

An Accident Study of the Performance of Restraints Used by Children Aged Three Years and Under

Final Report with sensitive material removed

A study commissioned by ANEC, the European consumer voice in standardisation, AISBL, Avenue de Tervueren 32, Box 27, B-1040 Brussels, Belgium



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VSC Ltd gratefully acknowledges the considerable work undertaken by the NASS researchers in compiling the accident records which go to make up the NASS database. It is to the credit of the US Government that the information gathered is freely available to potential researchers on the internet.

2 Executive Summary

For many years it has been the norm in the Nordic countries to carry children up to approximately four years of age in rear facing child restraints. In the rest of Europe and in the United States children have traditionally been put into forward facing restraints at about one year of age or less. There are detailed differences between the legislation controlling the production and performance of child seats in the USA and Europe, but nevertheless there is sufficient similarity for the accident experience in the two continents to be considered. This project set out to examine three sources of accident data with the aim of providing guidance as to which form of restraint is best for children up to four years old.



Nine month old child and same child at three and a half years old in same large Nordic rearward facing child seat installed in a VW Golf

The research considered a sample of accidents from the UK in which restrained children had died, a sample of US accidents in which restrained children had either died or received serious injury and the population of accidents in Sweden in which restrained children had died over a period of seven years.

The intention was to look for cases that illustrated the limits of protection in either form of restraint. In addition to the accident studies, a limited look at recent literature was undertaken to document the latest published findings in this area.

The UK, US and Swedish accident databases all have examples of unexpected poor protection in forward facing seats. These problems concern neck injury, head injury, chest and abdominal damage. In these cases where there are problems, use of well designed rearward facing restraints would avoid the injuries seen in most cases. This leads to the suggestion that children up to four years of age would be better protected if they travelled rearward facing in a suitable restraint. The Swedish data indicates that there are no dis-benefits associated with this pattern of use.

The literature contains clear information that car bodyshells are getting stiffer in frontal impacts, as vehicle manufacturers seek to maximise adult protection in consumer information programmes that potentially can influence their market

share. Use of the larger rearward facing seats for children up to four years would contribute to counteracting this increase in the severity of impacts experienced by restrained children. Without such a change, it seems likely that the incidence of overload for children in forward facing seats is likely to increase in the future.

To maximise the protection for children, it is important that additional loading from luggage in the boot area is avoided by more rigorous strength and test requirements for rear seat backs in vehicles.

For the rearward facing restraints themselves the following points emerged as important to maximise their effectiveness:

- The shells of the child seats need to be large enough to ensure that the larger child's head is well contained during the impact
- Energy absorption within the child seat, in the area where the head will contact, is important in ensuring tolerable skull loading and brain deceleration
- The possibilities for misuse must be minimised by design

Within the car, for rearward facing seats to deliver their best protection, it is important that:

- All occupants are restrained in order to avoid unfavourable interaction with the restrained child
- The passenger's frontal protection airbag is switched off reliably or disabled in some way when a rear facing restraint is placed on the front passenger seat
- The vehicle designer anticipates that children may be seated in a rearward facing child seat and that countermeasures, such as side curtains, should anticipate a child's head in the appropriate area.

It is clear that a wide gulf has developed between the conclusions of the technical community, based on accident and test experience, and the guidance provided to consumers via legislation. The technical community appears unanimous that rearward facing restraints offer the best protection until the child is around four years old. However, through the Mass Group classification European legislation implies that it is safe for a child to travel forward facing from 9 kg onwards. For an average child 9 kg represents ten months of age for females and eight months for males. It is clear therefore that the consumer is not receiving the best technical advice via the current mass group approach within legislation. It is notable that the average four year old weighs around 16.5 kg.

The report reviews what actions would be necessary in the fields of legislation and public information to encourage the best practice from the Nordic countries to be adopted throughout the rest of Europe.

I M P O R T A N T N O T I C E

It is most important that no photographs from the UK or Swedish data are used in any form of publication or presentation until formal clearance has been obtained for such use from the holders of the copyright. All photographs from the NASS database are able to be used without further clearance.

3 Introduction

This work was commissioned by ANEC, the European consumer voice in standardisation, to contribute to an understanding of how children aged three years or less should best be restrained in cars. There is a mix of current practice, with Nordic countries traditionally keeping their children in rearward facing restraints until three or four years old, whereas the rest of Europe and the US traditionally turn their children forward facing at around one year of age or less. For many years, researchers studying the performance of restraints in the field have found that whilst either form of restraint provides major benefits compared with being unrestrained, rearward facing restraints appear to offer the highest overall levels of protection for younger children.

Tests comparisons of forward and rearward facing restraints have shown similar preference for the rearward facing orientation. Dummy loading has been shown to be significantly reduced in rearward facing restraints and the loads generated are more evenly spread over the child's body.

Detailed accident studies have identified a few cases reported in the literature in which children in forward facing restraints have suffered unexpectedly severe injury in circumstances in which it would be hoped that they could be better protected.

Under the influence of consumer rating programmes looking at the crashworthiness of vehicles, car bodyshells have become progressively stiffer over the last decade. These design changes have been made to improve adult protection in the front seats, reducing the risk of passenger cell intrusion directly causing injury. Adult protection has been further enhanced by a range of sophisticated countermeasures such as seat belt pre-tensioners, load limiters and airbags. The bodyshell design countermeasures introduced for adults have inadvertently made the impact environment for restrained children in the rear seat worse in frontal impacts, in that the acceleration pulses to which they are exposed have become progressively more severe. There have been few innovations to counter this trend for the restrained child.

The current study has been undertaken to examine the hypothesis that keeping children rearward facing until they are four years old would be the best method of improving protection for this age group. This hypothesis is attractive as it could be done quickly, with existing technology that is in normal everyday use in Nordic countries.

The accident experiences in three regions were examined. The aim was to check two aspects:

1. Were there any field accident examples of unexpected injury in rearward facing restraints?
2. Were there further examples of unexpected injury in forward facing restraints that could contribute to an understanding of the situation?

The cases of interest are those that occurred at a crash severity in which good protection would be anticipated for a restrained child and in which there was no

local passenger compartment intrusion compromising the protection offered to the child.

Access to detailed accident data is not easy and some important potential sources of information are not available to the research community as a whole, for example the Co-operative Crash Injury Study (CCIS) in the UK. Access to detailed accident data is an important consumer issue but one that is not addressed in this study.

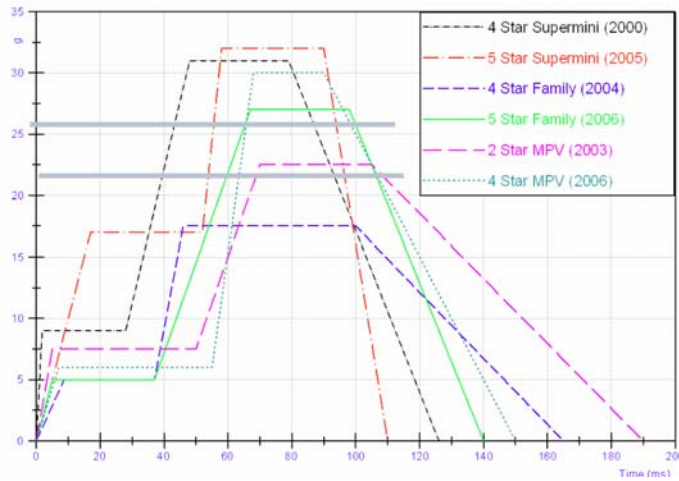
For the current work, access was granted to the population of Swedish fatal accident records and these were checked to see if any unexpected fatalities in rearward facing restraints had been observed. We were also permitted to look at a sample of UK fatal accident records to check for unexpected injury to restrained children. Finally the US National Accident Sampling System (NASS) was examined to check the experiences of restrained children under four years old. Commendably these records are freely available via the Internet. The UK and US are countries in which children tend to travel forward facing usually at less than one year old, whereas Sweden contains many children, up to around three or four years old, in larger rearward facing systems.

The report begins by considering the guidance contained within recent literature and then goes on to consider the lessons from the three different accident data sources examined.

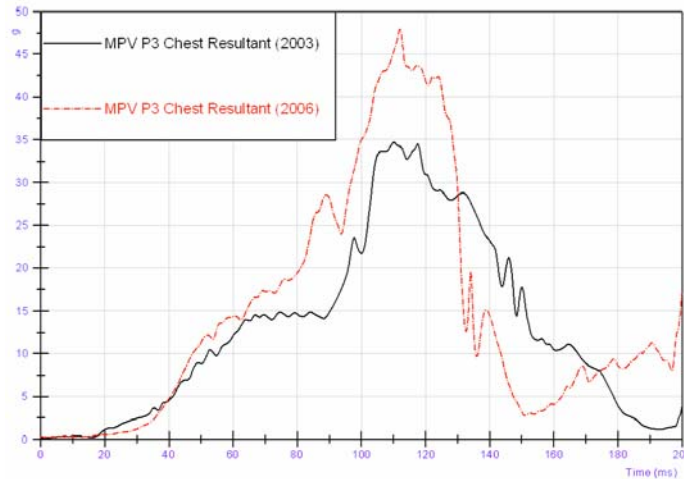
4 Guidance from the Literature

The project outline did not include a comprehensive literature survey, but nevertheless it was felt to be helpful to summarise the general conclusions from the published information. The following conclusions have been drawn:

1. For children of three years old or less, there are a number of reported accidents in which those seated in forward facing restraints have suffered severe or fatal injuries in circumstances in which it would be hoped they could be protected. Injuries include those to the head, neck chest and abdomen.
Kirley, et al (2007), Cassan, et al (2006), Kirk, et al (2006), Jakobsson, et al (2005)
2. A number of studies, both accident and test based, have concluded that rearward facing restraints offer advantages over forward facing systems for the age group covered by this study. The advantages come in part from better load spreading over the body in a frontal impact and direct support of the head, rather than relying on loading transmitted through the neck to decelerate the head. In side impacts with a forward component of force, there is the prospect of a child in a rearward facing restraint moving into the shell and the side protection potentially contained within the seat shell, rather than moving out of the protective shell, as tends to occur with a forward facing restraint in similar circumstances.
Sherwood and Crandall (2007), Görlitz, (2007), Sherwood, et al (2006), Jakobsson, et al (2005), Kamrén, et al (1993), Kamrén, et al (1991)
3. There is inevitably a delay in accident data becoming available to the research community. This means that findings from accident studies are at least three or so years old. The accidents in which the shortcomings of forward facing restraints are demonstrated necessarily occurred a few years ago.
4. In recent years, there has been a definite trend for car designers to respond to the market forces generated by consumer information programmes, such as Euro NCAP. Part of this response has resulted in stiffer passenger compartments and higher peak passenger compartment deceleration levels in frontal impacts. A number of studies have documented this trend in the vehicle deceleration data measured in the consumer information tests. This implies that the decelerations to which children in child restraints are exposed are rising, by design.
Bendjellal and Malmaison (2007), Menon, et al (2007)

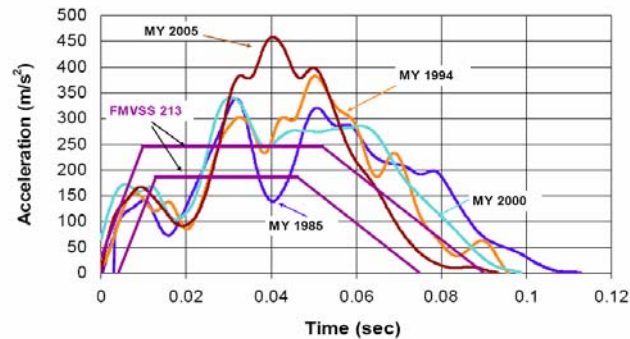


Simplified B-pillar pulses from Euro NCAP vehicles taken from *Bendjellal and Malmaison (2007)*



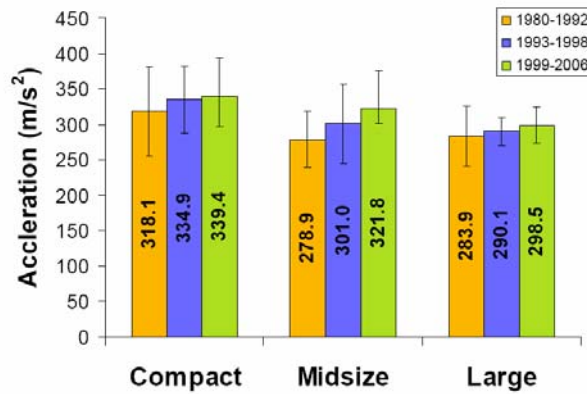
P3 dummy chest resultant traces in a Euro NCAP test using the same CRS in the same vehicle but from different model years taken from *Bendjellal and Malmaison (2007)*

Exemplar Vehicle



US NCAP pulses for different model years of the same vehicle taken from *Menon, et al (2007)*

Max Acceleration Trend



Pulse trends in US NCAP for different classes of vehicle taken from *Menon, et al (2007)*

5. Adult protection systems for frontal occupants have undergone major developments to enable these occupants to benefit from the increased ride down space generated by the stiffer passenger compartments. The accident experience with these more refined restraints, incorporating pre-tensioned and load limiting seat belts together with airbags for the head and sometimes the knees, is encouraging.
6. On the whole, children have not enjoyed equivalent developments in their protection systems.
7. The time is right to examine carefully the merits of extending rearward facing restraints for children up to four years old. The Scandinavian experience of these seats is very encouraging and the timely adoption of this form of restraint may provide the necessary countermeasure for the

increased decelerations that children will predictably be exposed to in the coming years.

Walter, et al (2007), Jakobsson, et al (2005),

8. To experience the full benefits of rearward facing restraints, particular care needs to be exercised in three areas:

- If used in the front seat, the frontal protection airbag must be switched off or disabled in some other way.

Lesire, et al (2007), Brämig (2006)

- All occupants in the car must be restrained otherwise they may be projected into the child in the rearward facing restraint in the front seat in a frontal impact

Kamrén, et al (1993)

- As with all forms of restraint, misuse must be avoided. Accident cases have been reported with infant restraints in which the adult seat belt has been misrouted around the restraint shell.

Ratzek and Paulus (2007)

5 Findings Based on the UK Fatal Accidents Data

The UK fatal database is a good source of information when looking at the limits of protection. We have sought to understand for each restrained child fatality; the nature of their injuries, the likely cause of each injury and to reflect on any countermeasures that might have enabled the child to survive. This database is a powerful tool for gathering examples of what has killed restrained children, in this instance. There has been no attempt to comment on the nature of the sample of accidents examined compared with all fatal accidents involving restrained children in the same time period, either in the UK or Europe. The intention is simply to add to the body of published knowledge about the limits of protection offered by child restraints for this age group of children.

5.1 Forward facing child seats

The limit of performance of forward facing seats was illustrated in eight accidents. Injuries to the head and neck, chest and abdomen were all seen. The risk of trying to decelerate the relatively massive head of a young child via the relatively fragile neck is well demonstrated.

In six of the eight accidents the research team judged that the child would have survived had they been seated in a suitable rearward facing child seat. The ages of these children ranged from five and three-quarter months to just under four years old. In the remaining two cases the protection offered by a rearward facing seat would have been compromised by additional loading from luggage in the boot area and gross roof intrusion into the seating position. The children in these accidents were aged seven months and one and half years old.

5.2 Rearward facing child seats

For the youngest children in rearward facing infant restraints, one example was encountered in which increased attention to providing meaningful energy absorption behind the head within the child seat itself would have helped. This seven month old fatality experienced blunt head trauma as a result of loading from the child seat itself.

Two cases are documented in which the routing of the adult seat belt around the rearward facing infant restraint has been incorrect. The children were aged five weeks and six months. In both cases this misuse resulted in poor protection in an otherwise survivable accident. These examples further emphasise the need to reduce the option for misuse to a minimum by design.

The remaining four cases involving rearward facing restraints all exhibited situations in which the ability of the restraint to protect the child was overwhelmed by intrusion in the seating position occupied by the child. Massive intrusion can compromise any restraint, irrespective of its orientation and such accidents are a feature of any study of restrained occupant deaths.

5.3 Adult seat belt

A single case is reported of a young child (three years old) in an adult seat belt alone. She suffered head, chest and abdominal injuries in circumstances that would be survivable in a rearward facing restraint. It is possible that a forward facing child seat would have provided better restraint than the adult seat belt alone but the rearward facing restraint appears to offer the most robust solution in these circumstances.

Two cases were encountered which are recorded for interest, although they lie outside the strict terms of reference of the study. The first involves a non-fatal ejection of a three and a half year old from behind an adult belt, used in conjunction with a booster cushion, in a side impact, a situation whose explanation offers challenges to the car designer. The second case involves a woman who was pregnant and gave birth to the child who subsequently died. This case may be of interest to those developing dummies to represent pregnant women.

6 Findings Based on the US NASS Data

The second source of data used for this research was the National Automotive Sampling System (NASS) database operated by the National Highway Traffic Safety Administration (NHTSA) in the United States. The information is useful in that it complements the data already gathered in the UK and Sweden and also allows insights into the US accident scene which will help engage the USA in discussions about the future of child restraint legislation in Geneva. In general terms patterns of use in the USA are more like mainland Europe than the Nordic experience.

There are detailed differences in the legislation which controls the performance and production of child seats in Europe and the US. This results in some specific differences such as the rigid T-shield attached to shoulder harnesses which plugs into the base of the child seat shell. This type of restraint is allowed in the US but prohibited in Europe. Another key difference is the use in the US of the lap belt only to restrain rearward facing child seats to the vehicle; whereas in Europe the lap and diagonal sections of the belt are used.

6.1 Forward facing child seats

Within the accidents looked at in detail, there were three examples of children in forward facing seats receiving neck injuries without any evidence of a head contact. The ages of the children were, 18 months old, two years old and three years old.

There are a further three examples of children in forward facing seats suffering neck injury with head contact. There were two three year olds and a 22 month old child.

There is an additional case in which an eight month old sustained a neck injury in a side impact.

Of these six instances of forward facing restraints where the child suffered a neck injury, the researchers judged that four would certainly have been better protected in a rearward facing restraint. The remaining two cases would also have benefited from rearward facing restraint, but would have required good restraint of luggage in the boot area to ensure the best protection. The detailed case studies can be found starting on page 24.

