local trauma center where she was admitted to the pediatric trauma unit. She sustained a loss of consciousness, laceration of the perineum, C2 vertebral body fracture with cord contusion, cerebral subarachnoid hemorrhage, and had no spontaneous movement in her extremities.			
17. *Key Words* Child safety seat Child passenger serious injury Crash related injuries		18. *Distribution Statement* General Public	
19. *Security Classif. (of this report)* Unclassified	20. *Security Classif. (of this page)* Unclassified	21. *No. of Pages* 10	22. *Price*

TABLE OF CONTENTS

VERIDIAN ON-SITE CHILD SAFETY SEAT CRASH INVESTIGATION
SCI TECHNICAL SUMMARY REPORT
NASS/SCI COMBO CASE NO. 00-11-134K
VEHICLE - 1994 FORD TEMPO
LOCATION - STATE OF MICHIGAN
CRASH DATE - SEPTEMBER 2000

BACKGROUND

Figure 1. 1994 Ford Tempo

This investigation focused on a single vehicle crash that involved a 1994 Ford Tempo **(Figure 1)** that was occupied by a 32-year-old male driver and 18-month-old female rear passenger. The female child passenger was positioned in a forward-facing convertible child safety seat with a tray shield that was installed in the rear center position of the Tempo. The vehicle departed the roadway and struck a tree with the front center area. The computed delta-V was 58.8 km/h (36.5 mph). The driver was restrained by the automatic 2-point shoulder belt, but was not utilizing the manual lap belt. He initiated a forward trajectory in response to the frontal impact force and submarined the automatic shoulder belt. He loaded the steering wheel rim/hub, knee bolster, and contacted the rear view mirror and instrument panel with his hands. He was transported by ambulance to a local trauma center and admitted for a right eye subconjunctiva injury, multiple lip lacerations, a concussion with loss of consciousness, lateral and posterior rib fractures of the right ribs 7 and 9, a liver laceration, a gall bladder laceration, a ruptured diaphragm, and a right kidney laceration. The child passenger was not properly restrained in the child safety seat. At impact, she initiated a forward trajectory and loaded the harness straps which were improperly positioned in the lower slots. The loading caused the harness straps to pull through the plastic shell of the child safety seat which allowed additional forward travel of the child. She loaded the tray shield which fractured on the left side. Additionally, she loaded the front left seat back and rebounded rearward into the child safety seat. She was found lying in the child safety seat and was in cardiac arrest. She was revived and transported by ambulance to a local trauma center where she was admitted to the pediatric trauma unit. She sustained a loss of consciousness, laceration of the perineum, C2 vertebral body fracture with cord contusion, cerebral subarachnoid hemorrhage, and had no spontaneous movement in her extremities.

The crash occurred in September 2000. Initial notification of this crash was made by the local police jurisdiction to the NASS Primary Sampling Unit (PSU) immediately following the crash due to the crash severity and presence of a child safety seat. The NASS PSU promptly responded to the scene following the notification and obtained a partial vehicle inspection before the vehicle was towed. The NASS researcher performed the complete vehicle inspection on the day of the crash after the vehicle was moved to the tow yard and forwarded the crash notification to the Veridian Special Crash Investigations team. This crash was then selected for investigation by the National Automotive Sampling System (NASS) as CDS case number 00–11-134K. The National Highway Transportation Safety Administration (NHTSA)

assigned an on-site investigation, case review and report preparation to the Veridian Special Crash Investigation (SCI) team on October 4, 2000 due to the involvement of the child safety seat. The SCI on-site vehicle inspection was completed on October 6, 2000.

SUMMARY

Crash Site

This single vehicle crash occurred during the nighttime hours of September 2000. At the time of the crash it was dark with no adverse weather conditions. The asphalt roadway surface was dry and the roadway was straight with a slight negative grade to the north. The crash occurred on a north/south two-lane undivided residential roadway with a double-yellow centerline. Concrete curbs bordered the roadway. The roadside environment consisted of grassy lawn areas with trees between the curbs and concrete sidewalks. There were residential driveways on the west road side. The posted speed limit was 40 km/h (25 mph).

Pre-Crash

The 1994 Ford Tempo was northbound on a two-lane roadway when the driver fell asleep and relinquished control of the vehicle **(Figure 2)**. The Tempo drifted to the left across the double-yellow centerline and departed the left side roadway **(Figure 3)**. The driver became aware of the impending harmful event and applied the brakes. Skid marks were noted on the road surface within the vehicle's trajectory indicative of pre-crash braking. They measured 1.7 m (5.6') and 4.8 m (15.7') from the left front and right front tires, respectively. The Tempo traveled over the curb edge and onto the grass. Gouge marks which measured 4.9 m (16.1') and 0.8 m (2.6') for the front left and front right tires, respectively were noted in the grass adjacent to the tree.

