PROTECTING CHILDREN IN CAR CRASHES: THE AUSTRALIAN EXPERIENCE

Michael Paine

Vehicle Design and Research

Michael Griffiths

Julie Brown

Road Safety Solutions

Michael Case

Royal Automobile Club of Victoria

Owen Johnstone

National Roads and Motorists Association Limited

Australia

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ABSTRACT

Developments in child restraints are currently being discussed and debated in Europe and the USA, amongst other countries. Lessons can be learned from earlier experience in other markets, such as Australia. When earlier real world experience is taken into account, there is the opportunity to ensure that the same costly mistakes are not repeated in new developments. Further, this can assist faster harmonisation in regulation and/or consumer rating systems.

Australian research on child restraints started in the late 1960s through organisations such as the Traffic Accident Research Unit of New South Wales (TARU). This early work recognised the benefits of children being restrained in the rear seat and "riding down" the crash with the vehicle.

Australian Standard AS E46 for child restraints was issued in 1970. It required at least three points of attachment between the child restraint system (CRS) and the vehicle. Most CRS utilised either three special attachment straps or a combination of an adult seat belt and a top tether to achieve this requirement. This was aided, in 1976, by an Australian Design Rule (then ADR34) that required standardised top tether anchorage points to be provided on the parcel shelf of all sedans. Australia has therefore had more than 25 years of experience with top tethers on CRS.

The performance of CRS in real world crashes has been closely monitored, including a number of in-depth studies, in Australia and has been complemented by laboratory research using sleds, crash barriers and computer modelling. In the light of this experience the Australian Standard has evolved to eliminate shortcomings. Unfortunately, in the early stages, Australian children have died or been seriously injured during the lesson-learning process of the development of the Australian Standard. Recent studies of real world crashes in Australia have shown that CRS provide exceptional protection to children, including quite young children who are restrained in forward facing child seats. Initial concerns about the vulnerability of such young occupants to neck injury have not been substantiated in real world crashes reported in Australia.. In Australia no serious neck injuries, in the absence of head contact, have been reported amongst children correctly restrained in forward facing child seats, even in very severe frontal impacts.

Despite the favourable Australian experience the restraint of young children in forward facing child seats sometimes remains a controversial issue internationally. This paper therefore addresses the issue in some detail.

A UNIQUE AUSTRALIAN STANDARD

All CRS sold in Australia must comply with Australian Standard 1754. This standard sets outs requirements for the design of child restraints, such as ease-of-use, and dynamic performance.

During the 1980s the New South Wales Government set up a network of child restraint fitting stations to improve the quality of installation of CRS, including retrofitting top tether anchorages. From this network road safety researchers gained invaluable first-hand knowledge of the kinds of problems that people encountered using child restraints. They then developed solutions to those problems, and identified areas where improvements in the Standard were required.

This was important, because it meant that when issues were brought to the Standards Committee's notice, the road safety authorities were able to provide good advice based on first-hand experience, and to make specific suggestions for any improvements or changes required. Rarely is such expert, "hands on" experience available for the purpose of developing standards.

The combination of a standard for CRS and an Australian Design Rule for CRS anchorages in vehicles has some significant outcomes which set them apart from other standards in North America and Europe. These include (see Figure 1):

1) mandatory top tether strap
2) single point of adjustment of the harness
3) six point harness with double crotch straps
4) rear seat mounting is normal practice
5) careful specification of the location of mounting points for top tether straps in vehicles (to assist accessibility and optimise performance)
6) a locally developed (rag doll style) infant test dummy which is much more flexible than overseas infant dummies. The increased flexibility was required to better replicate ejection. Less flexible ATDs were found to sometimes get caught unrealistically on harness webbing.

Some of these features are discussed in more detail below.

Top tether strap

Top tethers provide much more secure attachment of child restraints compared to being attached by the seat belt only. In particular, they provide more rigid attachment at the top part of the child restraint, so that it can "ride down" the crash whilst the vehicle is crushing. This considerably reduces excursion of the child's head relative to the vehicle interior so the head is far less likely to hit other parts of the vehicle interior - the most likely cause of serious injury to a properly restrained child.