6.2 Rearward facing child seats

Three cases of problems seen with rearward facing seats were documented. They illustrated a number of issues for rearward facing restraints including;

- Ejection of a five month old child from their infant restraint in a side impact followed by a rollover.
- The need for the shell of the child seat to be larger to better accommodate bigger children.

- The desirability of improved energy absorption within the child restraint behind the child's head to reduce skull loading and brain deceleration when the child is completely contained within the seat shell.
- The need to provide better control of seat rotation to reduce forward movement and reduce dependence on the internal harness for controlling the child's movement within the seat. The rotation of the child seat is less well controlled in the US compared with Europe as a result of allowing the child restraint to be held in the vehicle using the lap section of the belt alone. This may put higher demands on the harness for keeping the child within the seat. This is a difficult role for the harness to play especially in accidents when there is an impact followed by rollover, particularly for younger children where the shoulders are not anatomically well developed. Larger rearward facing seats in Europe often use a support leg or other means to reduce seat shell rotation.
- For all child seats, whether forward or rearward facing, it is important that they are not subjected to additional loading from luggage breaking through from the boot. If luggage in the boot causes either major rear seat back distortion or, indeed, seat back release, the child restraint can be subjected to higher loads than anticipated by the child seat designer. Such additional loading can lead to fracture of the child seat shell or cause the restraint and child occupant to have a trajectory much less favourable than would have occurred otherwise.

6.3 Other observations

Whilst the detailed case studies contain the lessons of most relevance to the current study, the remaining cases contain a wealth of lessons related to child restraint experience. For example, there are two further accidents in which additional loading from luggage has influenced the injuries to the restrained child. There is an example of a child unbuckling itself distracting the driver, leading to the deaths of three people. There are no less than 14 examples of misused child restraints, illustrating the accident consequences of misuse so often reported in user surveys. The hazard posed by unrestrained occupants to children in restraints is illustrated in three accidents.

As with all studies of restrained occupant experience, there are numerous examples (14 accidents) in which the restraint performance is completely overwhelmed by localised intrusion. For the children in forward facing seats there are accidents illustrating the circumstances in which fractures to the lower limbs can occur (five accidents). There are four accidents in which fracture of the clavicle occurred.

Somewhat unusually for a study of restrained children, there are ten examples of ejection, either partial or complete. It is hoped that this brief overview of the remaining cases, that have not been the subject of detailed description on this occasion, serves to emphasise the richness of this data source for those interested in further refining child restraint design.

7 Findings Based on Swedish Fatal Accident Data

The Swedish accident experience is of interest as, traditionally, children in Sweden are carried rearward facing until around three or four years of age, whereas in the rest of the world children tend to be carried forward facing from around one year of age. The Swedish fatal data provides a unique possibility to check if any unexpected fatalities have occurred in the larger rearward facing seats. It provides an answer to the question of whether there are any disadvantages to restraining children of this age in a rearward facing orientation.

All the fatal accidents involving children aged between zero and three years old from the time period 1999 to 2006 were examined. In all 17 fatal accidents were pulled from the database.

Four cases involving unrestrained children were excluded from the study. A further case was excluded as a post impact fire had made restraint use and seating position unverifiable and another case had been misidentified and in fact involved a newborn child being transported in a pram by a pedestrian.

7.1 Rearward facing child seats

In the 11 accidents there were four children in rearward facing seats who died. There were no cases in which the rearward facing seat's impact protection could be criticised. Those that died became the victims of; excessive localised intrusion (2 cases – 14 month old and two year old), fire (1 case – 1½ year old) or drowning (1 case – three year old).

7.2 Forward facing child seats

In the 11 accidents there were six children in forward facing restraints who also died. Three of them died in unexpected circumstances. In the first case a two and a half year old child on a booster seat routed the diagonal section of the adult seat belt under her arm whilst attempting to retrieve an item from the footwell, resulting in direct head contact with the car interior in the impact. In the second case a two and half year old child in a booster seat suffered severe abdominal injury and lung contusions. The third case involved a two year old seated on a booster cushion in a high energy frontal who sustained a shearing neck injury following head contact with the vehicle interior. These three accidents would have been potentially survivable frontal impacts if the children had been in rearward facing restraints. The remaining three cases involving children aged 2½, 3 and 3½ years old, occurred in circumstances where severe intrusion overwhelmed the restraints. It is likely that these children would have died irrespective of the orientation of their child restraint.

There was a single case in which a newborn child died in a carrycot restraint in a side impact that was considered survivable had the child been in a rearward facing infant restraint.

Thus overall, this check of Swedish restrained child fatal cases provides no examples of cases in which the impact protection of rearward facing seats could be criticised. There are two cases in forward facing seats that illustrate the types of problem seen in other countries where the use of forward facing seats is the norm for this age group.

8 Conclusions

The UK, US and Swedish databases all have examples of unexpected poor protection in forward facing child seats. The problems concern neck injury, head injury, chest and abdominal damage. In these cases where there are problems, use of well designed rearward facing child restraints would avoid the injuries seen in most cases. This leads to the suggestion that children up to four years of age would be better protected if they travelled rearward facing in a suitable child restraint. The Swedish data indicates that there are no dis-benefits associated with this policy.

The literature contains clear information that car bodyshells are getting stiffer in frontal impact, as vehicle manufacturers seek to maximise adult protection in consumer information programmes, such as Euro NCAP, that potentially influence their market share. Use of the larger rearward facing child seats for children up to four years of age would contribute to counteracting this increase in the severity of impacts experienced by restrained children. Without such a change, it seems likely that the incidence of overload for children in forward facing child seats is likely to increase in the future.

It is clear that a wide gulf has developed between the conclusions of the technical community, based on accident and test experience, and the guidance provided to consumers via legislation. The technical community appears unanimous that rearward facing restraints offer the best protection until the child is around four years old. However, through the Mass Group classification, European legislation implies that it is safe for a child to travel forward facing from 9 kg onwards. For an average child 9 kg represents ten months of age for females and eight months for males. It is clear therefore that the consumer is not receiving the best technical advice via the current mass group approach within legislation. It is notable that the average four year old weighs around 16.5 kg.

To maximise the protection for restrained children, it is important that additional loading from luggage is avoided by more rigorous strength and test requirements for rear seat backs.

For the rearward facing child restraints themselves the following points emerged as important in order to maximise their effectiveness:

- The possibilities for misuse must be minimised by design
- The child seat shells need to be large enough to ensure that the larger child's head is well contained during the impact
- Energy absorption within the child seat, in the area where the head will contact is important in ensuring tolerable skull loading and brain deceleration

Within the car, for rearward facing child seats to deliver their best protection, it is important that:

- All occupants are restrained in order to avoid unfavourable interaction with the restrained child

- The passenger's frontal protection airbag is switched off reliably or disabled in some way when a rear facing child restraint is placed on the front passenger seat
- The vehicle designer anticipates that children may be seated in a rearward facing child seat and that countermeasures, such as side curtains, should anticipate a child's head in the appropriate area.
- Space is allowed within the vehicle to accommodate rearward facing child restraints suitable for children up to four years of age

The US data shows a surprising number of examples of child ejection from their child seat. This doesn't seem to be a feature of the UK or Swedish data. The source of these problems seem to involve the following aspects:

- Shield type seats are more common in the US than in Europe and several of the ejections occurred from this type of seat
- The rotation of the child seat is less well controlled in the US compared with Europe as a result of allowing the child restraint to be held in the vehicle using the lap section of the belt alone. This may put higher demands on the harness for keeping the child within the child seat. This is a difficult role for the harness to play especially in accidents when there is an impact followed by rollover, particularly for younger children where the shoulders are not anatomically well developed. Larger rearward facing child seats in Europe often use a support leg or other means to reduce seat shell rotation.

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10 UK Fatal Accident Data

10.1 Introduction

10.1.1 Police Fatal Accident Files

The cases for the project were drawn from police fatal accident files which are archived and stored at the Transport Research Laboratory (TRL) for research purposes under a project funded by the UK Department for Transport.

The contents of the files serve a dual purpose. The files are prepared routinely for Coroner's Inquests – the formal inquiry into a sudden death in the UK where the cause of death is established. They are also aimed at providing any evidence of wrongdoing for possible prosecution by the Crown Prosecution Service.

The files typically contain:

- Photographs of the vehicles involved
- Photographs of the accident scene
- Plan of the accident
- Post Mortem report
- Witness statements including police interviews, and vehicle examiner's report
- Summary of the accident prepared for prosecution or otherwise
- Contemporaneous police accident report notes

There is one file per accident irrespective of the number of fatalities involved. Nominally all police forces in England and Wales, with the exception of the City of London, have an agreement to send TRL their inactive files for storage. In practice though, geographic coverage can be patchy as different forces and sections within forces have varying responses to file transfer and disposal. The time delay between the accident and the file arriving at TRL also varies across the police forces. The files tend to arrive from the police forces in batches. After 15 years the files are either destroyed or returned to the relevant police force.

The aim of the activity at TRL is to relieve the police of the need to store the files long-term and to provide a resource for the accident research community.

10.1.2 Stats 19

The national road accident statistics in the UK are compiled in a database called "Stats 19". It consists of a simply coded record of all injury producing vehicle accidents in the UK. The data is coded by the police forces and contains a basic description of each accident in terms of time, date, place, a description of the types of casualties, and their overall injury severities. The information is basic, for example the injury data falls into three categories of slight, serious and fatal; the criteria for a serious injury being an overnight stay in hospital or a fracture as a minimum. A fatal casualty is someone who dies within 30 days of the accident.

The restraint use of each casualty used to be recorded within the Stats 19 database, but this variable has now been dropped.

All of the fatalities within the police fatal files are included on the Stats 19 database, but not all of those files are available at TRL. The files may not be held at TRL for a number of reasons, including the fact that the police force concerned is not part of the agreement to send cases to TRL or that they hold on to cases longer before sending them on to TRL. In some cases a prosecution might still be pending.

The accidents in Stats 19 are identified via an individual reference number generated by the police force dealing with the accident. All files in the TRL archive have an individual TRL generated reference number. The TRL reference number is generated as files arrive for archiving at TRL and does not therefore follow a chronological order based on the date of the accident.

10.1.3 Analysis of Stats 19

A special analysis of the Stats 19 database was commissioned at TRL to identify cases which were in line with the criteria for the study. The analysis identified all fatal car occupant accidents in which the fatality was under 4 years old in the years 1999 - 2003. This time period was chosen to identify the most recent accident cases that might now be at TRL.

The first part of the special analysis of Stats 19 identified 63 accidents as potentially falling within the remit of the study. The second part of the special analysis linked the results from the first analysis to the actual cases held at TRL, using the police accident number to generate appropriate TRL case numbers. Of the original 63 accidents identified in the first part of the analysis, only 21 cases were available at TRL.

Access to the case files was negotiated with TRL. As the files contain sensitive personal information Vehicle Safety Consultancy Ltd utilised their Data Protection Code of Practice dealing with the internal use of accident data for research purposes.

To supplement the cases identified from the Stats 19 analysis, a further eight cases from earlier periods were selected for study as they contained relevant information for this age group.

10.1.4 Filtering of Cases

A total of 29 cases were requested from the archives at TRL. Only 28 were actually available for study, as one had been recalled by the police force concerned.

The cases were examined in order to ascertain whether they met the study criterion for restraint use and whether the case was sufficiently well documented to allow further in-depth analysis.

In order to ascertain whether the case fitted the study criteria the file was read through until restraint use was established. As previously noted the police files are not put together with in-depth injury causation analysis in mind. Therefore, key details of interest to the accident researcher may be hidden in witness statements, concealed in the background of a photo, or in some cases absent.

Of the 28 cases extracted from the archives at TRL, 16 cases were deemed usable for the current purposes. Many of the cases inevitably involved unrestrained fatalities, many seated on the lap of an adult. These cases were discarded. A further case involving an unborn child was also examined and documented bringing the total number of cases examined to 17.

The cases of interest are described below. It is worth emphasising the rich source of information that is available within the accumulated fatal files in general and to stress the value that this resource represents to the research community. It is currently, perhaps, undervalued. It represents a very unusual resource within the EU.

For the detailed case summaries that follow we start by looking at rearward facing seats before moving on to look at forward facing seats with harnesses, booster seats and cushions, adult seat belts and finally a case involving an unborn child.

11 NASS Case Summaries

The second source of data used for this research is the National Automotive Sampling System (NASS) database operated by the National Highway Traffic Safety Administration (NHTSA) in the United States.

NASS is basically an accident analysis database which comprises two systems – the Crashworthiness Data System (CDS) and the General Estimates System (GES). Both systems use cases selected from a sample of police crash reports within randomly selected areas of the USA. The CDS data is based on in-depth analysis of accidents compiled by field accident investigators concentrating on passenger vehicle crashes with a focus on injury mechanisms. The GES data comes from a larger sample of crashes, but only basic information from the police accident reports is entered into the NASS database. The CDS database covers injury as well as death, with the majority of sample cases related to injury rather than death. Unusually, and commendably, this data is freely available to researchers via the internet. All data is made anonymous before being placed on the internet and thus all the data is already in the public domain and can be used in whatever way is seen as useful.

The system was interrogated to provide all cases in which a restrained child of three years old or less received an injury rated on the Abbreviated Injury Scale (AIS) between 2-6. There were 97 accidents, containing 113 restrained children, meeting these basic search criteria. Each of these cases was scrutinised to check for the adequacy of coverage and to understand the basic accident circumstances. From this initial scan, the most interesting and relevant cases for the current study were identified and documented in detail. These case studies start in page 25. The cases are arranged in the following order: forward facing neck injury cases with no head contact, forward facing neck injury cases with head contact, side impact neck injury case and rearward facing cases.

The information is useful in that it complements the data already gathered in the UK and Sweden and also allows insights into the US accident scene which will help engage the US in discussions about the future of child restraint legislation in Geneva. In general terms patterns of use in the USA are more like mainland Europe than the Nordic experience.

11.1 Forward Facing Neck Injury Cases – No Head Contact

11.1.1 NASS Case Id 170001629



Summary

This is relatively low severity 11 o'clock frontal impact. There was no passenger compartment intrusion relevant to the positions occupied by the children. A two year old, seated in a harness and shield type forward facing child seat on the right rear third row seat, suffered a neck injury. It appears that she had no head contact. She suffered no other recorded injuries apart from a cervical spine dislocation, AIS 2. She survived this injury. This is an example of a neck injury induced by unfavourable loading on the neck rather than by any shearing induced in the neck following a head contact. The key factor appears to be the forward orientation of the seat and the induced neck loading rather than an issue of excessive forward movement. It represents poor protection in this relatively low energy event. Had the child been using a rearward facing child seat it is judged that the injuries would not have occurred.

On the left middle row seat there was an eleven month old seated in a rearward facing infant restraint. She suffered a bruise on her forehead, possibly due to some interaction with the unrestrained occupant in the seat beside her.

Lessons Learned

Forward facing shield and harness seat

- Travelling forward facing for this two year old child in a low energy impact placed excessive loads on the neck without any apparent head contact.

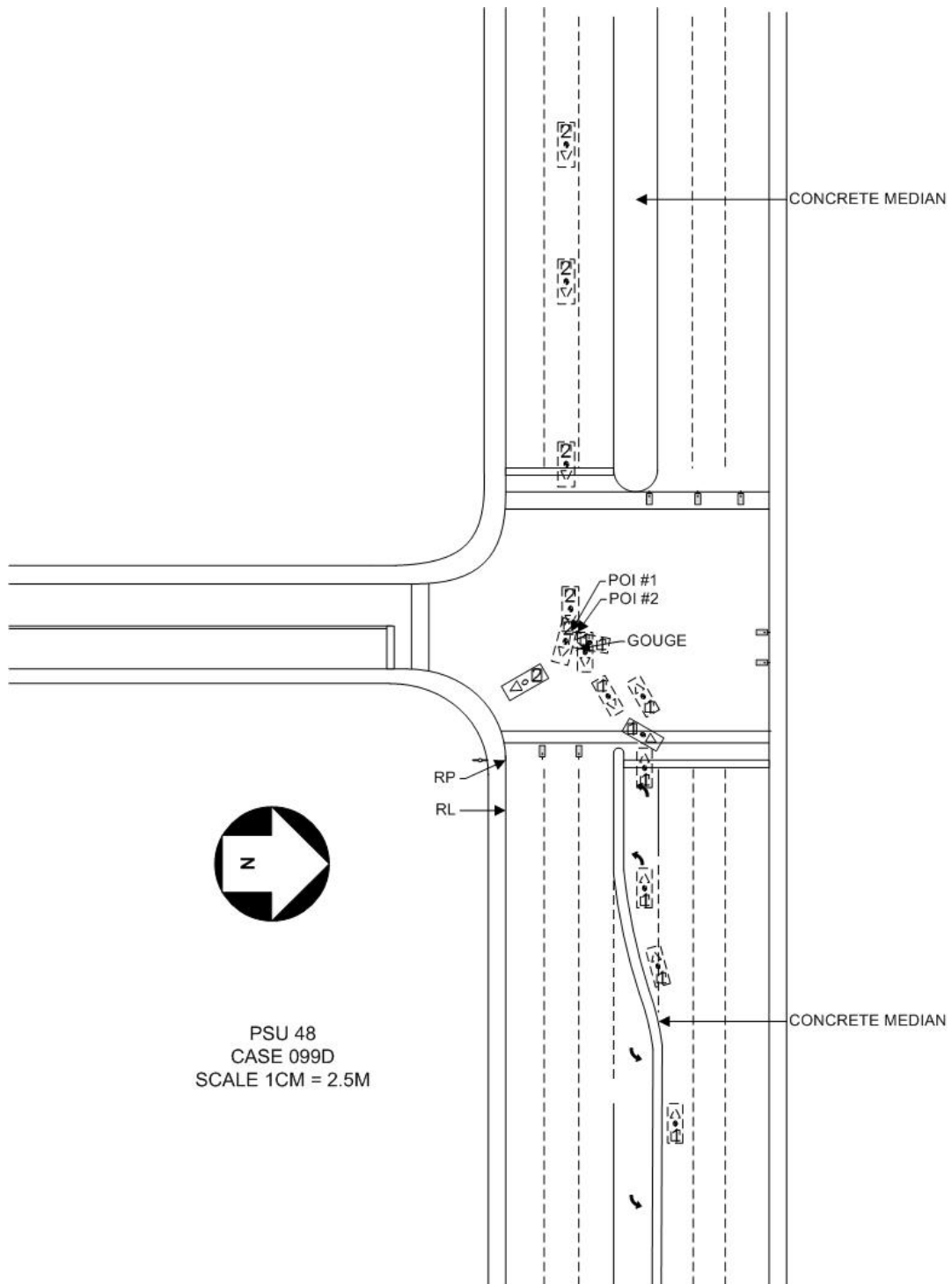
Suggests that travelling forward facing was not appropriate for this child at this age as witnessed by the experience of the other child in the impact.