Figure 2.Northbound approach for the 1994 Tempo

Figure 3. Northbound approach drifting to the left

Crash

The Ford Tempo impacted a tree that measured 61cm (24") in diameter with the front center area **(Figure 4)**. The NASS-reported principal direction of force and WinSMASH results were revised by SCI based on the on-site investigation. The trajectory algorithm of the WinSMASH program computed an impact speed of 64.1 km/h (39.8 mph). The principal direction of force was 0 degrees. The damage algorithm of the WinSMASH program computed a total velocity change of 58.8 km/h (36.5 mph). The longitudinal and latitudinal components were -58.8 km/h (36.5 mph) and 0.0 km/h, respectively. The vehicle came to rest on the roadside adjacent to the tree facing north.

Figure 4. Impact area on the tree

Post-Crash

The driver was unconscious and found by police lying outside the vehicle. He was transported by ambulance to a local hospital and admitted for his injuries. The child passenger was removed from the vehicle by police. According to the police accident report, the child was found unrestrained in the child safety seat. The first responders found the child safety seat harness latch plate disengaged from the buckle assembly, and lifted the tray shield upward to remove the child. She was in cardiac arrest and revived by rescue personnel. She was transported by ambulance to a local trauma center where she was admitted to the pediatric trauma unit.

The vehicle remained at the scene for approximately two hours following the crash. Approximately two hours after the crash before the vehicle was removed, the damaged battery ignited a fire in the engine compartment. The fire damage was minor, and contained to the engine compartment.

***VEHICLE DATA* - 1994 Ford Tempo**

The 1994 Ford Tempo was identified by the Vehicle Identification Number (VIN): 2FAPP36X6RB (production sequence omitted.) The vehicle was a 4-door sedan equipped with front wheel drive, automatic transmission, and a 2.3 liter, 4 cylinder engine. The odometer reading at the time of the crash was 136,992 km (85,124 miles). The seating was configured with front bucket seats with adjustable head restraints and a fixed rear bench seat. The Tempo was configured with automatic 2-point shoulder belts and manual lap belts for both front seat positions. The rear outboard seating positions were equipped with 3-point lap and shoulder belt systems and the center position was equipped with a 2-point manual lap belt.

Figure 5. View showing loose contents in the trunk

The 1994 Ford Tempo had numerous unsecured items in the trunk which loaded the rear seat back at impact. Based on the vehicle inspection, the trunk contents included the following: a bag containing two pairs of shoes, a child stroller, child bathtub, two containers of radiator coolant, and a temporary spare tire (T125/80D13) which was also unsecured **(Figure 5)**.

VEHICLE DAMAGE

Exterior Damage -1994 Ford Tempo

The 1994 Ford Tempo sustained severe frontal damage as a result of the impact to the tree **(Figure 6)**. Maximum crush was located at C4 and measured 75 cm (30"). Direct contact damage began 39 cm (15") inboard of the front left bumper corner and measured 47 cm (19"). The combined direct and induced damage measured 75 cm (30"). The Collision Deformation Classification (CDC) was 12-FYEW-3. The hood was buckled rearward and upward at the designated fold points. The bumper fascia and bumper beam were bowed inward on both outboard sides, and the center of the beam was crushed rearward to the lower radiator support. Both front fenders were deformed inward at the front aspects. Both front wheels were restricted and left front tire was deflated **(Figure 7)**. The left wheelbase was reduced by 29 cm (11") and the right wheelbase was reduced by 13 cm (5"). The leading edge of the sills were buckled on both sides and both fenders overlapped the leading edges of the front doors. The roof was buckled on both sides at the B-pillars. The windshield was cracked from impact forces. Six crush measurements were taken by the NASS Researcher at the level of the bumper and were as follows: C1: 21 cm (8"), C2: 74 cm (29"), C3: 72 cm (28"), C4: 75 cm (30"), C5: 46 cm (18"), C6: 10 cm (4").