A further advantage of top tethers is that they allow good, reliable performance with a lap-only adult seat belt. Therefore the centre rear seating position, which usually has a lap belt, can always be utilised (in NSW 40% of forward facing child seats are installed in the centre rear seat).

Figure 1. Features of Australian CRS.

Six point harness with double crotch straps

During the review of the Australian Standard in the early 1970s shield style CRS were considered as an alternative to the use of a harness. However, dynamic tests of shield style CRS that were sold widely outside Australia revealed structural deficiencies and a risk of ejection. There were also concerns about the application of force to the abdomen rather than the chest and pelvis that are better able to cope with crash forces. For these reasons the performance requirements of the revised standard discouraged shield style CRS. Shield style restraints never came into common usage in Australia, and none are currently approved .

Outside Australia there are conflicting views on the performance of shields. Webber (2000) reports on serious deficiencies with both "tray shield" and "T shield" CRS, common in the USA, and better relative performance of harness restraint. On the other hand, Hummel and others (1993) concluded from German study that "there is a significant higher tendency to severe injuries where 4/5 point (harness) systems are used". However, in the German study the sample sizes were small, the shield systems may have been a more effective design than those in the USA, the harness cases may have included the inferior four point systems and none of the CRS had top tethers.

In Australia early experience with four point harnesses proved to be very unsatisfactory with a high risk of the child submarining and being exposed to either ejection, dangerous loading of the abdomen or strangulation. Unfortunately there were several cases of children dying in stationary vehicles when the child slid down and was caught by the neck. In the early 1980s, CRSs with four point harnesses were recalled for the addition of crotch straps. Crotch straps reduce the risk of submarining and are now required by the Standard.

Double crotch straps were initially introduced because of a fear (not substantiated by any actual incidents) of causing damage to the child's reproductive organs. A considerable amount of research was conducted into trying to find a repeatable standards test to measure the pressure applied by child restraints, and identify an injury criteria for that part of a child's anatomy, however no reliable method was ever identified. Ultimately, after more than five years of research, the Australian Standards Committee decided to simply mandate the design feature of twin crotch straps, rather than try to find a way of assessing the performance of single crotch straps. Subsequently all child restraints made and imported into Australia have been successfully designed or adapted to incorporate dual crotch straps.

Single point of adjustment of the harness

Early model child restraints had adjusters on many of the harness straps. Road safety researchers found that the more adjusters in a child harness there were, the more potential there was for incorrect or slack adjustment. The decision was made to mandate a design feature of a single harness adjuster only, so as to reduce the potential for loose fitting harnesses. Some single point adjusters were initially awkward; however development has now seen adjusters become a lot easier to use.

Rear seat mounting

There has been considerable publicity relating to the problems of airbags interacting with child seats installed in the front seat. This has been a major issue in Europe and North America. It is recognised that parents in many Northern Hemisphere countries have an expectation their child be in the front seat alongside them, particularly so for infants. This is not the case in Australia and concerns about the use of the rear seat have been shown to be unfounded.

Because all Australian CRS must have a top tether and the anchorages for top tethers are exclusively located in the rear of Australian cars, Australian parents have developed the habit of always restraining young children in the rear seat. In fact most of the current generation of Australian parents were, as children, restrained in the rear in similar CRS to those used today.

The exclusive use of rear seats means Australia has not encountered any of the problems due to the interaction of CRS with front airbags and there is no need to disable front passenger airbags in Australia.

INTERNATIONAL STANDARDS AND ISOFIX

Australia has had ongoing involvement in the International Standards Organisation Committee developing a new Standard for child restraint systems (ISO-CRS) since its earliest meeting in the mid 1980s. At that time it was recognised that child restraints needed to be more firmly attached in cars and there was a need for separate attachment systems for child restraints that did not rely on adult seat belts.