Rearward facing integral harness seat

- This is an example of a rearward facing child seat providing superior restraint to the forward facing child seat in this impact.

Accident summary according to NASS

V1 a Chevrolet S-10 Blazer 1985 was travelling west in the rain on a divided (w/o positive barrier) 7 lane roadway, in the left turn lane approaching an intersection regulated by a traffic signal. Meanwhile, V2 a Plymouth Voyager minivan 1992, was eastbound on the same roadway in the middle lane approaching the same intersection. V1 made a left turn at the intersection when the front of V2 struck the right plane of V1, causing V1 to spin ccw, side slapping V2 on the left plane with its right rear corner. V1 continued to rotate ccw to final resting place in the intersection facing NE. V2 rotated cw slightly, coming to frp in the intersection facing SE. The restrained driver in V1 was not reported injured. The restrained driver of V2 with deployed air bag was not reported injured. The 2nd row left occupant of V2, restrained in a child safety seat, was transported, treated and released from a local trauma centre. The unrestrained 2nd row, centre seated occupant of V2 was transported, treated and released. The 3rd row right occupant of V2, also restrained in a child safety seat was transported, treated and released. Both vehicles were towed due to disabling damage.



Schematic diagram of the accident

Vehicle Details

Vehicle: Plymouth Voyager 1992

VIN: 1P4GH44R4N

Engine: 3.3 litre petrol

Delta V: 16 km/hr 10 mph (longitudinal 15 km/hr 8 mph lateral 6 km/hr 4 mph)

CDC: 11FYEW2 then 09LPEN2

Passenger Cell integrity: all doors remained closed
Intrusion: minor intrusion in the region of the left of the third row of seats
Ejection: none
Entrapment: none
Cargo: 54kg, 119 lbs
Front seats: mid track position on right, rearmost for left. Middle row of seat were not adjustable. Third row of seats were fully forward.

Child Occupant 1

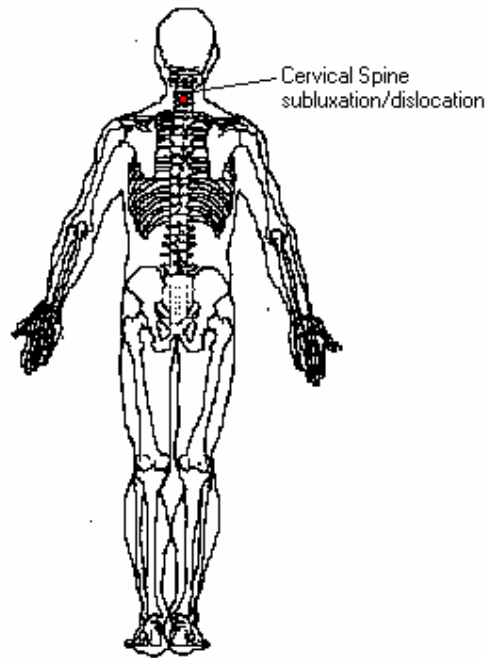
Seating position: Right third row
Restraint use: CRS see below
Sex: Female
Age: 2 years old
Weight: 14 kg, 31 lbs
Height: 91 cm, 3'0"

Child Seat

Make and model: unknown make and model
Type: forward facing said to have been used with shield and harness
Seat belt pretensioner: no

Injuries from NASS database:

No	NASS Code	Aspect	Source	Inj Source	Confidence	Direction	Intrusion	Rank
1	6502042 Cervical Spine dislocation	Posterior /Back/Dorsal	Emergency Room Records	Child safety seat (specify)	Probable	Indirect Contact Injury	Not related to intrusion	1



Child Occupant 2

Seating position: Left second row

Restraint use: CRS see below

Sex: Female

Age: 11 months old

Weight: 11 kg, 24 lbs

Height: 61 cm, 2'0"

Child Seat

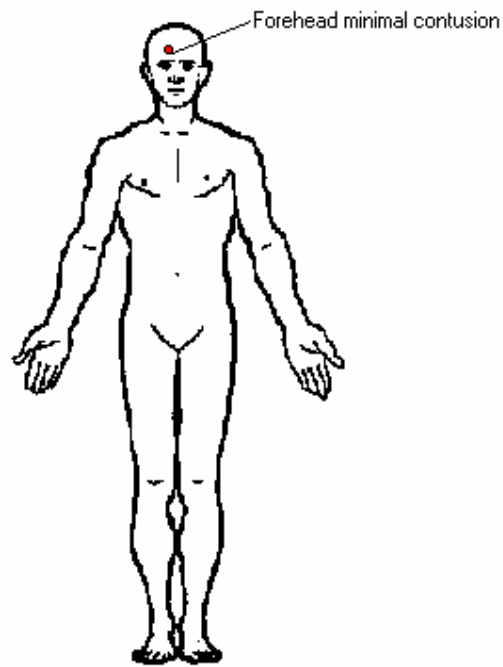
Make and model: unknown make and model

Type: rearward facing infant restraint

Seat belt pretensioner: no

Injuries from NASS database:

No	NASS Code	Aspect	Source	Inj Source	Confidence	Direction	Intrusion	Rank
1	2904021 Facial Skin contusion	Superior /Upper	Emergency Room Records	Child safety seat (specify)	Probable	Direct Contact Injury	Not related to intrusion	1



There was a heavy unrestrained occupant seated in the centre position of the second row of seats.

Photographs



Case vehicle frontal damage



No damage to right side of vehicle



Minor damage to left side of vehicle.



Vehicle contacted by case vehicle



Two year old child was seated in the right third row seat



Two year old child was seated in the right third row seat



11 month old child was seated in the left second row seat



11 month old child was seated in the left second row seat

11.1.2 NASS Case Id 134003485



Summary

This is high severity 12 o'clock concentrated frontal impact with a tree. There was no passenger compartment intrusion relevant to the position occupied by the child, but there was additional loading on the child restraint as luggage from the boot deformed the rear seat back and pushed forward on the child restraint held in the centre rear position by a lap belt. An 18 month old who was using a harness and shield type forward facing child seat in the centre rear, suffered a neck injury and brain injury, together with a laceration of the perineum. There were no surface injuries to the head and face reported and it appears that she had no head contact. The injuries to the cervical spine consisted of complete cord syndrome with fracture dislocation at C1, C2, and C3 (AIS 6). The brain injury, without any skull fracture, was rated as AIS 5 based on response to stimuli (GCS less than 9). This is an example of a neck and brain injury induced by unfavourable loading rather than by any shearing induced in the neck following a head contact with the car interior. The key factor appears to be the forward orientation of the seat and the induced head and neck loading rather than an issue of excessive forward movement, despite the influence of luggage. However, if the child had been seated rearward facing, the performance of the restraint would have been compromised to some extent by additional loading from luggage. On balance it is considered that the outcome would have been better for the rearward facing orientation but that the situation could have been significantly further improved had the luggage been properly restrained. It

represents poor protection in a potentially survivable frontal impact. The child was left quadriplegic and ventilator dependent.

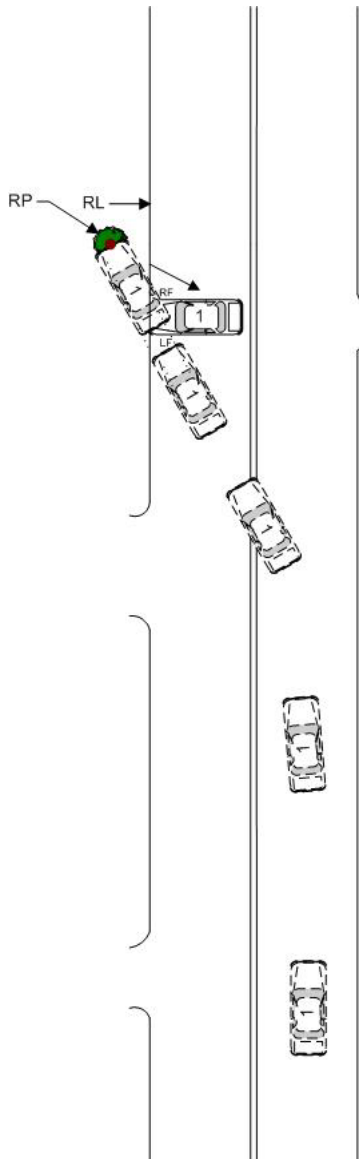
Lessons Learned

Forward facing shield and harness type seat

- Travelling forward facing for this 18 month child placed excessive loads on the neck and brain without any apparent head contact. This suggests that travelling forward facing was not appropriate for this child at this age.

Accident summary according to NASS

Vehicle one a 1994 Ford Tempo was travelling northbound in lane one of a two way roadway. Vehicle one went off the roadway on the west side. The front of vehicle one contacted a tree on the west road edge. Vehicle one caught fire as a result of the crash. Vehicle one was towed due to vehicle damage. The driver of vehicle one was transported and hospitalized due to his injuries. The passenger, a child who was seated in an infant forward facing child seat, was also hospitalized due to her injuries. (Both suffered severe injuries during the crash.)



Case #134K
 PSU 11
 1cm=2.5m
 posted 25mph

Schematic diagram of the accident

Vehicle Details

Vehicle: Ford tempo 19994

VIN: 2FAPP36X6R

Engine: 2.3 litre petrol

Delta V: 57 km/hr 35 mph (longitudinal 56 km/hr 34 mph lateral 10 km/hr 5 mph)

CDC: 12FEW3

Passenger Cell integrity: all doors remained closed

Intrusion: Luggage in boot provided additional loading

Ejection: none

Entrapment: none

Cargo: 14 kg, 31 lbs Rear seat deformed by cargo

Front seats: Both front seats were between the mid and rear track position.

Minor engine compartment fire post impact.

Child Occupant 1

Seating position: Centre rear seat

Restraint use: CRS see below

Sex: Female

Age: 18 month old

Weight: 14 kg, 31 lbs

Height: 81 cm, 2'8"

Child Seat

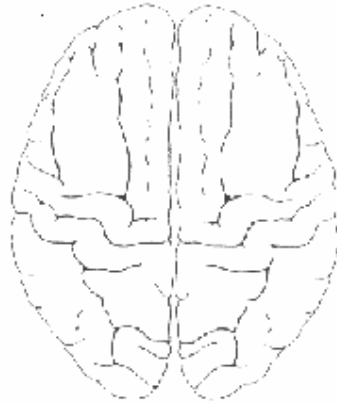
Make and model: Century Products 3000 STE, 3500 STE

Type: forward facing said to have been used with shield and harness held on lap belt only

Seat belt pretensioner: no

Injuries from NASS database:

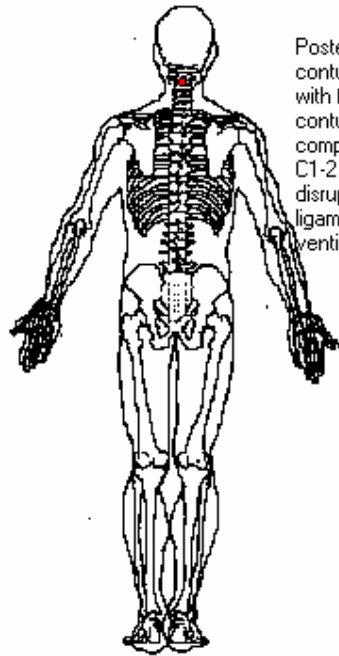
No	NASS Code	Aspect	Source	Inj Source	Confidence	Direction	Intrusion	Rank
1	1608245 Unconscious post resuscitation on Admission or Initial Observation at Scene (GCS <9) inappropriate movements no matter length of unconsciousness	Whole Region	Post-ER Medical Record	Other non contact injury source (specify)	Probable	Non contact Injury	Not related to intrusion	
2	5432201 Perineum laceration NFS	Inferior/Lower	Post-ER Medical Record	Child safety seat (specify)	Certain	Direct Contact Injury	Not related to intrusion	
3	1406843 Cerebrum subarachnoid haemorrhage	Unknown	Post-ER Medical Record	Child safety seat (specify)	Probable	Direct Contact Injury	Not related to intrusion	
4	6402366 Cervical Spine Cord contusion complete cord syndrome C-3 or above with fracture and dislocation	Posterior /Back/Dorsal	Post-ER Medical Record	Other non contact injury source (specify)	Certain	Non contact Injury	Not related to intrusion	1



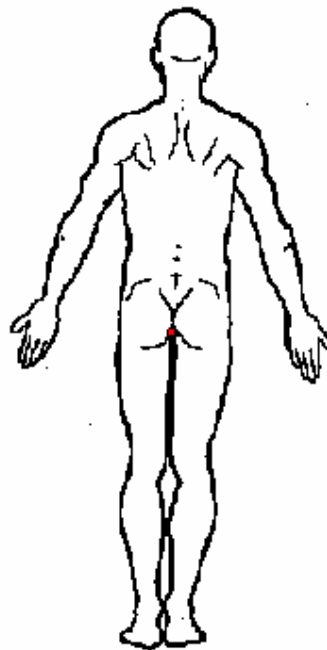
Unknown/Multiple Regions, small amount Cerebrum subarachnoid hemorrhage (intracranially)

Whole Region, Unconscious post resuscitation on Admission or Initial Observation at Scene (GCS <9) inappropriate movements no matter length of unconsciousness : Unconscious, no spontaneous respirations, pupils approx. 3mm and nonreactive, does not respond to external stimuli initially, no spontaneous movement of extremities (after intubation and increase in oxygen saturations pt noted to have spontaneous movement of tongue only





Posterior/Back/Dorsal, Cervical Spine Cord contusion complete cord syndrome C-3 or above with fracture and dislocation : Severe spinal cord contusion with C2 fracture dislocation with complete quadraplegia, anterior displacement of C1-2 over C3 (flexion subluxation injury), severe disruption of anterior and posterior longitudinal ligaments at C2-3 [severe spinal cord injury, ventilator dependent, and quadraplegic]



Inferior/Lower, Perineal laceration NFS (from back part of anus to vagina)

Photographs



Tree contacted by case vehicle



Case vehicle frontal damage



Case vehicle frontal damage



Minor damage to left side of vehicle.



CRS in centre rear seat of case vehicle



CRS held on lap belt – note broken shield and deformed rear seat back



Additional loading from luggage



Shoulder harness in lowest setting



Broken shield



Harness attachment to shield



Shield attachments broken – left – and pulled off – right.



Shoulder harness webbing has cut through seat shell



Internal harness



Child seat with broken attachment to shield

11.1.3 NASS Case Id 180007186



Summary

This is an example of a frontal impact in a modern bodyshell. A three year old child has been in a forward facing booster seat in a rear seat belt equipped with a pre-tensioner. The loads imposed on the child by the adult seat belt system have been intolerable and have resulted in a neck injury (AIS 2), together with deceleration injuries to the brain (AIS 3). In the chest there was haemo-thorax (AIS 3), without rib fracture and there was ileum and jejunum contusion (AIS 2), together with other signs of abdominal damage, consistent with some unfavourable loading from the lap section of the adult belt on the abdominal area. The child died at the scene. This represents totally unsatisfactory restraint for this three year old in a potentially survivable frontal impact, with no intrusion around the child restraint and no additional loading on the child to compromise the potential protection available. Therefore had this child been in a suitable rearward facing seat the injuries would have been greatly reduced if not eradicated.

Lessons Learned

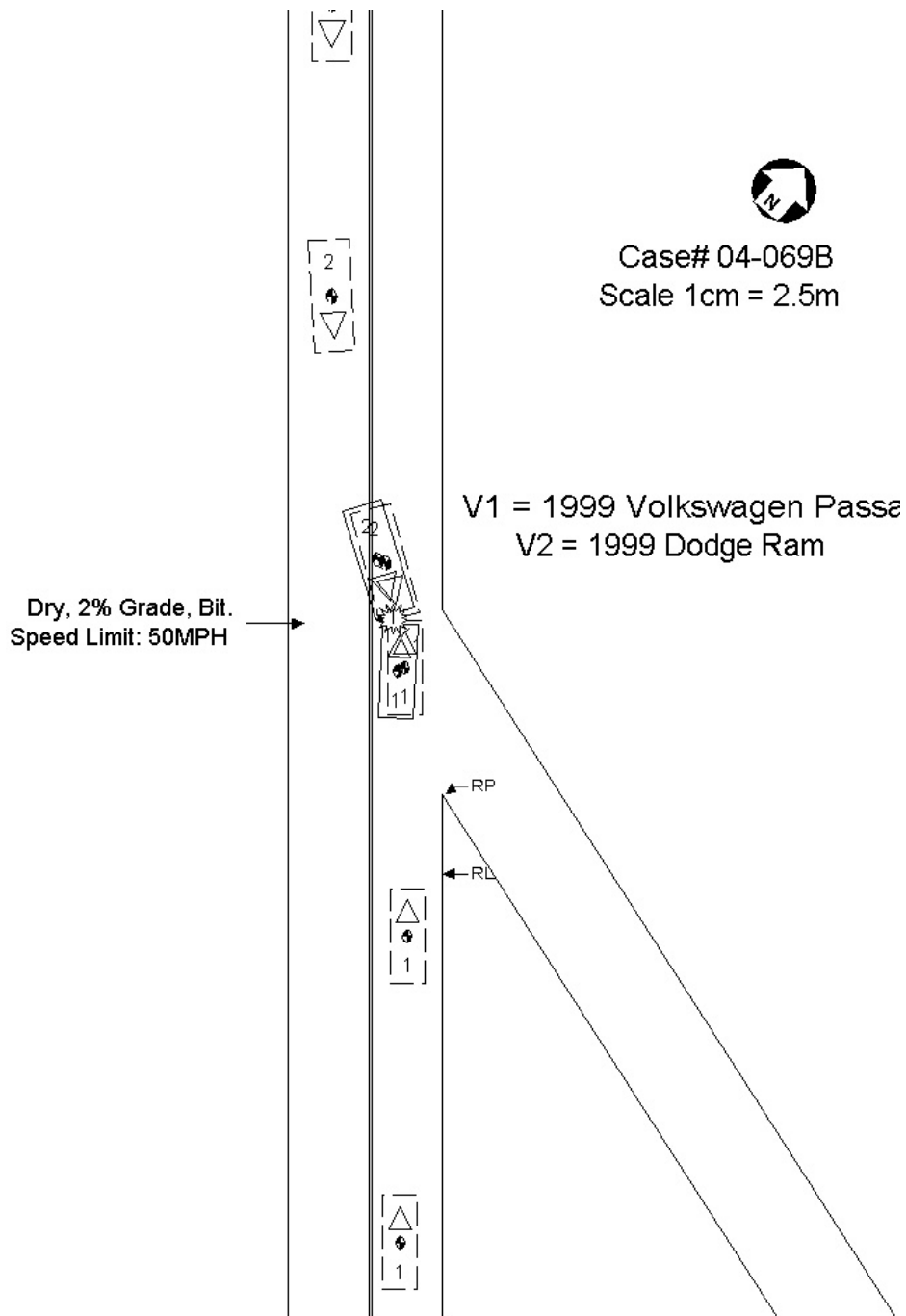
Forward facing CRS

- Adult seat belts are too stiff to directly restrain a three year old child in this severity of accident putting excessive loads on the neck and chest

- The lap section of the belt requires better redirection to avoid loading the vulnerable abdomen. The belt guides are too high relative to the seat base and so, by design, guide the belt onto the abdomen.