Figure 6. Frontal damage to Ford Tempo

Figure 7. Left side view of exterior damage

Interior Damage - 1994 Ford Tempo

Interior damage to the 1994 Ford Tempo was moderate and attributed to occupant contact and compartment intrusion **(Figure 8)**. A scuff mark was noted on the left instrument panel under the headlight switch. The plastic bolster cover under the steering column was displaced from occupant contact. Scuff marks were documented on the right aspect of the cover. A small abrasion was noted on the upper aspect of the steering wheel rim. The top half of the steering wheel rim was bent forward 5 cm (2") from occupant loading and the spokes were displaced from the steering wheel hub. The steering column was compressed from occupant loading. The left and right shear capsules were displaced rearward 1.2 cm (0.5"). The center instrument panel was fractured and the circular control knob for the fan control was displaced from the instrument panel. The rearview mirror was displaced, but remained fixed on the windshield. The driver's 2-point shoulder belt showed signs of loading. The center console between the front bucket seats was displaced forward. The glove box door had opened as a result of the impact. The front left seat back and right side aspect were deformed and scuffed from occupant loading and loading of the child safety seat.

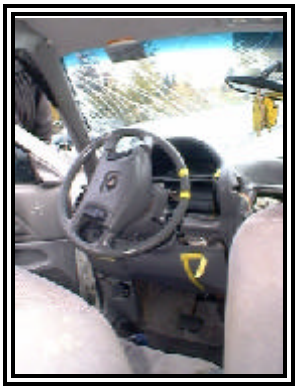

Figure 8. Interior view of front left position showing contacts

The rear seat back was intruded **(Figure 9)**. The most severe portion of the intruded rear seat back was the center position.

The NASS researcher documented the following intrusions and associated measurements:

Figure 9. Interior view of rear seat showing intrusion

Component	Magnitude of Intrusion	Direction
Front left toe pan	11 cm (4")	Longitudinal
Front left instrument panel	12 cm (5")	Longitudinal
Steering assembly	17 cm (7")	Longitudinal
Front center instrument panel	13 cm (5")	Longitudinal
Front right instrument panel	13 cm (5")	Longitudinal
Front right toe pan	19 cm (7")	Longitudinal
Rear left seat back	26 cm (10")	Longitudinal
Rear center seat back	35 cm (14")	Longitudinal
Rear right seat back	28 cm (11")	Longitudinal

CHILD SAFETY SEAT

Figure 10. Convertible child safety seat

The child safety seat installed in the Ford Tempo was a Century Select Model 3000STE **(Figure 10)**.The model number was 4388MAL01 and the date of manufacture was December 3, 1999. There were no NHTSA safety recalls associated with this convertible type child safety seat. The child safety seat was equipped with a 3-point harness system and adjustable rigid plastic tray shield. The tray shield was attached to pivoting arms on the outboard sides of the seat which allowed it to move upward and downward. The tray shield also moved forward and rearward along the plastic arms. The convertible child safety seat is designed to be oriented rear-facing or forward-facing. The recommended use indicated that the seat should be forward-facing for children weighing 9 - 18 kg. (20 - 40 lbs.) and up to 102 cm (40") in height. The 18-month-old female weighed 14 kg (31 lbs) and was 81 cm (32") tall. Instruction labels for the proper belt path were affixed to the side aspects of the seat shell. Labels with installation diagrams as well as height and weight parameters were affixed to the left side aspect of the child safety seat to illustrate proper usage. The child safety seat was equipped with a tether strap attached to the rear aspect above the reinforced area of the seat. The kick stand was engaged at the time of the crash. The tether strap was not used in this crash.

Misuse of the child safety seat was noted in this crash. According to the observations of the on-scene police officer, the child was found in the child safety seat with the harness system latch plate disengaged from the buckle. Based on the damage to the latch plate of the harness system, the latch plate was probably secured properly in the buckle assembly however, it can not be confirmed. The harness straps were in the lowest slot position even though the seat was in a forward orientation. The harness straps were probably not tight enough to properly restrain the child. At the time of the vehicle inspection, the one-piece plastic harness retainer clip was placed at the lowest point on the right harness strap, and the left harness strap was not routed through the harness retainer clip.

CHILD SAFETY SEAT DAMAGE

Figure 11. Harness straps pulled through plastic shell

The child safety seat involved in this crash sustained moderate damage as a result of occupant loading. Because the harness straps were not placed in the upper-most slot position, they were not positioned over the reinforced portion of the child safety seat, which allowed the harness straps to pull through the plastic shell on the rear aspect when the child loaded the harness straps **(Figure 11)**. Tears in the plastic rear aspect of the seat measured 3 cm (1") downward from outboard aspects of the lower slots. Damage was also noted to the rigid plastic tray shield which was displaced forward from the arms on the side of the seat. The occupant loading to the tray shield and the contact with the front left seat back caused the inside arm to

fracture on the left side and become disengaged. The right side of the tray shield was displaced from the right arm. The harness latch plate was deformed in a forward direction from occupant loading **(Figure 12)**. The rigid plastic bottom aspect of the child safety seat was scuffed from the forward travel on the rear seat cushion.