The UK representative on the ISO CRS committee, Richard Lowne, presented to the committee the results of an evaluation of a wide range of methods of attachment of child restraints and concluded that the most effective and easily implemented system would be one which had the child restraint attached at two points at the base and a single top tether. At that time, however, opposition to top tethers was so strong in some parts of Europe that this concept was not adopted and the system proposed was a four point attachment system, with attachments at each of the four corners of the base of the child restraint and no upper restraint.

Ten years of development of the rigid, four-point ISOFIX system was undertaken, and it was close to implementation when the U.S. automotive manufacturer, General Motors lobbied the ISO CRS committee with the proposition that the combination of top tethers with lower flexible anchor straps could offer most, if not all, of the benefits of a four point rigid base system at a lower cost, with easier compatibility for adult occupants..

This brought about an impasse position on the ISO Committee and stalled progress. Fortunately soon after that, following lobbying, the U.S. Government set up a special U.S. 'Blue Ribbon' taskforce to look at how better restraint systems could be offered to North American children. An outcome of that review was the LATCH system and a requirement for top tether anchorages in cars. This directed development of child restraints in North America to top tethers (Webber 2000).

The new USA rules gave the option of child restraints being attached by a top tether and two lower anchorage points. This caused a review of the ISOFIX so that vehicle seats intended for use with CRS must be provided with two rigid lower anchorages and "a means to limit the pitch rotation of the CRS". In most countries the latter requirement will be achieved with a top tether. Remaining opposition to top tethers, which is now mostly German-researcher based, and the unique CRS provisions in Sweden is unfortunate but has no significant effect on the global adoption of top tethers.

The provision of top tether anchorages is not an issue with most European, Japanese and Korean car manufacturers - all imported vehicles in Australia have the fixings in place. Indeed, for some time now, many manufacturers have included the top-tether anchor/weld nuts on all models in non-Australian markets to reduce manufacturing complexity.

Vehicles with ISOFIX anchorages are now on the market. The Australian CRS standard is being reviewed to encourage designs that take advantage of the potentially improved lower restraint provided by ISOFIX and LATCH, compared with adult seat belts. Australian research indicates that some forms of LATCH could improve the performance of Australian CRS in side impact crashes. LATCH also has the potential to eliminate the main form of misuse in Australia - incorrect use of the adult seat belt for securing the CRS (discussed later).

On the other hand, the lack of ISOFIX lower anchorages for the centre rear seating position may reduce the use of this more protected seating position by children in CRS. Although, under the proposed Australian Standard, the CRS must be able to be used in vehicles with and without ISOFIX it is possible that, unless a local (compatible) variant of LATCH is implemented, parents will use outboard seating positions that have ISOFIX/LATCH anchorages in preference to the centre seat that only has a seat belt. Australian child restraints with top tethers are able to utilise either three point or two point adult seat belts (or ISOFIX, under the changes to the Standard). Conversely, older children who use an adult seat belt are much safer in a three point seat belt (booster seats with no upper restraint must not be used with a two point seat belt). The increased use of outboard seating positions with ISOFIX anchorages for CRS might result a greater proportion of older children using the centre rear seat. This is a concern because there are still many models that only have a two-point seat belt in this position.

CONSUMER INFORMATION

Australia has operated a Child Restraint Evaluation Program (CREP) for more than a decade. CRS are subjected to dynamic tests (some more severe than the Australian Standard) and usability trials. Consumers are advised of the best performing restraints (via brochures and the internet).

It was realised early in the development of CREP that it would not be appropriate to apply dummy injury performance limits to the ratings due to a lack of biofidelity of the dummies and uncertainty about the interpretation of dummy head injury measurements to injury risk in children. Dummy injury measurements are considered during the CREP assessment process but are secondary factors - head excursion and risk of head contact are considered far more important (Kelly and others, 1996).