Accident summary according to NASS

V1, VW Passat (1999) was travelling westbound on a dry, 2% uphill grade, bituminous roadway approaching an uncontrolled intersection intending to continue straight. V2 Dodge Ram (1999) was travelling eastbound on this same roadway, with a 2% downhill grade, approaching the same intersection intending to turn left. The posted speed limit for this roadway was 50 mph. The front of V2 struck the front of V1 in the westbound lane. Both vehicles were towed due to damage. Driver of V2 was transported sustaining moderate injuries. Driver and passenger of V1 were transported due to severe injuries where passenger expired at the trauma centre. Occupant two from V1 was restrained in a child safety seat.



Schematic diagram of the accident

Vehicle Details

Vehicle: VW Passat 1999

VIN: WVVMA63B5X

Engine: 1.8 litre petrol

Delta V: (41 mph) 66 km/h Components: longitudinal: (39 mph) 65 km/h, lateral: (7 mph) 12 km/h

CDC: 12FDEW3

Passenger Cell integrity: all doors remained closed

Intrusion: none relevant to child

Ejection: none

Entrapment: none

Cargo: None

Child Occupant 1

Seating position: Left rear

Restraint use: CRS see below

Sex: Female

Age: 3 years old

Weight: 17 kg, 37 lbs

Height: 99 cm, 3'3"

Child Seat

Make and model: Costco/Doral Voyager

Type: Booster seat

Model no. 22-210-TIM

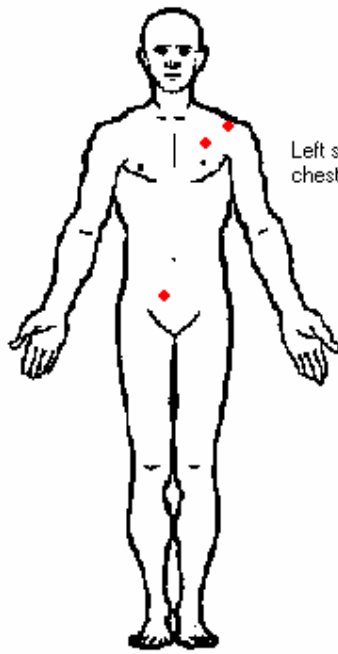
Date of manufacture: 5/03/2004

Seat belt pretensioner: yes



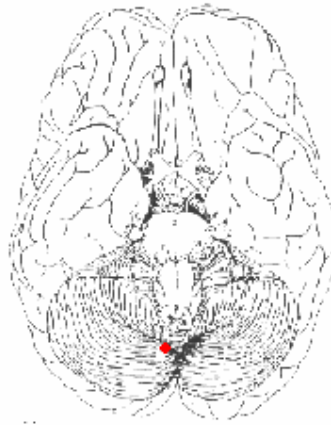
Injuries from NASS database:

No	NASS Code	Aspect	Source	Inj Source	Confidence	Direction	Intrusion	Rank
1	7904021 Upper Extremity Skin contusion		Autopsy	Belt restraint webbing /buckle	Certain	Direct Contact Injury		
2	4904021 Chest Skin contusion (OIS Grade I)		Autopsy	Belt restraint webbing /buckle	Certain	Direct Contact Injury		
3	5904021 Abdomen Skin contusion		Autopsy	Belt restraint webbing /buckle	Certain	Direct Contact Injury		
4	1406843 Cerebrum subarachnoid haemorrhage		Autopsy	Child safety seat (specify)	Possible	Direct Contact Injury		1
5	1404663 Cerebellum subarachnoid haemorrhage		Autopsy	Child safety seat (specify)	Possible	Direct Contact Injury		
6	6502162 Cervical Spine fracture		Autopsy	Other non contact injury source (specify)	Probable	Non contact Injury		
7	1406623 Cerebrum brain swelling mild		Autopsy	Other non contact injury source (specify)	Probable	Non contact Injury		
8	4422023 Thoracic cavity injury with hemo- /pneumothorax		Autopsy	Belt restraint webbing /buckle	Certain	Direct Contact Injury		
9	5414102 Jejunum-ileum contusion (OIS Grade I)		Autopsy	Belt restraint webbing /buckle	Certain	Direct Contact Injury		
10	5420102 Mesentery contusion		Autopsy	Belt restraint webbing /buckle	Certain	Direct Contact Injury		



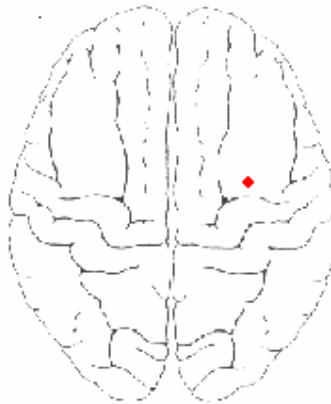
Left shoulder and upper left chest contusion 5 x 1.5" area

Inferior/Lower Abdomen (above umbilicus) horizontal contusion 5 x 0.75"

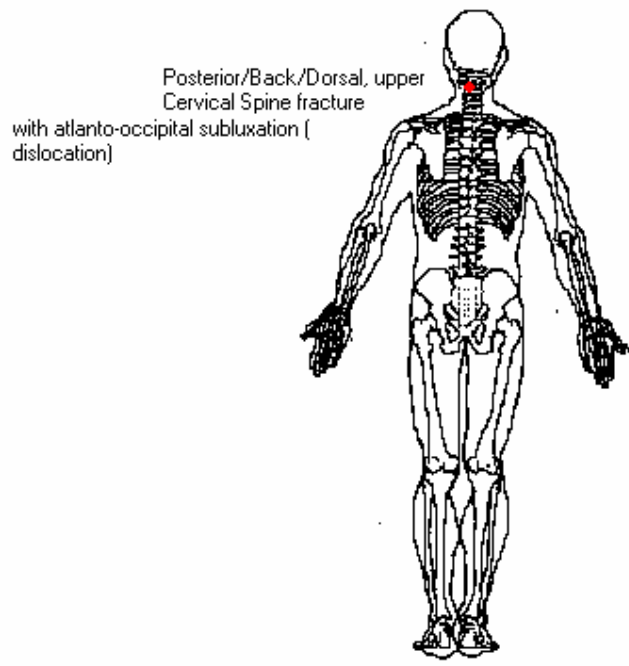


Posterior/Back/Dorsal , Cerebellum small subarachnoid hemorrhage

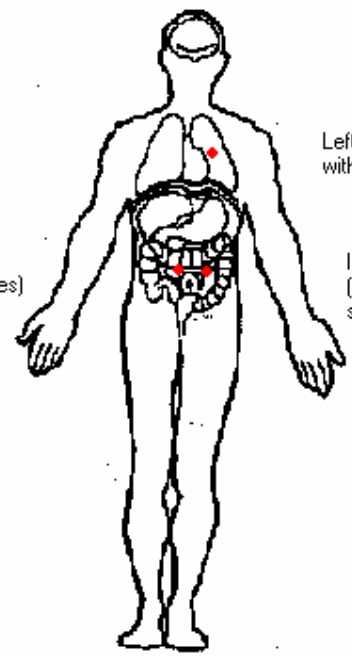
- ◆ Unknown Cerebrum small subarachnoid hemorrhage in posterior aspects



Unknown Cerebrum brain swelling mild



Posterior/Back/Dorsal, upper
Cervical Spine fracture
with atlanto-occipital subluxation (dislocation)



Left Thoracic cavity injury
with hemothorax

Inferior/Lower, Mesentery
contusion (focal hemorrhages)

Inferior/Lower, Jejunum-ileum contusion
(OIS Grade I) (serosal surface of upper
small intestines focal hemorrhages)

Left retroperitoneum large hematoma over the
left kidney area

Photographs



Case vehicle showing frontal damage



Rear view of case vehicle – child was seated in the left rear seat



Other vehicle involved in the impact.



Child seat showing intact area ahead.



Lap belt geometry – high lap belt



Belt geometry



Lap belt geometry



Stressing to area around inboard belt guide



General view showing area of stressing to area around inboard belt guide



Space available for the driver post impact

11.2 Forward Facing Neck Injury Cases – With Head Contact

11.2.1 NASS Case Id 161002584



Summary

This is a relatively low severity concentrated frontal impact followed by a 90° roll onto the right side. There was no passenger compartment intrusion and no additional loading that might have compromised the protection available. A three year old seated in a booster cushion with a shield on the right rear seat suffered a neck injury. It appears that she had a head contact with the seat in front of her, as evidenced by abrasions to the lower half of her face. She suffered no other recorded injuries apart from the C2 cervical spine fracture (AIS 2). She survived this injury. This is an example of a neck injury induced by shearing during a head contact. The large forward excursion permitted by shield type seats and the lack of early torso restraint provided by such systems could be seen as responsible for the very poor protection offered in this relatively low energy event. Use of a suitable rearward facing restraint would have eliminated the injuries.

On the left rear seat there was a one year old female in the same design of child seat and she was uninjured. Presumably with her smaller height, the shield provided sufficient restraint to prevent her making interior contact with the vehicle.

Lessons Learned

Forward facing shield seat – 3 year old

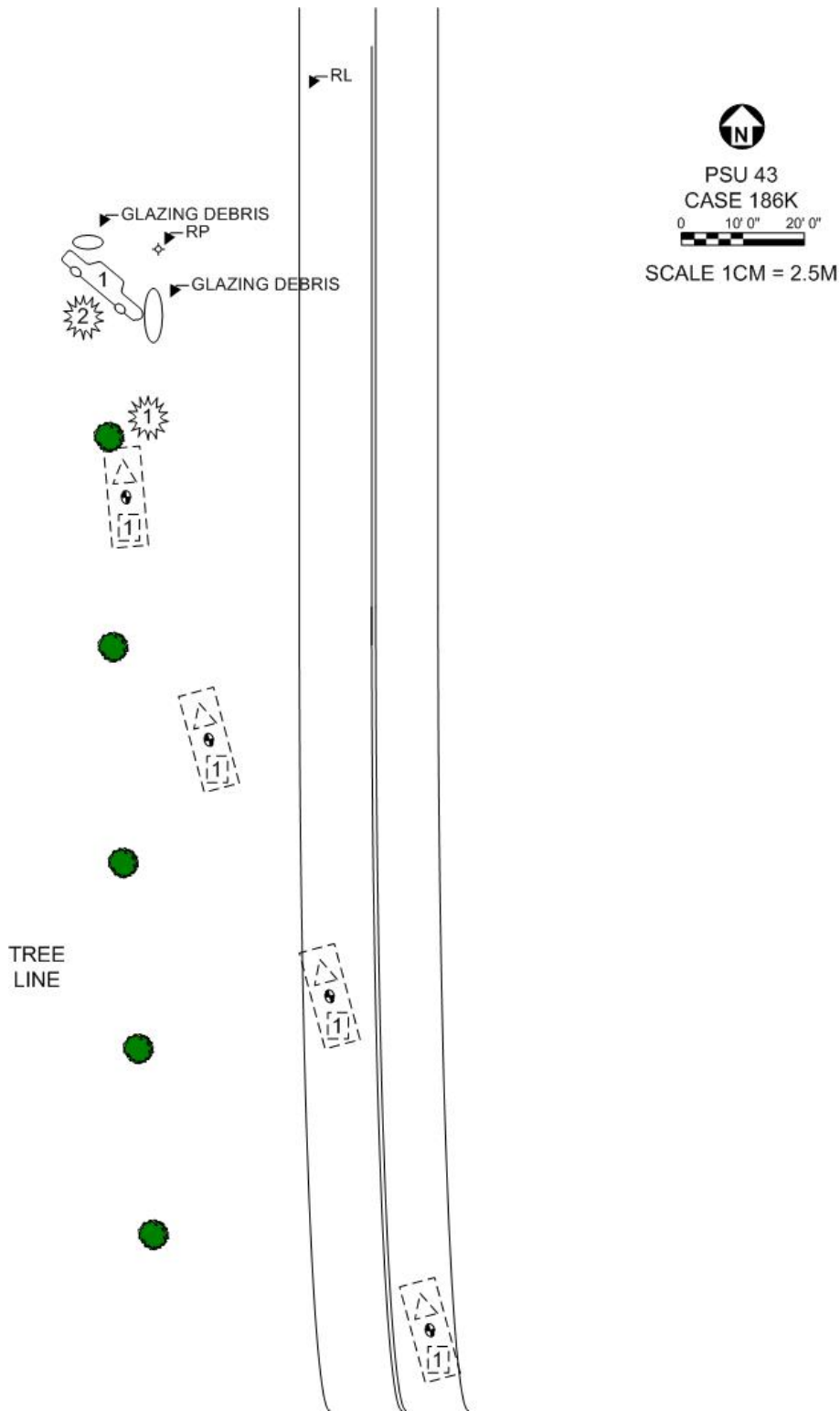
- Excessive forward excursion in a forward facing seat leaves the unprotected head vulnerable to contact with the vehicle interior. Excursion limits within regulations should be compatible with actual minimum space available in vehicles – the front seat was in the mid track position in this impact.

Forward facing shield seat – 12 month old

- This is an example of a younger child in a similar seat apparently enjoying better protection than the seat adjacent to it even though it might have been subject to a stiffer pulse than the older child. Probably the smaller stature of the younger child produced more favourable interaction with the shield and required less interior space for forward excursion.

Accident summary according to NASS

Vehicle one, a 1993 Buick Regal, was travelling north on a two lane dry bituminous roadway entering a curve to the right. Vehicle one went left of centre and departed the roadway on the left impacting a tree with its front plane. Vehicle one uprooted the tree and rolled over one quarter turn and landed on its right plane. The driver of vehicle one received a "B" injury and was transported and released. The left rear occupant was not injured. The right rear occupant received an "A" injury and was transported and hospitalised for ten days.



Schematic diagram of the accident

Vehicle Details

Vehicle: Buick Regal 1993

VIN: 2G4WB54T1P

Engine: 3.1litre petrol
Delta V: not computed Barrier equivalent 16 mph
CDC: 12FLEE2 then 00RDLO2
Passenger Cell integrity: all doors remained closed
Intrusion: none relevant to child
Ejection: none
Entrapment: none
Cargo: None
Front seats: mid track position

Child Occupant 1

Seating position: Right rear
Restraint use: CRS see below
Sex: Female
Age: 3 years old
Weight: 17 kg, 37 lbs
Height: 91 cm, 3'0"

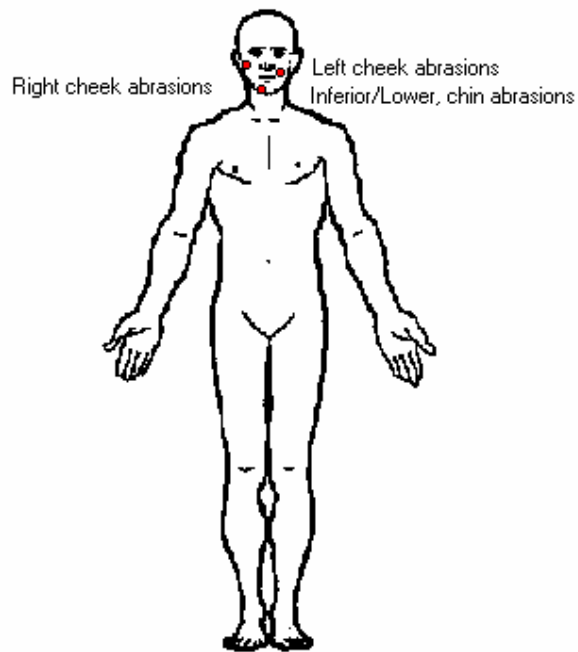
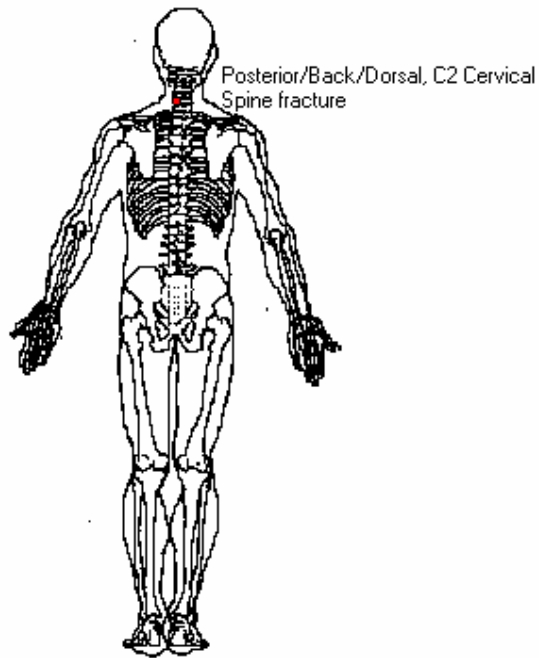
Child Seat

Make and model: Costco/Doral Explorer 1
Type: Booster cushion with shield
Seat belt pretensioner: no



Injuries from NASS database:

No	NASS Code	Aspect	Source	Inj Source	Confidence	Direction	Intrusion	Rank
1	2902021 Facial Skin abrasion	Inferior/Lower	Emergency Room Records	Child safety seat (specify)	Probable	Direct Contact Injury	Not related to intrusion	
2	2902021 Facial Skin abrasion	Right	Emergency Room Records	Child safety seat (specify)	Probable	Direct Contact Injury	Not related to intrusion	
3	2902021 Facial Skin abrasion	Left	Emergency Room Records	Child safety seat (specify)	Probable	Direct Contact Injury	Not related to intrusion	
4	6502162 Cervical Spine fracture	Posterior/Back/Dorsal	Post-ER Medical Record	Child safety seat (specify)	Probable	Indirect Contact Injury	Not related to intrusion	1



Child Occupant 2

Seating position: Left rear

Restraint use: CRS see below

Sex: Female

Age: 12 months old

Weight: 10 kg, 22 lbs

Height: 61 cm, 2'0"

Child Seat

Make and model: Costco/Doral Explorer 1

Type: Booster cushion with shield

Seat belt pretensioner: no



Injuries from NASS database:

No injuries

Photographs



Small tree hit by case vehicle



Frontal damage to case vehicle



Case vehicle – 3 year old child was seated in the right rear seat



Three year old child was seated in the right rear seat, 12 month old in left rear



Three year old child was seated in the right rear seat, 12 month old in left rear



Right rear seating position occupied by three year old



Left rear seating position occupied by 12 month old



Contact on front seat head restraint



Child seat extracted from vehicle



General view of the accident scene showing departure from road

11.2.2 NASS Case Id 876004983



Summary

This is medium/high severity 11 o'clock frontal impact with a van. There was no passenger compartment intrusion relevant to the positions occupied by the two children in the rear, but there was a possibility of some additional loading on the child restraint as luggage from the boot deformed the rear seat back and pushed forward on the child restraints in the rear.