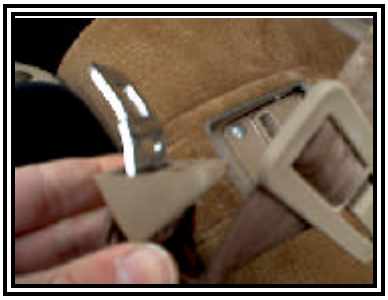

Figure 12. Damage to the harness latch plate and improper positioning of the harness retainer clip

***OCCUPANT DEMOGRAPHICS* - 1994 Ford Tempo**

Driver

Age/Sex:	32-year-old male
Height:	175 cm (69")
Weight:	107 kg (236 lbs)
Seat Track Position:	Between the mid-track and full-rear positions
Manual Restraint Use:	2-point automatic shoulder belt (2-point manual lap belt not used)
Usage Source:	Police report, vehicle inspection, injury data
Eyewear:	Not reported
Type of Medical Treatment:	Transported by ambulance to local hospital and admitted for 47 days

Driver Injuries

Injury	Injury Severity (AIS 90/Update 98)	Injury Mechanisms
Liver laceration - complex	Critical (541828.5,1)	Automatic belt restraint webbing/buckle
Diaphragm rupture with herniation	Severe (440606.4,8)	Automatic belt restraint webbing/buckle
Gallbladder laceration - massive	Serious (541224.3,7)	Automatic belt restraint webbing/buckle
Unconsciousness known to be less than one hour	Moderate (160202.2,0)	Steering wheel hub/spoke
Right rib fractures 7 and 9	Moderate (450220.2,1)	Automatic belt restraint webbing/buckle
Kidney laceration, NFS	Moderate (541620.2,1)	Automatic belt restraint webbing/buckle
Right eye subconjunctiva injury	Minor (240416.1,1)	Steering wheel rim
Facial laceration, NFS	Minor (290600.1,8)	Steering wheel hub/spoke

Injury source: Trauma center Emergency Room report, post-Emergency Room records

Driver Kinematics

The 32-year-old male driver of the Ford Tempo was presumed to be seated in an upright posture with the seat track adjusted between the mid track and full rear positions. The seat back was slightly reclined prior the crash, and retained its pre-crash orientation after the crash. He was restrained only by the automatic 2-point lap belt. He was not wearing the manual lap belt. According to police, the driver was fatigued and possibly fell asleep. He relinquished control of the vehicle and it drifted across the centerline. He may have realized the impending harmful event and applied the brakes in an attempt to avoid the crash. Tire marks were noted on the road surface within the vehicle's trajectory indicative of pre-crash braking.

As the Tempo impacted the tree, the driver initiated a forward trajectory and loaded the 2-point shoulder belt with his upper torso while his lower body submarined the shoulder belt. The loading against the shoulder belt caused severe abdominal injuries. He sustained a complex liver laceration, a diaphragm rupture with herniation, a gall bladder laceration, and fractures of right ribs 7 and 9. The steering wheel was probably rotated 180 degrees. He loaded the upper half of the steering wheel with his abdomen and deflected it forward. The loading to the steering wheel rim was transferred through the steering column as evidenced by the forward displacement of the left and right shear capsules 1.2 cm (0.5"). His head jack knifed over the shoulder belt and he struck the steering wheel rim/hub with his face which resulted in a right eye subconjunctiva injury and a facial laceration. Contact was noted on the outboard aspects of the left lower instrument panel from probable knee contacts, as well as contact to the upper center instrument panel from a probable fling of the right hand. However, there were no injuries associated with these contacts. He was found unconscious outside of the vehicle by first responders. He was transported by ambulance to a local trauma center and admitted for 47 days.

Rear Center Child Passenger

Age/Sex:	18-month-old female
Height:	81 cm (32")
Weight:	14 kg (31 lbs)
Seat Track Position:	Fixed
Manual Restraint Use:	Child safety seat installed with manual lap belt, and the child improperly restrained in the harness system
Usage Source:	Police report, vehicle inspection, and child safety seat inspection
Eyewear:	Not reported
Type of Medical Treatment:	Transported by ambulance to a local trauma center and admitted for 61 days