Of particular concern to Australian researchers is that misguided attempts to reduce dummy head injury measurements could result in greater head excursion and therefore greatly increased risk of a head contact, resulting in serious head and neck injury. Controversial assessment of EuroNCAP child occupant tests is resulting in some observers concluding that the more rigid fixation of CRS given by ISOFIX anchorages, is leading to greater risk of injury. Real crash experience in Australia with top tethers that provide a firm attachment to the vehicle, has found that children are able to survive extremely severe crashes without serious injury. This real world experience is contra-indicative of the children injury criteria being considered in Europe and North America, some of which are based on extrapolation of adult limits (Brown and others 2001, Trosseille and others 2001, Melvin 1995, Beusenberg and others 1993).

Japan NCAP recently introduced a CRS rating system for consumers. NHTSA is considering the introduction of a consumer rating program for CRS in the USA (NHTSA website). Submissions to NHTSA have expressed concern about the reliance on dummy injury measurements. Australian experience supports such caution. In the current state of dummy development and knowledge about child injury tolerances, it would be inappropriate, and quite likely counter-productive, to base a CRS consumer rating program primarily on child dummy injury measurements.

Similar concerns apply to a CRS assessment protocol being developed by the European New Car Assessment Program (EuroNCAP). Australian researchers, consumer organisations and state authorities involved in ANCAP are concerned that

insistence by EuroNCAP on inappropriate head, neck and chest injury limits might encourage CRS that offer inferior real world protection (Paine and Brown 2001). ANCAP maintains a strong position and input to EuroNCAP regarding this issue.

When head injury criteria, instead of the more important head excursion limits, are the main form of performance evaluation, then more rigid child restraint attachment systems tend to be rated poorly. However, these more rigid systems reduce the prospect of harmful head contacts, and subsequent head injury.

AUSTRALIAN RESEARCH

A comprehensive range of research has been undertaken in Australia to support the development of Australian and international standards, Australian Design Rules and CREP. This has included in-depth crash investigations (discussed in the next section), laboratory testing using sleds or vehicle-to-barrier tests, computer modelling and user surveys. This experience has reaffirmed the soundness of the design concepts of Australian CRS.

Sled tests at Crashlab (Roads and Traffic Authority of New South Wales) have been used to compare CRS with and without top tethers; assess the effects of different mounting points for top tethers; assess restraint effectiveness for different size child dummies and assess prototype CRS design features such as ISOFIX concepts.

One remarkable series of crash barrier tests at Crashlab involved the same model car being subjected to a full frontal crash barrier test at progressively higher speeds, from 40km/h to 100km/h. Child dummies were placed in CRS with top tethers in both outboard rear seating positions. One CRS had a high mount top tether(Australian style), whilst the other had a low mount (early US style) .An important finding was that the deceleration of the rear parcel shelf levelled off at about 60km/h. Beyond this speed the front seat occupant space was severely compromised but the survival space in the rear seat remained intact (top image, Figure 2 - note the open rear door, revealing the CRS and child dummy).

The child dummy injury measurements also did not increase markedly beyond those of the 60km/h impact (for which there is real world evidence of survival without injury). After considering these dummy measurements and the retention of rear seat occupant space it was concluded that the 100km/h crash was survivable for young children in forward facing child seats.

Figure 2. Variable speed crash tests by Crashlab. Lower image shows peak of 40km/h crash. Top images shows peak of 100km/h crash, which was considered to be survivable for the child dummies in CRS installed in the rear seat.

STUDIES OF REAL WORLD CRASHES

Studies of real world crashes involve varying levels of details about the characteristics of the crash and the resulting injuries.

Limitations of mass crash data

Analysis of mass crash data is useful for examining general road safety trends and factors that are an influence in a large proportion of crashes. However, experience has shown that mass crash data is of very limited use for evaluating infrequent events, such as fatalities to child occupants. For example in New South Wales during the 1990s there was an average of 6 children aged up to 4 years who were killed in motor cars each year. With such small numbers any year to year variation could easily be due to the randomness of the event and it would take exceptional circumstances to conclude that there had been a significant change from one year to another. Similar caution is needed when comparing child occupant fatalities between countries. This uncertainty, combined with a lack of good information about exposure of children to car accidents (for example, child kilometres travelled), hinders efforts to compare accident rates between countries.

A far better approach is to investigate the effectiveness of CRS in real world accidents - so called "in-depth" studies.