A 22 month old was using an unknown, but probably forward facing child seat in the centre rear. The child seat was held by a lap belt only. She suffered a neck injury at C3 (AIS 6) and brain injury involving the brain stem (AIS 5) and other structures. There was a scalp contusion reported which suggests a possible head contact. There were bilateral shoulder abrasions together with a fractured clavicle (AIS 2) that would be consistent with loading from a harness system within the child restraint. The injuries to the cervical spine consisted of complete cord syndrome with fracture dislocation of C1 and C2 (AIS 6). This is an example of a neck and brain injury that could have been induced as a result of a head contact with the car interior. The key factor appears to be the forward orientation of the seat and excessive forward movement. It represents poor protection in a potentially survivable frontal impact. Use of a suitable rearward facing restraint would have significantly reduced the injuries and ensured survival. However, the luggage in the boot significantly deformed the rear seat back and this would have put significant additional loading on a rearward facing seat in this position.

A four month old child was in a rearward facing infant restraint with an integral three point harness. This was placed on the right rear seating position in the car. The belt guide on the inboard side of the restraint fractured and thus the restraint offered would have been severely compromised, with the infant restraint probably swinging free of, at least, the inboard section of the adult belt. The child received diffuse brain haemorrhages (AIS 4). Such injuries would not be anticipated with the child restraint functioning correctly. It is likely that the additional loading that was applied to the child seat by the luggage, which deformed the rear seat back, contributed to overloading the belt guides. For rearward facing infant restraints in Europe it is not allowed to utilise just the lap section of the belt to fix the restraint in the vehicle.

Lessons Learned

Forward facing CRS

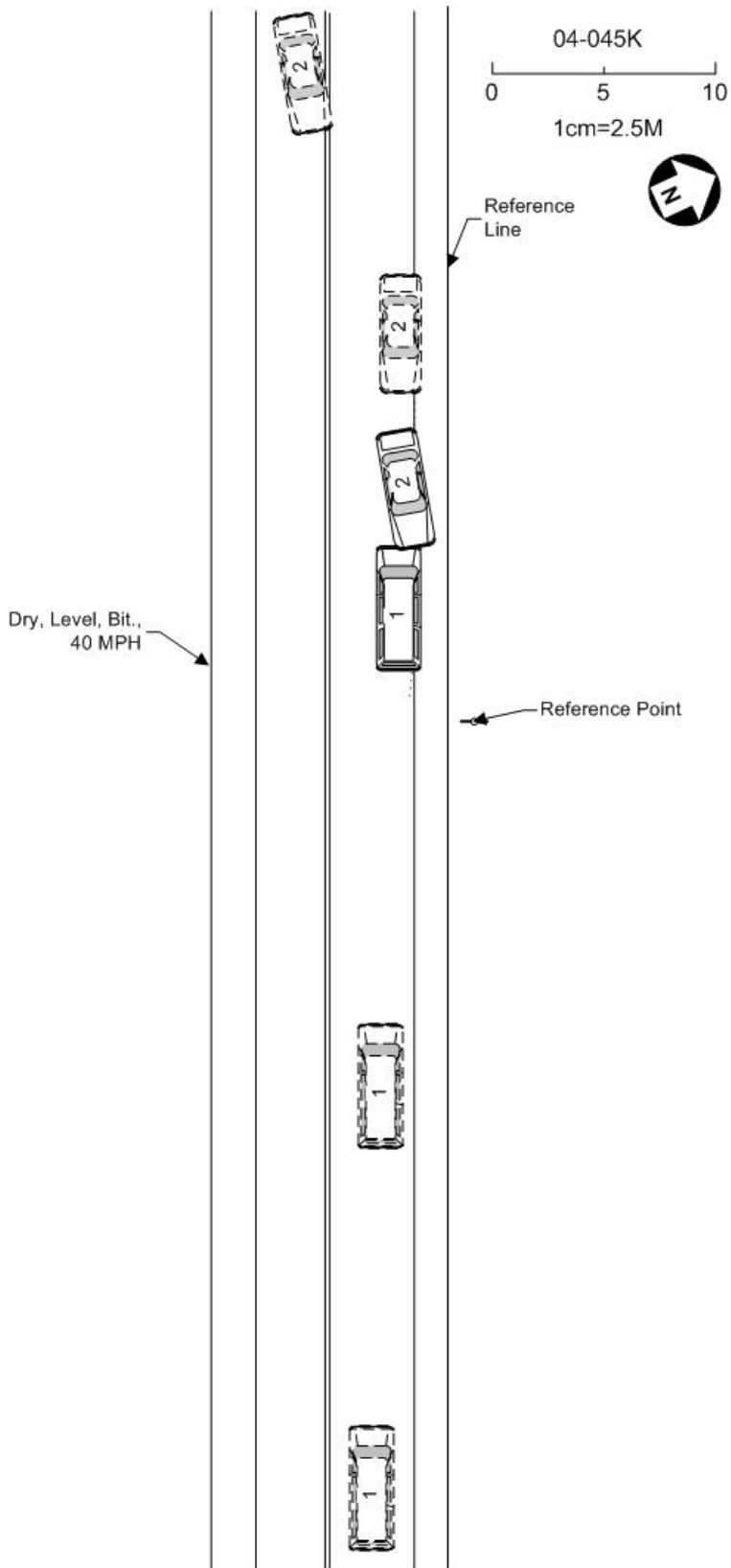
- Rear seats must be able to contain luggage within the luggage area without significant deformation
- Excessive forward excursion in a forward facing seat leaves the unprotected head vulnerable to contact with the vehicle interior. Excursion limits within regulations should be compatible with actual minimum space available in vehicles.
- When head contacts occur there are two types of injury that can result:
 - injuries to the brain from rapid deceleration generated by head contact
 - injuries to the cervical spine induced by shearing loads generated indirectly by head contact

Rearward facing CRS

- The severity of the legislative test needs to be sufficient to ensure CRS integrity in the range of survivable accidents and legislation needs to control the restraint of luggage in such a way as it does not load child restraints.

Accident summary according to NASS

Vehicle 1, a 2002 GMC Savana G3500 Cargo Van, was travelling west on a dry, level, and bituminous road. Vehicle 2, a 1992 Oldsmobile Ciera was heading in the opposite direction. The posted speed limit for both vehicles is 40 mph. As V2 was travelling eastbound, the front portion of this vehicle came in contact with the front portion of the other vehicle. Both vehicles were towed due to moderate damage sustained during the crash. The driver of V1 was transported to a local medical facility, and treated for C injuries. All four occupants of V2 were transported and admitted. The 22 month old 2nd row centre passenger was seated in an unknown child seat. No further information was available. The 4 month old right rear passenger occupied a rearward facing infant safety seat. An inspection of the seat was obtained.



Schematic diagram of the accident

Vehicle Details

Vehicle: Oldsmobile Ciera 1992

VIN: 1G3AL54NXN

Engine: 2.5 litre petrol

Delta V: 68 km/hr 42 mph (longitudinal 64 km/hr 39 mph lateral 23 km/hr 14 mph)

CDC: 11FDEW3

Passenger Cell integrity: all doors remained closed

Intrusion:

Ejection: none

Entrapment: none

Cargo: no cargo – but later say left rear seat distorted by luggage

Front seats: Left front seat forward most track position – note seat failure – , right front seat was at the mid track position.

Child Occupant 1

Seating position: Centre rear seat

Restraint use: CRS see below

Sex: Female

Age: 22 months old

Weight: unknown

Height: unknown

Child Seat

Make and model: Unknown

Type: unknown, but probably forward facing with internal harness given bilateral shoulder abrasions

Seat belt pretensioner: no

Injuries from NASS database:

No	NASS Code	Aspect	Source	Inj Source	Confidence	Direction	Intrusion	Rank
1	6402366 Cervical Spine Cord contusion complete cord syndrome C-3 or above with fracture and dislocation	Posterior /Back/Dorsal	Lay Coroner	Other non contact injury source (specify)	Probable	Non contact Injury	Not related to intrusion	1
2	1402045 Brain stem contusion	Inferior/L ower	Lay Coroner	Other non contact injury source (specify)	Probable	Non contact Injury	Not related to intrusion	

3	1904021 Scalp contusion/subgaleal hematoma	Left	Emergency Room Records	Seat, back support	Probable	Direct Contact Injury	Not related to intrusion	
4	7902021 Upper Extremity Skin abrasion	Bilateral	Lay Coroner	Child safety seat (specify)	Probable	Direct Contact Injury	Not related to intrusion	
5	7522002 Clavicle fracture (OIS Grade I or II)	Left	Lay Coroner	Child safety seat (specify)	Probable	Direct Contact Injury	Not related to intrusion	
6	1406784 Cerebrum intraventricular hemorrhage/intracerebral hematoma in ventricular system	Right	Lay Coroner	Other non contact injury source (specify)	Probable	Non contact Injury	Not related to intrusion	
7	1406784 Cerebrum intraventricular hemorrhage/intracerebral hematoma in ventricular system	Left	Lay Coroner	Other non contact injury source (specify)	Probable	Non contact Injury	Not related to intrusion	

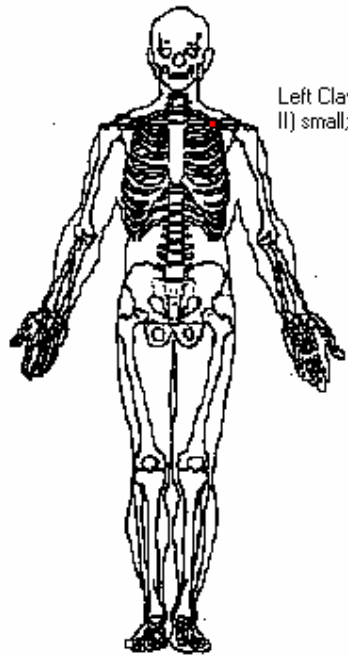
Left (lateral horn posterior horn and fourth and fifth ventricle) Cerebrum intraventricular hemorrhage



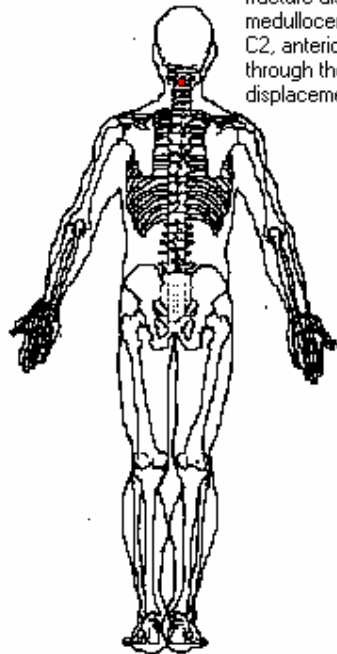
Right (lateral ventricle; posterior horn) Cerebrum intraventricular hemorrhage



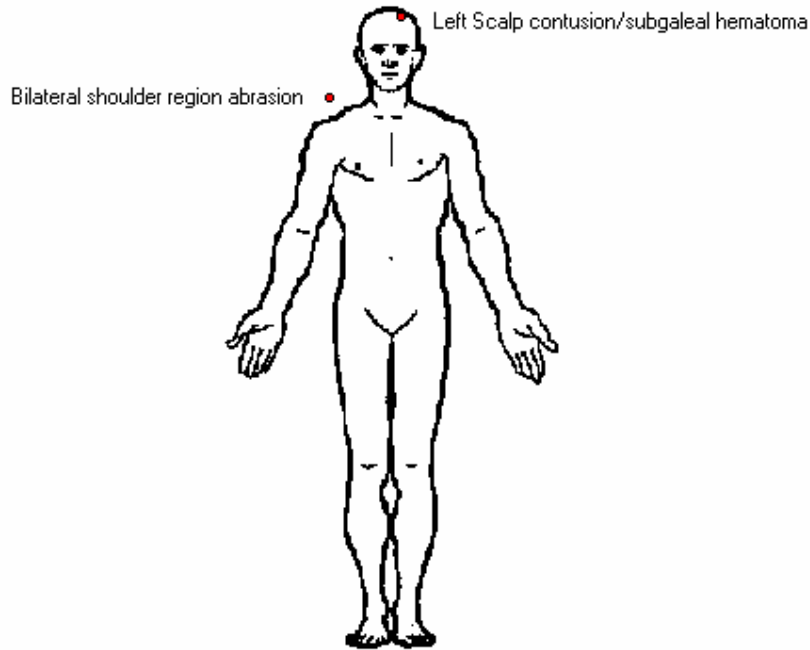
Inferior/Lower, Brain stem contusion



Left Clavicle fracture (DIS Grade I or II) small; nondisplaced



Posterior/Back/Dorsal, Cervical Spine Cord contusion complete cord syndrome C-3 or above with fracture and dislocation (C1/C2 fracture dislocation; cervicomedullary hemorrhage; quadraplegia; medullocervical hemorrhage/thrombosis; dissociation odontoid C2, anterior subluxation/dislocation; Type II dens fracture; fracture through the base of the odontoid process with significant anterior displacement along the base of the skull)



Child Occupant 2

Seating position: Right rear seat

Restraint use: CRS see below

Sex: Male

Age: 4 months old

Weight: 7 kg, 15 lbs

Height: unknown

Child Seat

Make and model: Century Products Smart Fit

Type: Rearward facing infant seat with three-point integral harness

Model No. 4545FRN

Date of manufacture: 19/8/2000

Seat belt pretensioner: no

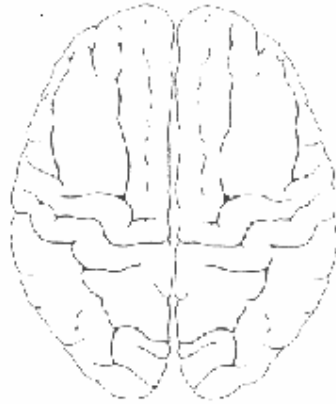
Shoulder harness position: Photos show top slots but NASS recorded bottom slots



CRS used by the four month old child in the right rear seat of the vehicle

Injuries from NASS database:

No	NASS Code	Aspect	Source	Inj Source	Confidence	Direction	Intrusion	Rank
1	1406843 Cerebrum subarachnoid haemorrhage	Unknown	Lay Coroner	Child safety seat (specify)	Probable	Direct Contact Injury	Not related to intrusion	
2	1406294 Cerebrum hematoma/ haemorrhage NFS - extra axial	Unknown	Lay Coroner	Child safety seat (specify)	Probable	Direct Contact Injury	Not related to intrusion	1



Unknown/Multiple Regions,
Cerebrum subarachnoid hemorrhage

Unknown/Multiple Regions, Cerebrum
hematoma/hemorrhage NFS - extra axial
(small foci of hemorrhage along the
posterior falx and within the sulci of the
high convexities)

Photographs



Other vehicle involved in the accident



Frontal damage to the other vehicle involved in the accident



Frontal damage to the case vehicle



Frontal damage to the case vehicle



Case vehicle damage



22 month old female was on the centre seat – note bowing of rear seats due to luggage



Driver's seat runner broke in the impact



Rearward facing CRS with broken belt guide used by 4 month old child



CRS internal harness in highest slots – note: twisted webbing



Broken inboard (left hand) belt guide



Stressed right hand belt guide



Installation instructions



Seating position for the 4 month old in the rearward facing child seat

11.2.3 NASS Case Id 917000181



Summary

This is a relatively high-energy frontal impact in a modern bodyshell with no intrusion or additional loading that could potentially compromise the protection offered to the children seated in the rear. The case is interesting as a three year old, seated in a booster seat, using the adult belt without a pre-tensioner to restrain the child, was positioned beside a two year old in a five point harness seat, which in turn was held in place by the adult seat belt. The three year old in the booster seat suffered fatal injuries whereas the two year old simply suffered a clavicle fracture. The deceleration pulses seen in the two seating positions would have been very similar.