Rear Center Child Passenger Injuries

Injury	Injury Severity (AIS 90/Update 98)	Injury Mechanisms
Unconscious post resuscitation with inappropriate movements	Critical (160824.5,0)	Non-contact injury, head motion
Flexion injury with C2 vertebral body fracture separated from C1 with cord contusion and ligament damage	Severe (640218.4,6)*	Non-contact injury, forward head motion
Cerebral subarachnoid hemorrhage	Serious (140684.3,9)	Rebound into child safety seat back
Perineum laceration, NFS	Minor (543220.1,8)	Child seat harness/crotch strap

Injury source: Trauma center post-Emergency Room records
*NASS injury code was revised by SCI after case review

Rear Center Passenger Kinematics

The 18-month-old female rear center passenger was seated in a convertible child safety seat equipped with a tray shield and 3-point harness system. The child safety seat was installed in the center position of the rear seat and secured with the lap belt that was equipped with a locking latch plate. The child safety seat was in a forward-facing orientation with the forward-facing extension (kick stand) engaged and the lap belt routed through the forward-facing belt path. Several misuses were noted with the child safety seat, which likely contributed to the injuries of the child.

Prior to impact with the tree, pre-crash braking caused the child to initiate a forward trajectory. The contents of the trunk also initiated a forward trajectory. The harness straps were not routed through the top slots and were likely loose. According to the investigating officer, who was a Certified Child Safety Seat Technician, the first responding officer did not remove or adjust any of the components on the child safety seat at the scene, and the seat's configuration remained unaltered from the time of the crash. At the time of the child seat inspection, the harness retainer clip was attached only to the right harness strap, and was positioned at the lowest point on the strap. Since there was no damage to the one-piece plastic harness retainer clip, it was probably not engaged with the left harness strap at the time of the crash. These observations were consistent with the investigating officer's observations on the day of the crash.

At impact with the tree, the child continued the forward trajectory. The child passenger loaded the 3-point harness system of the child safety seat. The harness straps were in the lowest pair of slots and not in the upper slots above the reinforced portion of the child safety seat. The loading that was applied to them caused them to tear 3 cm (1") into the plastic shell on the rear aspect of the seat. The loading and forward head excursion caused a flexion injury with a C2 vertebral body fracture separated from C1 with cord

contusion and ligament damage. The additional slack in the harness system allowed the child to continue her forward direction of travel. She loaded the crotch strap and buckle assembly between her legs and sustained a perineal laceration. The harness latch plate showed significant loading from this event, as it was bent forward. The severe loading may have caused the latch to disengage from the buckle, but it could not be confirmed. The child loaded the tray shield with her torso and abdomen which caused the right tray shield plastic sleeve to disengage from the rigid plastic right arm. The left aspect of the tray shield struck the front left seat back. The rigid plastic left arm inside the left sleeve of the tray shield fractured completely as a result of the child's loading and the loading of the tray shield against the front left seat back. The yielding of the tray shield allowed her upper torso to continue forward into the front left seat back.

The loose contents of the trunk loaded the rear seat back, causing the center rear seat back to intrude forward 36 cm (14") **(Figure 13)**. This caused the child safety seat to travel forward and load the lap belt. The child safety seat was probably not tightly secured, as there was minimal abrading to the plastic shell through which the lap belt was routed. The lack of more severe loading evidence to the lap belt indicates that there was probably slack in the lap belt prior to the loading applied to it. The lap belt buckle assembly remained engaged and there were no performance failures despite the intrusion and forward travel of the child safety seat. The forward travel of the child safety seat allowed it to contact the rear aspect of the center console which displaced the top portion of the console.

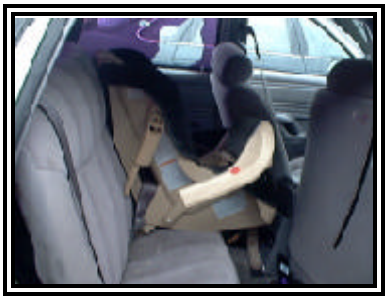

Figure 13. Approximate position of the child safety seat and intruded rear seat back

The child rebounded rearward and the rear aspect of her head struck the child safety seat back below the head cushion which resulted in a cerebral subarachnoid hemorrhage. She came to rest in the child safety seat with her chin resting on her upper chest. According to the police, she was found lying in the child safety seat with the harness latch plate disengaged from the buckle. She was found to be in cardiac arrest. The first responding officer lifted the tray shield over the child's head and removed her from the child safety seat. The child was revived with CPR. She was transported to a local trauma center and admitted for 61 days.

At the time of discharge, the child still required respiratory support by mechanical ventilation, and demonstrated quadriplegia with limited inconsistent return of extremity motor function. She was discharged under family care and continued to receive skilled nursing care and outpatient occupational and physical therapy.