In-depth crash studies

Study design

Great care is needed in the design and analysis of studies involving injuries to children. In addition to sampling issues (such as the inherent bias in the selection of cases), it is very important that injury mechanisms be thoroughly investigated. For example, there have been cases in Australia and overseas where serious neck injuries have been reported with restrained children. However, in all Australian cases that have come to the attention of road safety researchers it has been found that the neck injury was associated with a head contact, which in turn was due to gross misuse of the restraint or gross intrusion into the occupant survival space. This work has indicated that a child's neck appears to be surprisingly resilient in pure tension but is susceptible to a combination of tension and shear force - as typically occurs with a head strike.

It is hypothesised even a small force applied to the head, while the neck is in tension, can change a high, but manageable neck tension into a injury causing event.

This provides further reason to give priority to minimising head excursion, rather than reducing non-contact head forces, with associated greater excursion. (Herbert and others 1974, Henderson 1994).

Australian CAPFA study

The most recent and most comprehensive Australian study of children and child restraint performance in real world crashes was conducted in NSW throughout the year 1993 (Henderson 1994; Henderson et al 1994). The primary objectives of this study, which was conducted for the Child Accident Prevention Foundation of Australia (CAPFA, now Kidsafe), was to investigate the performance of the child restraint systems available at the time. The ability of Australian child restraint systems to provide effective crash protection was confirmed by this study. Of the 247 children aged 14 years or younger included in this study, 228 were using some form of restraint and very few sustained serious injury. This was the case even though the sampling methods were such that data collection was skewed towards the serious end of crashes.

Of particular interest was the sub-set of children restrained in forward facing child seats with a top tether and harness. There were 38 children in this subset.

Figure 4a. Two year old child in FFCR in centre rear position uninjured.

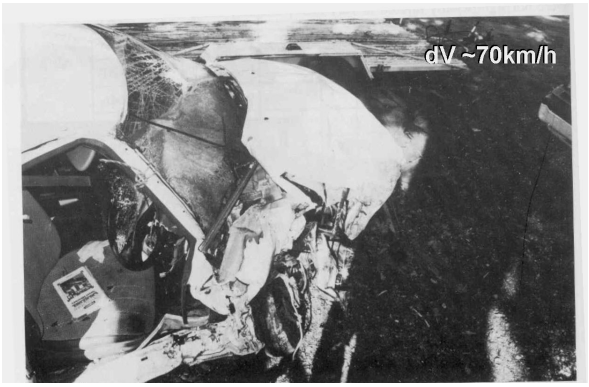

Figure 4b. 18 month old child in FFCR in left rear seat uninjured.

Figure 4c. Nine month old child in FFCR sustained only bruising.

Figure 4d. Three year old in FFCR in centre rear seat sustained broken arm from adjacent occupant. Three adults killed.

There was one fatality - a young child using a forward facing restraint. Investigation found that the child had not been secured in the harness and the CRS had not been secured to the vehicle. Instead the adult seat belt had simply been placed around both the child and the CRS. The sash portion of the seat belt was lined up with the neck of the child and this was the most likely cause of the fatal neck injury. The important point about this case is that it took an in-depth analysis, including expert examination of the vehicle and CRS, to determine the likely cause of the fatal injury. Cursory examination of this case might have suggested a neck injury due to the CRS.

There were four more cases of serious injuries or worse (AIS2 or more). All involved either gross misuse or gross intrusion.

There were no cases of serious injury resulting from deceleration forces alone. On the contrary, there were several remarkable cases of survival in very severe crashes. Some of these are described in figures 4a to 4d.