The child in the booster seat suffered brain injury (AIS 4), possibly associated with a head contact, cervical spine injury at C1/C2 (AIS 2), thoracic spine fracture at T4 with cord involvement (AIS 5), lung contusions (AIS 4) and rupture of the small bowel (AIS 3). There was also a fracture of the humerus (AIS 2). The bruising indicates a relatively high lap belt position consistent with the abdominal injuries. The neck and chest injuries suggest loading above tolerable limits. This very poor restraint is in sharp contrast to the experience of a two year old in the adjacent seat. A suitable rearward facing restraint would have ensured survival with minimal injury for this three year old.

Lessons Learned

Forward facing booster seat

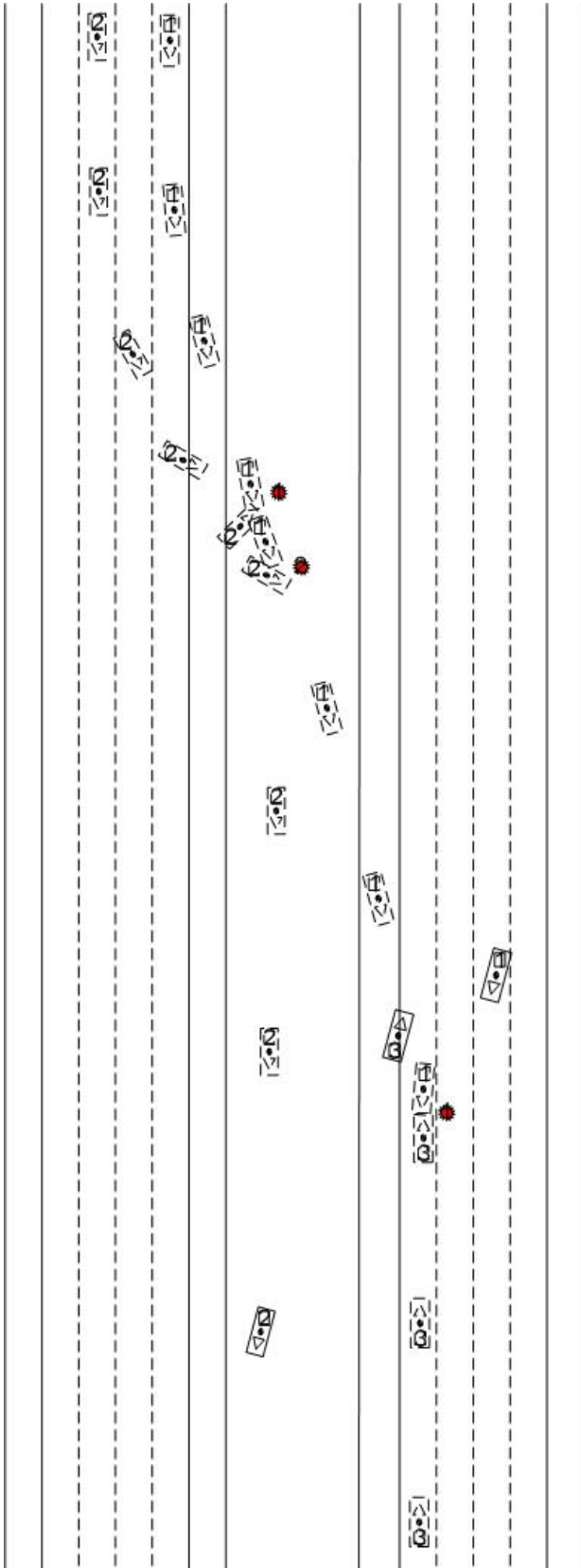
- Adult seat belts are too stiff to directly restrain a three year old child in an accident of this severity putting excessive loads on the chest
- The lap section of the belt requires better redirection to avoid loading the vulnerable abdomen. The belt guides too high in this respect.
- Forward excursion in a forward facing seat leaves the unprotected head vulnerable to contact with the vehicle interior and such contact can lead to neck shearing and consequent neck injury. This is an inherent problem with forward facing restraints and accident severity increases.

Forward facing integral harness seat

- This is an example of a forward facing five-point harness system apparently providing better protection than the booster seat adjacent to it even though there was less space in the vehicle ahead of this seat.

Accident summary according to NASS

Vehicle 1, a 2002 Jaguar X-Type, was travelling south in the fourth lane of an eight-lane/two-way divided highway. Vehicle 2, a 1991 Subaru Legacy, was travelling south in the second lane of the same roadway. Vehicle 3, a 1996 Ford Aerostar, was travelling north in the fourth lane of the same roadway. V2 lost control and began yawing in an east direction across lanes three and four and into the grassy median. V1 steered left travelling onto the median to avoid V2. The front of V1 contacted the left front fender of V2 in the median. V2 rotated clockwise and its left rear was struck a second time by the front of V1. V1 continued travelling south east across the median entering the northbound fourth lane. V1's front struck the front of V3. V1 rotated slightly clockwise as it moved north after impact with V3. V2 moved south in the median and came to rest after the impacts with V1. V3 moved northwest to final rest after impact. All three vehicles were towed due to damage. V1 was equipped with 6 airbags; the front airbags deployed. The driver and rear left passenger (in a hybrid high back booster seat) sustained incapacitating injuries and were transported to a local trauma center. The right rear passenger was in a belt positioning booster seat and was fatally injured. The right front passenger also sustained fatal injuries and expired after being transported to a local trauma center. The driver of V2 sustained an incapacitating injury and was transported to a trauma center. Vehicle 2 was not equipped with airbags. The driver of V3 was fatally injured. The other 4 passengers were transported to a local trauma center with incapacitating injuries.



PSU-42
 CASE 025A
 SCALE 1CM=5.5M
 CONCRETE
 STRAIGHT
 ASPHALT SHOULDERS
 SPEED:60
 DRY, CLOUDY
 DUSK

Schematic diagram of the accident

Vehicle Details

Vehicle: Jaguar X-type 2002

VIN: SAJEB53DX2

Engine: 2.5 litre petrol

Delta V: not quoted

CDC: 11FDEW4

Passenger Cell integrity: all doors remained closed

Intrusion: none relevant to child

Ejection: none

Entrapment: none

Cargo: none

Front Seat positions: right passenger seat was between the forward most and middle track position, the driver's seat was in the rearmost track position.

Child Occupant 1

Seating position: Right rear

Restraint use: CRS see below

Sex: Male

Age: 3 years old

Weight: 16 kg, 35 lbs

Height: 91 cm, 3'0"

Child Seat 1

Make and model: Costco/Doral Voyager

Type: Booster seat

Model no. 22-452-GRB

Date of manufacture: 20/07/2000

Seat belt pretensioner: no

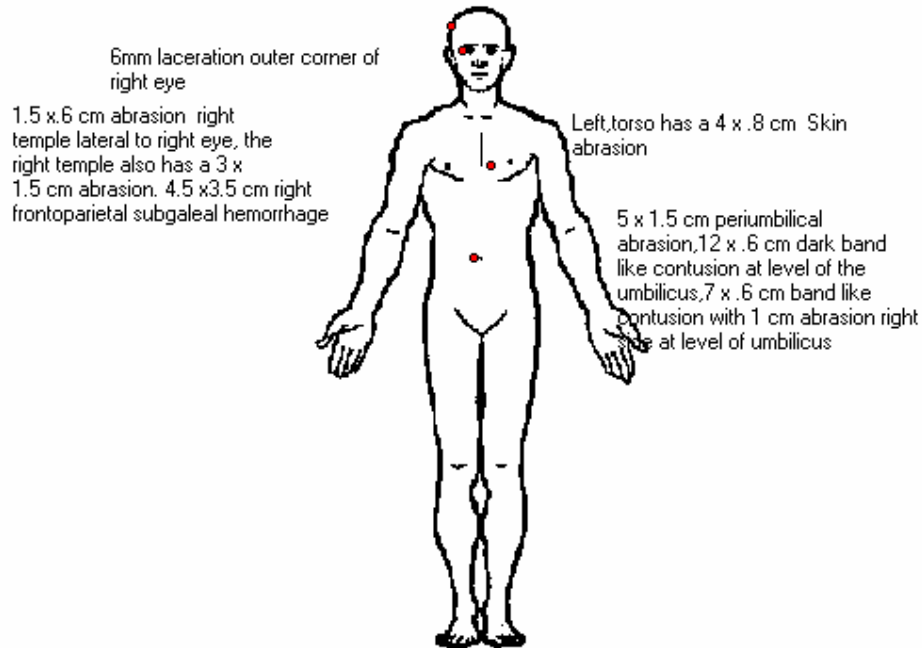


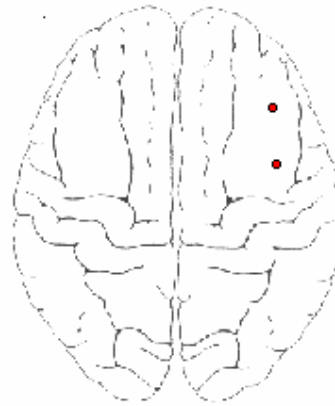
Injuries from NASS database:

No	NASS Code	Aspect	Source	Inj Source	Confidence	Direction	Intrusion	Rank
1	2976021 Eyelid laceration	Right	Autopsy	Flying glass	Probable	Non contact Injury	Not related to intrusion	
2	1902021 Scalp abrasion	Right	Autopsy	Right side interior surface, excluding hardware or armrests	Possible	Direct Contact Injury	Not related to intrusion	
3	1904021 Scalp contusion/subgaleal haematoma	Right	Autopsy	Right side interior surface, excluding	Possible	Direct Contact Injury	Not related to intrusion	

				g hardware or armrests				
4	1406504 Cerebrum haematoma /haemorrhage subdural NFS	Right	Autopsy	Other non contact injury source (specify)	Possible	Non contact Injury	Not related to intrusion	
5	1406843 Cerebrum subarachnoid haemorrhage	Right	Autopsy	Right side window sill	Possible	Direct Contact Injury	Not related to intrusion	
6	1406843 Cerebrum subarachnoid haemorrhage	Left	Autopsy	Right side window sill	Possible	Direct Contact Injury	Not related to intrusion	
7	6502042 Cervical Spine dislocation	Posterior /Back/Dorsal	Autopsy	Other non contact injury source (specify)	Possible	Non contact Injury	Not related to intrusion	
8	5902021 Abdomen Skin abrasion	Central	Autopsy	Belt restraint webbing /buckle	Probable	Direct Contact Injury	Not related to intrusion	
9	5904021 Abdomen Skin contusion	Central	Autopsy	Belt restraint webbing /buckle	Probable	Direct Contact Injury	Not related to intrusion	
10	4902021 Chest Skin abrasion	Left	Autopsy	Belt restraint webbing /buckle	Probable	Direct Contact Injury	Not related to intrusion	
11	4414104 Lung contusion bilateral with or without hemo- /pneumothorax	Bilateral	Autopsy	Belt restraint webbing /buckle	Probable	Direct Contact Injury	Not related to intrusion	
12	5414243 Jejunum-ileum	Inferior/Lower	Autopsy	Belt restraint	Probable	Direct Contact	Not relate	

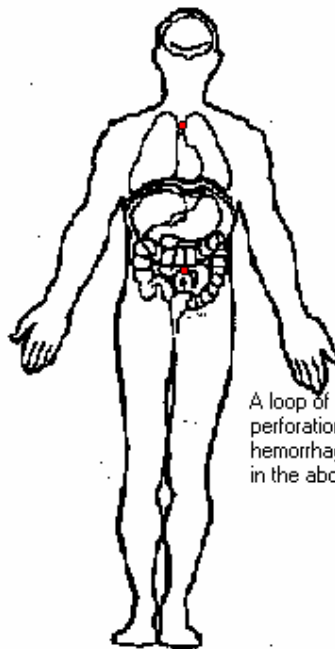
	laceration perforation (OIS Grade III)			webbing /buckle		Injury	d to intrusion	
13	6404465 Thoracic Spine cord laceration incomplete cord syndrome with fracture	Superior /Upper	Autopsy	Other non contact injury source (specify)	Probable	Non contact Injury	Not related to intrusion	1
14	7526002 Humerus fracture NFS	Right	Autopsy	Right side hardware or armrest	Probable	Direct Contact Injury	Not related to intrusion	





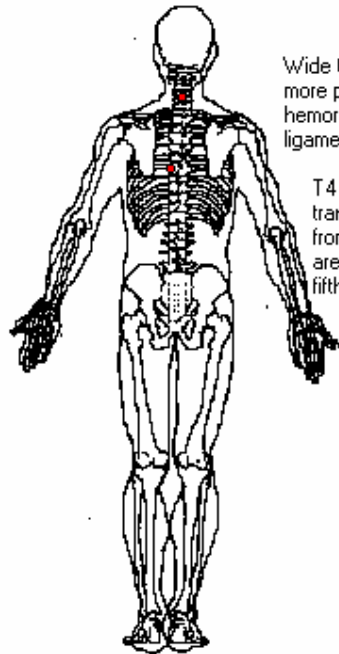
Right, Cerebrum
hematoma/hemorrhage subdural NFS

Focal subarachnoid hemorrhage
cerebral convexities and base of
the brain



Upper and lower lobes of
both lungs have multiple
dark purple contusions ranging from 1
to 3 cms.

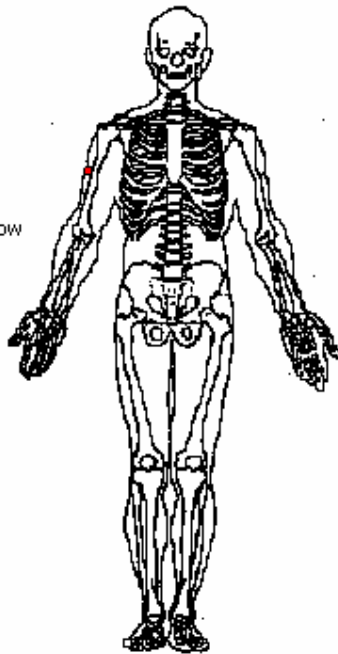
A loop of small bowel has a single
perforation with surrounding
hemorrhage. Bowel contents are free
in the abdomen and pelvis



Wide C1-C2 joint space separation
more prominent on left with
hemorrhage of the surrounding
ligaments and musculature

T4 vertebral body fracture with
transection of spinal cord. Extending
from the edges of the vertebral fracture
are lacerations of the right and left
fifth intercostal spaces

Right, Humerus fracture at elbow
NFS



Child Occupant 2

Seating position: Left rear
Restraint use: CRS see below
Sex: Female
Age: 2 years old
Weight: 14 kg, 31 lbs
Height: 76 cm, 2'6"

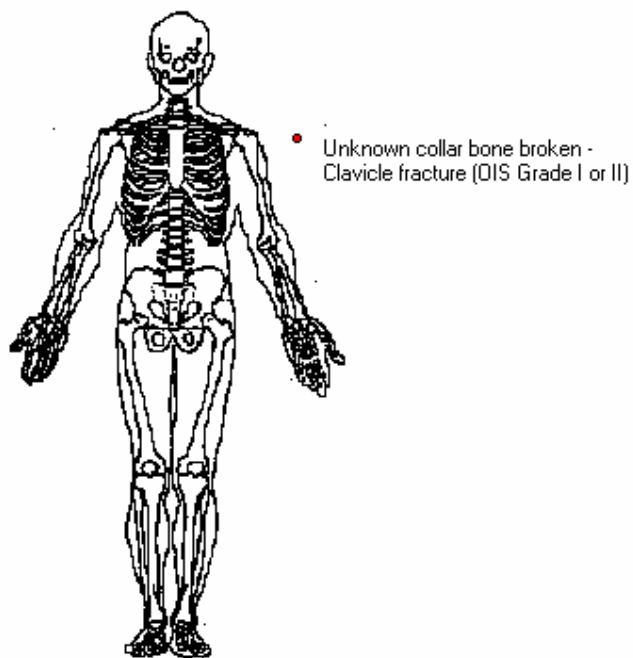
Child Seat 1

Make and model: Century Products Breverra Classic
Type: CRS with integral harness
Model no. 4486 BABN
Date of manufacture: 1/10/1999
Harness straps: in highest slots
Seat belt pretensioner: no

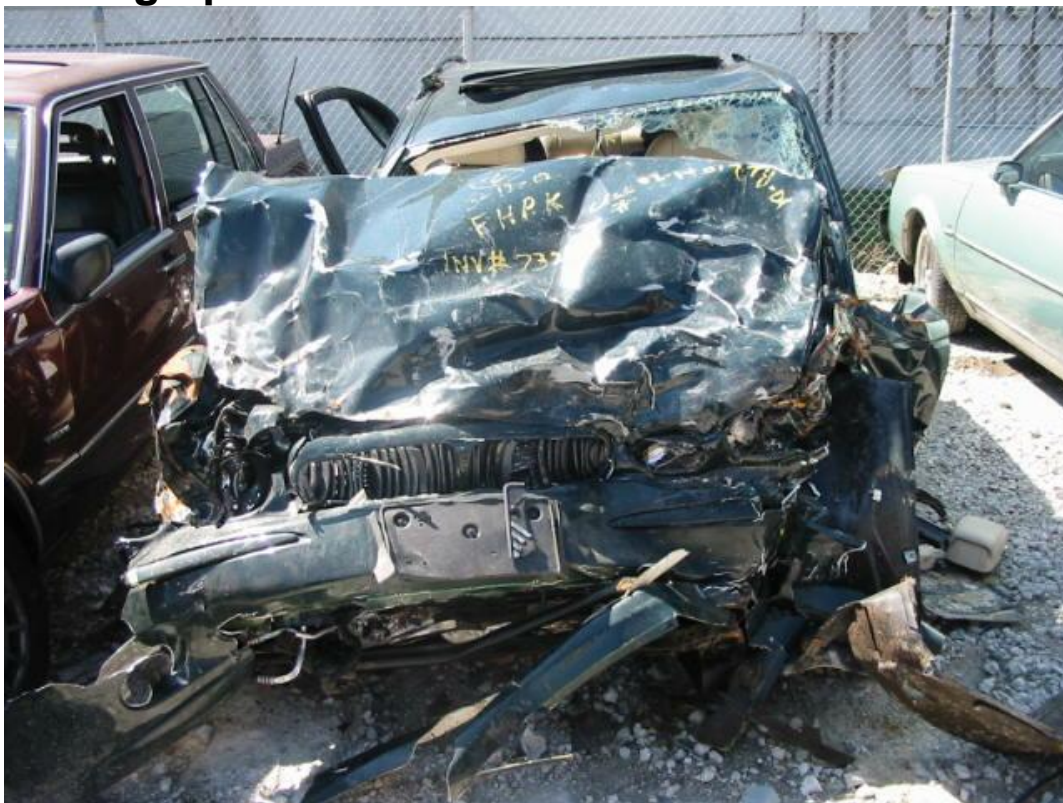


Injuries from NASS database:

No	NASS Code	Aspect	Source	Inj Source	Confidence	Direction	Intrusion	Rank
1	7522002 Clavicle fracture (OIS Grade I or II)	Unknown	Interviewee	Child safety seat (specify)	Probable	Direct Contact Injury	Not related to intrusion	1



Photographs



Case vehicle showing frontal damage



Other vehicle involved in the frontal impact with the case vehicle



Rear view of case vehicle – three year old child fatality was seated in the right rear seat



Three year old child fatality was seated in the right rear seat



Space ahead of the right rear child



Interior view of space ahead of the right rear child



Child seat occupied by two year old child shown in vehicle



Space ahead of the child on the left rear



Instructions on rear of harness CRS



Child seat occupied by two year old child – fractured clavicle. Note the lap sections of the belt do not appear to be properly attached in the photo.