Within recent EuroNCAP technical meetings there have been claims that vehicles are becoming stiffer, to cope with the offset crash test, and therefore the very good high speed performance of CRS may now have been exceeded by stiffer cars. Australian research findings do not support this. Firstly a review of full-frontal and offset crash tests conducted by ANCAP since 1993 and EuroNCAP since 1996 reveals no clear trend with peak deceleration of the passenger compartment. Secondly, several of the cases of survival documented in the CAPFA study involve frontal crashes that are much more severe than the NCAP offset crash test - in other words, there is a large factor of safety inherent in the NCAP test. Thirdly, the injury measurements from current, non-biofidelic child dummies cannot be reliably linked to the risk of serious injury to forward-facing children in real crashes. Indeed, in-depth studies of severe crashes will continue to be required to validate the next generation of child dummies (Trosseille and others 2001, Melvin 1995, Beusenberg and others 1993).

Other in-depth studies

The findings reported by overseas researchers studying the types of injury sustained by restrained children have been strikingly similar to those of the CAPFA Study, regardless of the type of study or where in the world the study was carried out. (for example: Rattenbury & Gloyns, 1993; Tingvall, 1987; Newgard and Jolly in 1998; Isaksson-Hellman, 1997). The most important findings are that:-

- Most injuries suffered by restrained children are minor - CRS perform exceptionally well when compared with adult seat belts, and
- The head (including the face) is the most commonly injured and most frequently seriously injured region of the child's body.

Webber (2000) refers to a recent study of children aged 2 to 5 which found that children in seat belts are 3.5 times more likely to suffer moderate to severe injuries, particularly to the head, than those in CRS.

These studies confirm there is a need for placing a high priority on potential for head injury when assessing the design of child restraints and their performance in particular vehicles. Head injuries mainly occur following contact with the vehicle interior or intruding objects. Limiting head excursion in frontal impact is therefore a priority in child restraint performance. The ability of child restraint to prevent head contact and absorb energy in side impacts is also of critical importance.

Arm and leg injuries in children in forward facing seats are usually a result of contact with the vehicle interior or other occupants in the vehicle.

Gross misuse has been reported in a large proportion of the serious and fatal injury cases from in-depth studies. Reducing the incidence of misuse therefore deserves high priority.

Review of neck injury cases

Australian researchers are well aware of concerns about the risk of neck injury for young children in forward facing child seats. They have therefore carefully investigated claims of serious neck injury due to tensile loads in the neck. No cases have been encountered in Australia, despite monitoring by road safety authorities. There have been a number of overseas cases where it was initially claimed that serious injury from pure tensile loads occurred. However, in all cases that have been investigated by Australian researchers, it was subsequently found that a head contact occurred and contributed to the neck injury.

The most extensive study ever of children injured in car crashes in North America, is currently being conducted by Traumalink at the Children's Hospital of Philadelphia with funding from Statefarm. The study's in-depth stream has attempted to follow up on any reports of significant neck injury to a child car occupant. To date their study has not found any significant neck injury, where head contact could be excluded. There was one case of fatal neck injury (atlanto-occipital distraction) where the researchers reported it was not clear if the child's head sustained

an injury load path contact. However, this case had a penetrating injury in the submandibular area. External intrusion forced the drivers seat rearward into the child's centre rear position, and there was injury evidence that the harness was quite loose. (Arbogast et al, 2002).

In the mid 1990s, there were reports to the ISO CRS committee from German researchers that serious neck injuries were being encountered in forward facing child restraint systems. It was initially thought these may be occurring without head contact. The member reporting the cases was asked for further information. Subsequent reports to the ISO CRS committee indicated that there was possible head contact in all cases. In any event there were no reports of neck injury, for forward facing child restraints that had pitch control devices, such as top tethers. One of us (Griffiths) was an ISO CRS committee member at the time and recalls these outcomes, which do not appear to have been formally published.

MISUSE OF CHILD RESTRAINTS

Top tethers

An early concern with top tethers was that they might not be used. This concern may have been a factor in the reluctance, in the 1970s and 1980s, of USA and Europe to use top tethers. Australian experience found that this was initially correct. A network of Restraint Fitting Stations was developed and publicised. After several years of perseverance, correct usage became common, and the benefits of improved performance began to be realised. . The latest usage survey revealed less than 5% of child seats in New South Wales were being used without a top tether (Paine and Vertsonis 1998). In any case, early crash studies revealed that the CRS still performed reasonably well when restrained solely by the adult seat belt – a less than optimal situation but not necessarily dangerous.