11.3 Side Impact Neck Injury Case

11.3.1 NASS Case Id 195008188



Summary

This is two o'clock side impact with direct loading being applied to the right rear side of the passenger compartment. There was passenger compartment intrusion directly influencing the seating position of the eight month old child in the right rear seat. There was a likelihood of some additional loading on this child from the unrestrained six year old sitting in the left rear position. This six year old was completely ejected via the right rear window.

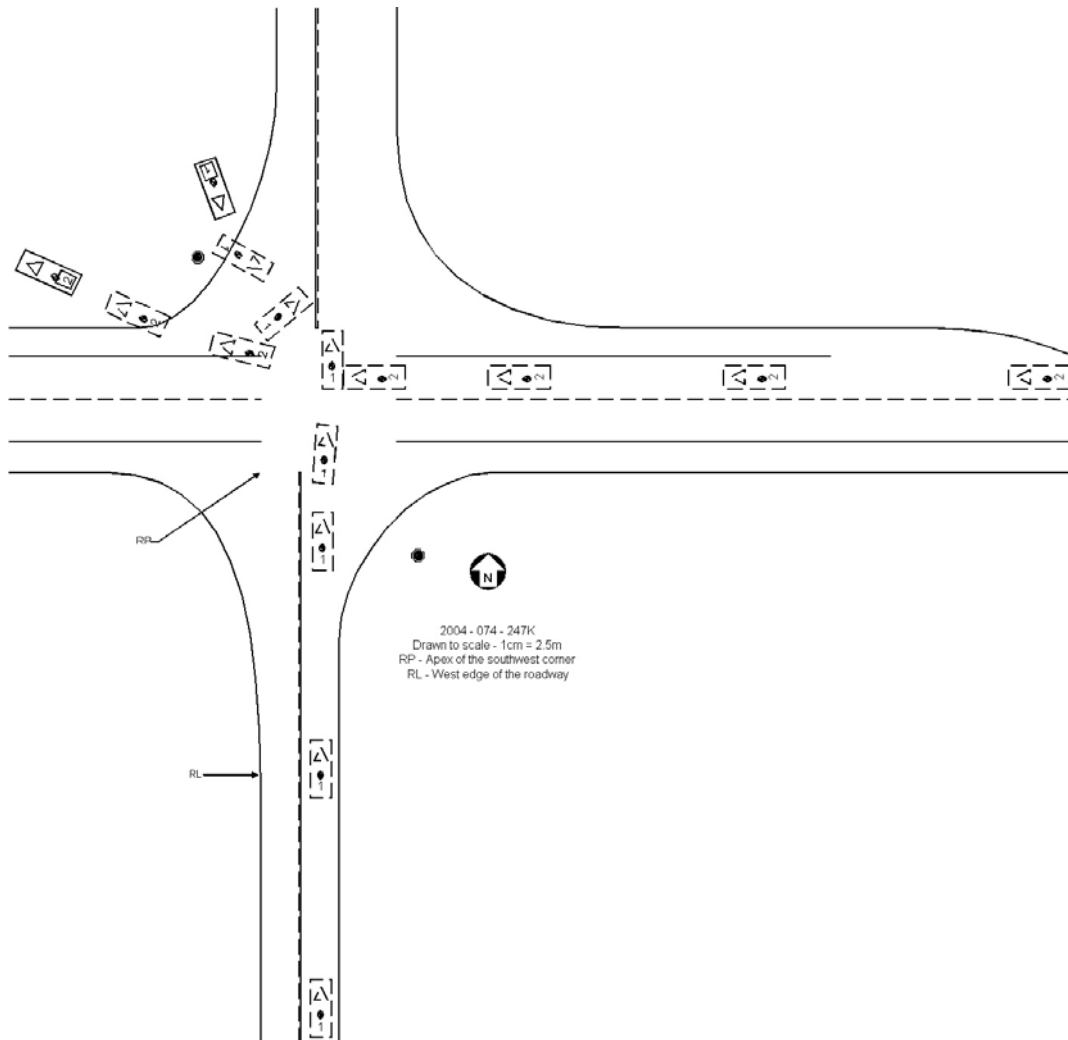
An eight month old was using an unknown child seat in the right rear. The child seat was held by a lap and diagonal belt. He suffered a neck injury at C5/6 (AIS 2). There were scalp lacerations. This is an example of a neck injury induced in a side impact, with the loading possibly complicated by the presence of an unrestrained child on the non-struck side. Due to the uncertainty of the orientation of the seat no judgement can be made about the possibly performance of a rearward facing seat in this instance.

Lessons Learned

- This accident raises the issue of whether it would be advisable to measure neck loads in side impact testing.

Accident summary according to NASS

Vehicle 1 (1996 Mercury Sable) was travelling north on a two-lane, undivided, level, bituminous roadway, approaching an intersection. Vehicle 2 (1994 Ford F-150) was travelling west on an intersecting, three-lane, undivided, level, bituminous roadway. In the intersection, the front of vehicle 2 struck the right rear side of vehicle 1. Both vehicles moved off to the northwest corner to final rest. Both vehicles were towed due to damage. Both front air bags in vehicle 1 deployed. Vehicle 2 was equipped with a driver air bag that deployed. Vehicle 1 restrained driver was hospitalized with neck fracture. Vehicle 1 restrained front seat passenger was treated and released with abrasion and contusion. Vehicle 1 unrestrained left rear seat passenger, who was completely ejected, was hospitalized with a skull fracture. Vehicle 1 right rear seat passenger, who was restrained in a child seat, was hospitalized overnight and released with neck dislocation. Vehicle 2 restrained driver received a minor forearm burn but was not treated.



Schematic diagram of the accident

Vehicle Details

Vehicle: Mercury Sable 1996
VIN: 1MELM53S6T
Engine: 3.0 litre petrol
Delta V: 18 km/hr 11 mph (longitudinal 14 km/hr 8 mph lateral 12 km/hr 6 mph)
CDC: 01RZAW3
Passenger Cell integrity: all doors remained closed
Intrusion: Centre and right rear seats affected by intrusion
Ejection: none
Entrapment: none
Cargo: no cargo
Front seats: Left front seat between forward most and rear track position, right front seat was between the rearmost and mid track position.

Child Occupant 1

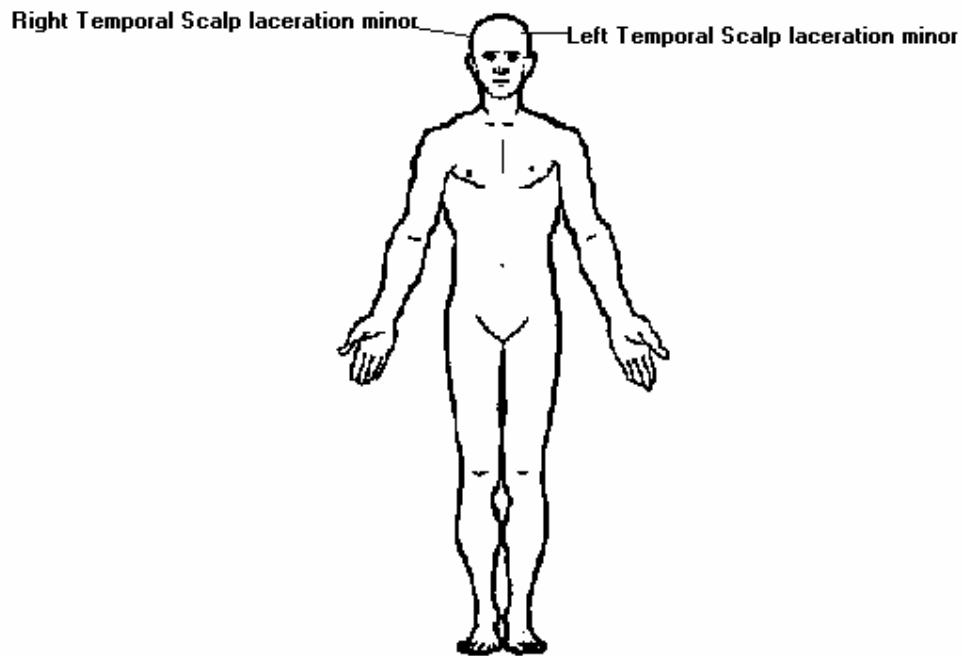
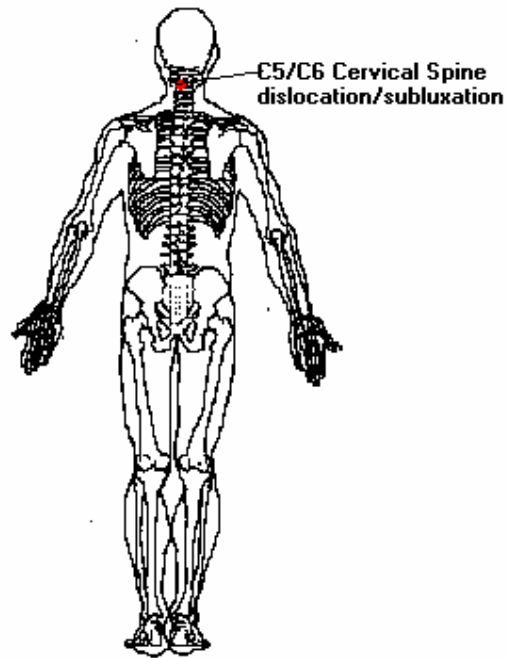
Seating position: Right rear seat
Restraint use: CRS see below
Sex: Male
Age: 8 months old
Weight: unknown
Height: unknown

Child Seat

Make and model: Unknown
Type: unknown
Seat belt pretensioner: no

Injuries from NASS database:

No	NASS Code	Aspect	Source	Inj Source	Confidence	Direction	Intrusion	Rank
1	6502042 Cervical Spine dislocation		Post-ER Medical Record	Other occupants (specify)	Probable	Direct Contact Injury		1
2	1906021 Scalp laceration minor		Emergency Room Records	Flying glass	Probable	Non contact Injury		
3	1906021 Scalp laceration minor		Emergency Room Records	Flying glass	Probable	Non contact Injury		



Photographs



Case vehicle showing damage to right rear



Case vehicle damage



Case vehicle damage to right rear door



Frontal damage to the other vehicle involved in the accident



Rear seats – 8 month old child was in right rear seat, unrestrained child in left rear seat



Rear seat backs dislocated



Right rear seating position occupied by the 8 month old child

11.4 Rearward Facing Cases

11.4.1 NASS Case Id 169007833



Summary

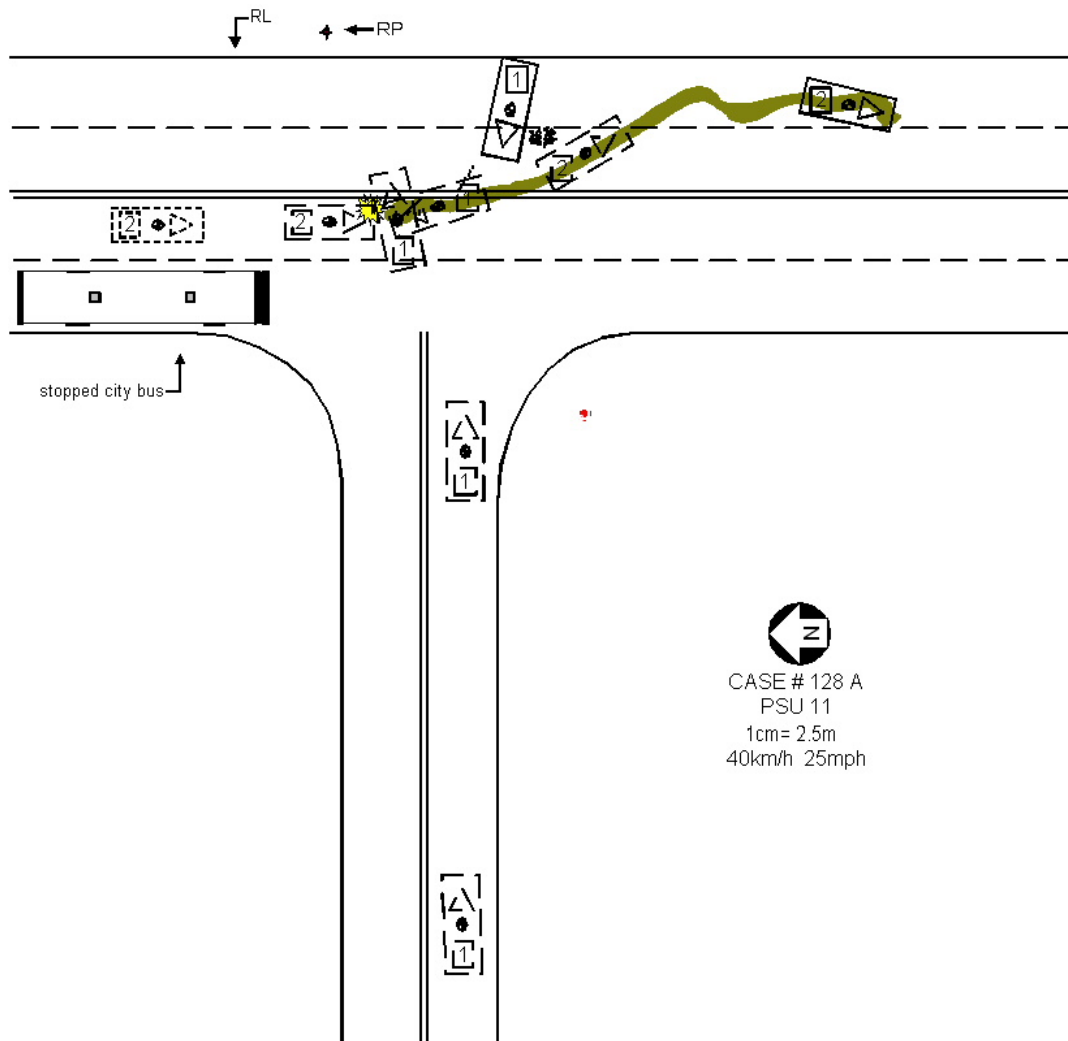
This was a moderate energy frontal impact. A 14 month old child was in a rearward facing infant restraint held on the left rear seat by the lap section of a lap and diagonal seat belt. There was no intrusion or additional loading influencing this child. He suffered a fractured skull (AIS 2) with underlying brain injury (AIS 4). There was an associated scalp contusion. This represents very poor protection in this impact. It seems likely that either, the infant restraint must have tipped sufficiently to allow the child to ramp up the back of the restraint and expose the head to direct contact with the back of the front seat, or that head loading came via the child seat shell when it struck the front seat. Two countermeasures are indicated;

- Larger shell for the rear facing CRS to ensure child's head stays within the CRS
- Introduction of improved energy absorption behind the head
- Better control of seat rotation to reduce forward movement and head exposure

A restrained seven-year-old in the adjacent rear seat suffered very minor surface injuries. A three-year-old child restrained by an adult seat belt in the front right seat also suffered minor injuries to the gum and face. The restrained driver received only minor injuries also.

Accident summary according to NASS

V1, a 2004 Ford Taurus station wagon, was eastbound on a two-way, two lane roadway at a stop sign at the intersection where the road ended. V2, a 1996 Chevrolet Blazer, was southbound in lane one of a two-way, four lane roadway approaching the same intersection. A non-contact city bus was stopped in the road ahead of V2 just before the intersection. V2 changed to lane two to continue going straight. V1 proceeded to turn left at the intersection. The front of V2 struck the left passenger area of V1. V1 rotated counter-clockwise and came to rest facing west in the northbound curb lane of the north south road. V2 continued going straight and came to rest in the northbound curb lane facing south. V1 was towed due to left side damage. V2 was towed due to front damage. The driver of V1 was fatally injured in the crash. The driver of V2 and the three child passengers were transported to a local trauma centre. The driver, right front and right rear passengers were treated and released. The left rear passenger, restrained in a rear facing infant seat, was hospitalized for two days.



Schematic diagram of the accident

Vehicle Details

Vehicle: Chevrolet S-10 Blazer 1996

VIN: 1GNDDT13W0T

Engine: 4.3 litre petrol

Delta V: 36 km/hr 22 mph (longitudinal 35 km/hr 21 mph lateral 6 km/hr 3 mph)

CDC: 12FDEW2

Passenger Cell integrity: all doors remained closed

Intrusion: none

Ejection: none

Entrapment: none

Cargo: 20lbs, 9 kg

Front seats: Left front seat was in the middle track position, right front seat was also at the mid track position.

Child Occupant 1

Seating position: Left rear seat

Restraint use: CRS see below

Sex: Male

Age: 14 months old

Weight: 10 kg, 22 lbs

Height: 63 cm, 2' 1"

Child Seat

Make and model: Graco unknown model

Type: rearward facing infant seat with three point integral harness

Harness shoulder position: top slots in seat shell were used.

Date of manufacture: 30/12/1999

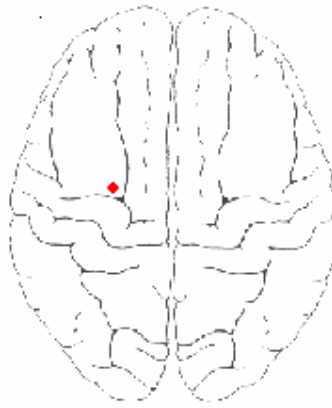
Seat belt pretensioner: no

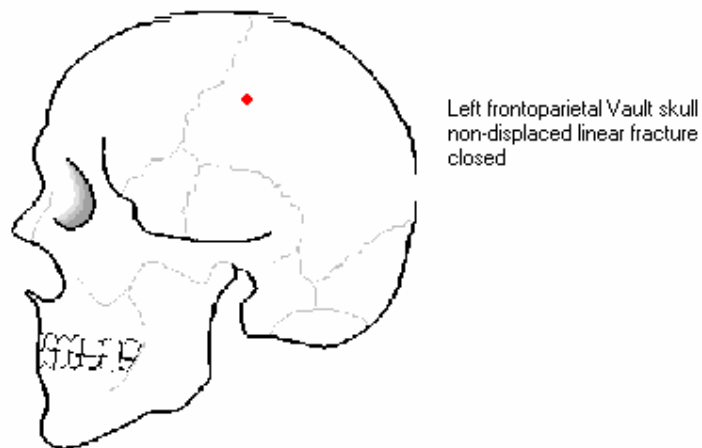
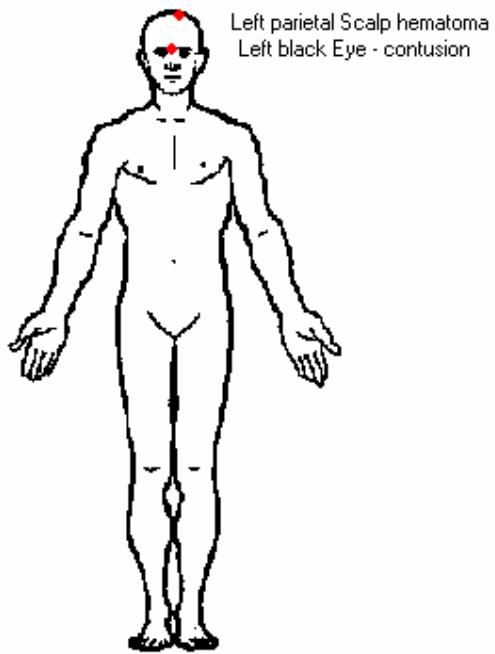
Injuries from NASS database:

No	NASS Code	Aspect	Source	Inj Source	Confidence	Direction	Intrusion	Rank
1	1904021 Scalp contusion/subgaleal haematoma		Emergency Room Records	Child safety seat (specify)	Possible	Direct Contact Injury		
2	1504022 Vault skull fracture closed		Post-ER Medical Record	Child safety seat (specify)	Possible	Direct Contact Injury		
3	1406324 Cerebrum haematoma /hemorrhage		Post-ER Medical Record	Child safety seat (specify)	Possible	Direct Contact Injury		1

	epidural or extradural small							
4	2974021 Eyelid contusion		Interview	Child safety seat (specify)	Possible	Direct Contact Injury		

small Left Cerebrum epidural hematoma underlying left frontoparietal fx





Child Occupant 2

Seating position: Right front seat

Restraint use: three-point adult belt

Sex: Female

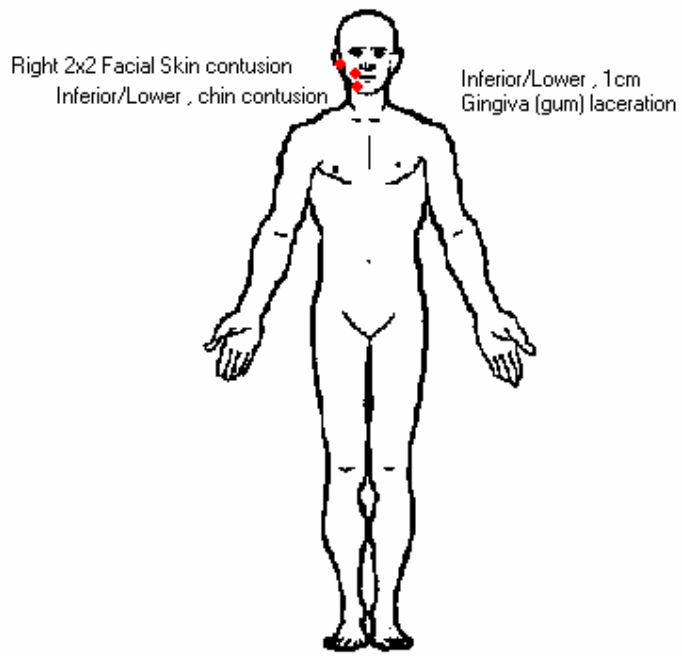
Age: 3 year old

Weight: 14 kg, 31 lbs

Height: 94cm, 3' 1"

Injuries from NASS database:

No	NASS Code	Aspect	Source	Inj Source	Confidence	Direction	Intrusion	Rank
1	2432041 Gingiva (gum) laceration		Emergency Room Records	Right side interior surface, excluding hardware or armrests	Probable	Direct Contact Injury		1
2	2904021 Facial Skin contusion		Interviewee	Right side interior surface, excluding hardware or armrests	Probable	Direct Contact Injury		
3	2904021 Facial Skin contusion		Interviewee	Right side interior surface, excluding hardware or armrests	Probable	Direct Contact Injury		



Photographs



Frontal damage to case vehicle



Frontal damage to the case vehicle



Case vehicle



Other vehicle involved in the accident showing left side damage



Left side damage to the other vehicle involved in the accident



Right front seat occupied by the three year old



14 month old male was on the left rear seat in a rearward facing child restraint



Rear of front seats



Rear of driver's seat



Rear of driver's seat possibly contacted by 14 month old child



Shoulder belt guide on left rear belt

11.4.2 NASS Case Id 219000826



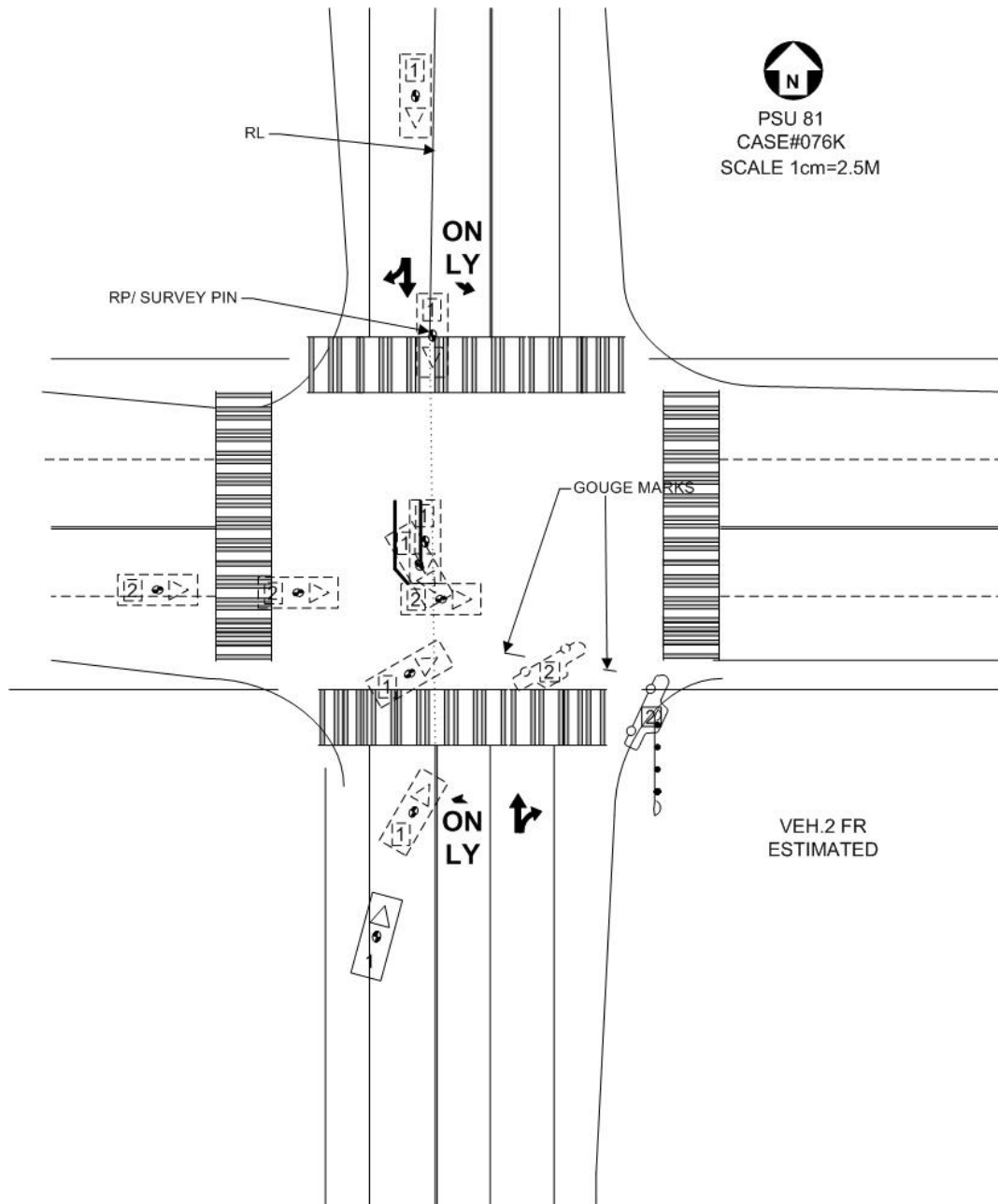
Summary

This is a low energy side impact on the left of the passenger compartment followed by a 90° roll onto the right side of the vehicle. A five-month-old child was restrained in a rearward facing infant restraint on the left rear seat. The infant restraint was held in place by a lap belt. Despite apparently being correctly restrained initially, the child was completely ejected from the vehicle via the left rear side window that was probably broken in the initial side impact. The child suffered a closed head injury (AIS 5) and a fractured femur (AIS 2). This appears to be an example of a small baby coming out of the internal harness within the infant restraint in a multiple impact involving roll over. Effective restraint of the child in this accident should have prevented serious injury. For rearward facing infant restraints in Europe it is not allowed to utilise just the lap section of the belt to fix the restraint in the vehicle.

Accident summary according to NASS

Vehicle1, a Buick Skylark 1990, was southbound on a two-way bituminous roadway approaching an intersection. Vehicle 2, a Nissan Pathfinder 1988, was eastbound on a four-lane, two-way, bituminous roadway approaching the same intersection. Vehicle 2 entered the intersection prior to Vehicle 1 and the front of Vehicle.1 struck the left side of Vehicle 2. Upon impact Vehicle 2 rolled onto its right side and slid to rest on the S.E. corner. Vehicle 1 rotated counter-clockwise

approx. 180 degrees before coming to rest on the south side of the intersection. There were no injuries to the driver of vehicle 1 or driver of vehicle 2. Occupants 2 and 3 of vehicle 2 received minor injuries despite not being belted and occupant 3 (infant) was sitting in the lap of occupant 2. Occupant 4 was seated in a child safety seat but somehow was completely ejected while the safety seat appeared to remain belted in the vehicle. Both vehicles were towed due to damage.



Schematic diagram of the accident

Vehicle Details

Vehicle: Nissan Pathfinder 1988

VIN: JN8HD16Y7J

Engine: 2.4 litre petrol

Delta V: 11 km/hr 7 mph (longitudinal 9 km/hr 5 mph lateral 6 km/hr 4 mph)

CDC: 11LPEW3 then 00RDAO3

Passenger Cell integrity: all doors remained closed

Intrusion: There was some limited passenger compartment intrusion below the seat base level relative to the left rear seating position occupied by the five month old male.

Ejection: five month old male ejected from vehicle via fixed glazing

Entrapment: none

Cargo: no cargo

Front seats: Left front seat between forward most and mid track position, right front seat track position was unknown.

Child Occupant 1

Seating position: Left rear seat

Restraint use: CRS see below

Sex: Male

Age: 5 months old

Weight: 7 kg, 15 lbs

Height: 56 cm, 1' 10"

Child Seat

Make and model: Evenflo Joyride

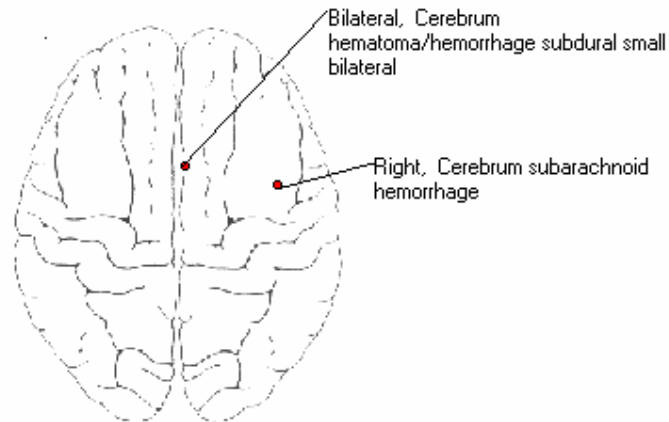
Type: Rearward facing infant seat with integral harness

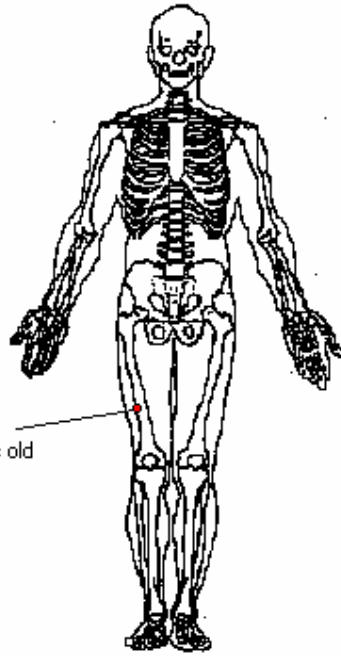
Seat belt: held in vehicle by lap belt only

Injuries from NASS database:

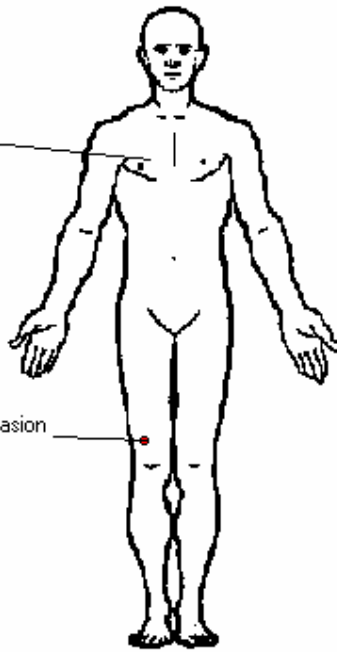
No	NASS Code	Aspect	Source	Inj Source	Confidence	Direction	Intrusion	Rank
1	1902021 Scalp abrasion	Posterior /Back/Dorsal	Emergency Room Records	Ground	Probable	Direct Contact Injury	Not related to intrusion	
2	1904021 Scalp contusion/ subgaleal haematoma	Posterior /Back/Dorsal	Emergency Room Records	Ground	Probable	Direct Contact Injury	Not related to intrusion	
3	8518162 Femur fracture shaft < 12 years old	Right	Emergency Room Records	Ground	Probable	Direct Contact Injury	Not related to intrusion	

4	1406843 Cerebrum subarachnoid haemorrhage	Right	Emergency Room Records	Ground	Probabl e	Direct Contact Injury	Not relate d to intrusi on	
5	1406545 Cerebrum haematoma/ haemorrhage subdural small bilateral	Bilateral	Emergency Room Records	Ground	Probabl e	Direct Contact Injury	Not relate d to intrusi on	1
6	8902021 Lower Extremity Skin abrasion	Right	Emergency Room Records	Ground	Probabl e	Direct Contact Injury	Not relate d to intrusi on	
7	4902021 Chest Skin abrasion	Right	Emergency Room Records	Ground	Probabl e	Direct Contact Injury	Not relate d to intrusi on	



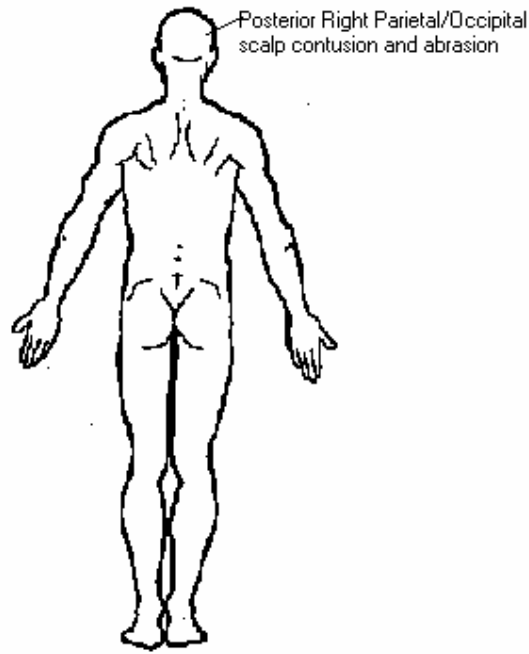


Right, Femur fracture distal metaphyseal shaft < 12 years old



Right Chest abrasion

Right, Distal Thigh abrasion



Photographs



Other vehicle involved in the accident



Frontal damage to the other vehicle involved in the accident



Left side damage to the case vehicle from initial impact with other vehicle



Damage to the left of the case vehicle



Roll damage to the case vehicle



Case vehicle damage



Case vehicle



Five month old child was seated in the left rear seating position



Possible ejection route through rear glazing



Rearward facing infant CRS used by five month old child



Rearward facing infant CRS used by five month old child



Rearward facing infant CRS used by five month old child



Harness latch



Release lever for harness under seat



Close up of harness release lever