Use of adult seat belt for attaching CRS

Amongst the range of CRS available in Australia there are a variety of methods by which the adult seat belt is intended to be threaded through the CRS. Adding to the complication faced by carers is that "convertible" style CRS, that can be used facing rearwards or forwards, have different belt paths and adjustment mechanisms. Partly as a result of this complication, about 12% of forward facing child seats in New South Wales had the seat belt threaded incorrectly (Paine and Vertsonis 1998). This was the dominant form of misuse of forward facing child seats. Many of these cases were confined to a few older designs of CRS where the belt could be threaded several different ways and looked correct each way. In these cases the "incorrect" belt path still provided adequate restraint and, by itself was generally not a serious safety hazard (a further advantage of top tethers).

Harness adjustment

A loose harness increases the loads applied to the child, increases the forward excursion of the child and increases the likelihood of a child wriggling partially out of the harness.

The quality of harness adjustment can only be reliably assessed with a child in the CRS. This is difficult to achieve in the field and the assessment is likely to be subjective. Subject to this uncertainty, the proportion of loose harnesses in Australia is likely to have decreased as CRS designs have improved. The provision of a single point of adjustment of the harness has contributed to this improvement.

CONCLUSIONS

The child restraint designs used in Australia have been shown to provide exceptional protection to child occupants in severe crashes. Cases of serious injury always involve misuse of the child restraint or gross intrusion.

Lessons learnt

- Australian research has indicated that the first priority in CRS design is to minimise excursion of the child's head. To achieve this, the child should be coupled as tightly as possible to the structure of the vehicle.
- Top tethers, in combination with an adult seat belt, are a very effective way to firmly attach the CRS to the vehicle. Correct usage of top tethers can be achieved by fitting stations and education.
- Six point harnesses distribute the crash forces to load-bearing parts of a child's body and eliminate the risk of ejection.
- No cases of serious neck injury to a child in a forward facing child seat with top tether and six point harness have ever come to the attention of Australian researchers, provided the CRS and harness are correctly used and there is no intrusion into the child's survival space. Australian researchers have found many cases of children, some as young as 8 months old, surviving very severe crashes without injury.

Still room for improvement

The following areas show potential for further improvement.

- Reduction in forward excursion of the child's head appears to be more important than reducing non contact head forces. Some styles of CRS marketed in Australia have featured top tethers that are not mounted as high as possible on the CRS. These have be shown to have inferior performance to high-mounted top tethers.
- Compatibility between vehicle and CRS needs greater attention. Top tether anchorage location could be revised to improve dynamic performance, improve accessibility and eliminate the potential for interference from luggage. Seat back contours could be improved so that CRS fit better. A draft assessment protocol has been developed by Australian NCAP for this purpose.
- CRS could provide much better head protection in side impacts. Large padded "wings" with energy absorbing material interposed between the child's head and the side of the car or intruding object could achieve this (also applies with booster seats that are used in conjunction with adult seat belts).
- The ease of use of various adjustments within CRS could be improved. Retractable top tethers and harnesses would eliminate slack. Shoulder height adjustment could be made simpler to use.
- To minimise excursion of the lower part of the CRS, the routing of the adult seat belt should be as low as possible.
- Designs of CRS that can easily utilise either adult seat belts or ISOFIX anchorages for lower restraint are needed, together with an education program about the use of such CRS. Tell-tale devices that confirm the CRS is correctly installed could be considered.
- There are increasing numbers of vehicles with luggage tie-down rings behind the rear seat. These could be confused with top tether anchorage points and their purpose needs to be more clearly indicated to parents/carers who install CRS.

Australian consumer test programs such as CREP and NCAP can provide incentive for improvement. These programs also provide feedback for improvements to standards, by giving an indication of those products that perform much better than the minimum required to meet the standards.

There is an ongoing need to monitor crashes involving injury to children and to conduct in-depth crash studies from time to time. CRS usage surveys also provide feedback on CRS design problems and the need for parent/carer educational programs.

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