

How can a detailed Accident Recording help to improve Child Safety in Cars?

Gerd Müller*, Heiko Johannsen*

*Verein für Fahrzeugsicherheit Berlin e.V., TIB 13, Gustav-Meyer-Allee 25, 13355 Berlin, Germany

Abstract - The misuse of CRS (child restraint system) is one of the most urgent problems in connection of child safety in cars. Numerous field studies show that more than two thirds of all CRS are used in a wrong way. This misuse could lead to serious injuries for the children. Surprisingly the quality of CRS use is coded much better in accident data (e.g. GIDAS) than the results of observatory field studies show. It is expected that misuse of CRS was not detected by the accident teams in a large number of the cases.

An essential part in improving child seats and their usability is the knowledge of the relation between misuse and resulting injuries. For that the analysis and experimental reconstruction of accidents is an important part. For allowing an exact experimental accident reconstruction, it is necessary to have detailed information about the securing situation of the child and about the installation of the CRS in the car.

INTRODUCTION

For research activities in the field of child safety, it is essential to investigate and to reconstruct accidents. In this paper “accident reconstruction” means the experimental reconstruction of an accident by doing crash tests with vehicles or sleds. Here, substantial information could be collected, which are relevant for a variety of research areas. On the one hand, a reconstruction can show how a child seat in a real accident works and which dynamic movements could be observed. On the other hand the measured values could be used for validating dummies and for the determination of biomechanical limits. If the exact injury of a child in a real accident is known, then the measured values of the reconstruction experiment can be linked with it. As a result of many reconstruction tests valid injury risk curves can be created see for example [1]. However, to make this possible it is necessary that an accident will be reconstructed as accurate as possible and that all the relevant parameters are taken into account.

In this paper it is shown which information is important for the reconstruction of an accident and how to acquire this information with the help of traces in the car and on the child seat. Furthermore typical injuries as a result of typical misuse of a child seat are shown.

BASICS OF CHILD SAFETY IN CARS

Restraint systems in cars, like belts or airbags, are designed for adults and they are not suitable for children. Therefore, special systems for the protection of children in cars, so called child restraint systems (CRS) are needed. These seats are divided into different groups, depending on the weight of the child. In the following the most common systems are described.

For babies up to a weight of at least 9 kg the use of a baby shell is required (group 0+), which have to be installed in a rearward facing position in the car. With this transporting position the relative movement between head and upper body is limited, which reduces the risk of severe neck injuries in frontal impact. Due to a comparatively large and heavy head and nearly no muscles in the neck area, there would be a big potential of neck injuries in case of a forward deceleration. For children from 9 to 18 kg group 1 CRS are available. These seats are normally installed in a forward facing direction. The child is secured with a five point harness system in the CRS, the CRS itself is fixed with the vehicle belt or with ISOFIX in the car. These seats are designed in a way, that the harness has only contact with the stable bone structure of the child (clavicle, ribs, pelvis) and that they offer also a good protection in case of a side collision.

For children up to a weight of 36 kg group 2/3 seats are available. Here the child and the seat are fixed together with the vehicle belt in the car. The task of the CRS in this case is to ensure a good belt path over the shoulder and over the upper legs of the child to avoid submarining resulting from premature iliac crest. Additionally it offers a side and head protection. Examples for the most common systems are shown in Figure 1.



Figure 1: Different CRS types: Left group 0+, Middle group 1, Right group 2/3 [2, 3, 4]

In Germany, children have to be seated in an appropriate CRS in a car up to including 11 years or up to a height of 150 cm.

Many studies of the last 15 years [5-8] showed that one of the most prevalent problems in connection with child safety in cars is the misuse of the CRS. In about two thirds of all cases children are not secured in the child seat correctly or the CRS is installed in the car wrongly. This misuse can lead to severe injuries while on the other hand a correctly used CRS offers a high protection level. This leads to the statement that if there is an injured child after an accident it is very likely, that there was misuse in connection with the use of a child seat. This applies especially for frontal crashes, for side impacts and rollover accidents the situation is less clear. However, based on the field study experience it is in general likely that children are not secured correctly in the car.

EXPERIMENTAL RECONSTRUCTION OF ACCIDENTS

In order to investigate an accident and its consequences for the child occupants as accurately as possible, a sufficient number of parameters about the accident must be known. This includes not only basic parameters such as the constellation of the cars, the collision velocity and collision angle, but also about the security situation of the child detailed information is necessary: age, stature, weight, the seating position in the vehicle, the used child seat and, if possible, information concerning the securing quality. However, it is difficult to answer questions about securing quality and whether or not the child seat was used correctly after the occurrence of an accident. Normally, first responders have taken the child out of the vehicle before the arrival of rescue team and less often but still frequently even the CRS is removed from the car before accident investigation teams could start their analysis. Direct observations of the seat installation are no longer possible. In order to acquire reliable information about the CRS installation, it is necessary to ask witnesses of the accident or even the people who rescued the child. Also traces on the child seat and in the car can provide information how the child seat was secured in the vehicle. For example the vehicle belt can be inspected for signs that may indicate a load introduction by the child seat, ideally, the exact belt anchorage point on the child seat can be identified, which has left a mark on the vehicle belt. Other traces may be impact or pressure points inside the vehicle, which can be an indicator of a contact of the child seat with the interior.

The following describes a procedure which information about the accident and the actual situation of the child protection can be obtained from the vehicle. By answering questions in a meaningful order a comprehensive picture is created, which usually gives a useful view of the whole situation. In general it must be mentioned that not all statements are made solely based on pure facts, but that they are the result of experience and analysis of numerous accidents. In the procedure described here the average accident rate is described. Nevertheless, there are always cases which cannot be covered by a schematic view due to their seriousness or their unique circumstances.

General Information about the Accident

What was the collision speed, where is the collision point located on the vehicle, what was the collision angle?

Answering these questions is usually not a big challenge for an experienced accident expert. With the help of brake and skid marks, the final position of the vehicle, the deformation of the vehicle and on other vehicles or the collision obstacle, the basic kinematics of the vehicle can be verified. In addition, appropriate simulation programs and databases in which information on vehicles with similar damage patterns is stored, may help in determining the collision speed and angle of the collision. Although if in general quite good results are achieved, it must be noted at this point that the reconstruction of an accident is always fraught with some degree of uncertainty. Even a slight deviation of the collision speed, collision angle or collision location may lead to significant differences of the occupant loads. Already slight variations can lead to different contact of structural parts of the vehicle body compared to the real accident. This also leads to different loads, other vehicle deformations and intrusions of the passenger compartment. In determining these parameters that describe the accident in principle, therefore maximum accuracy must be taken.

Where was the Child seated?

Answering this question appears at first certainly self-evident and therefore unnecessary to mention at this point. However, it should be noted that the finding of the child's seating position is not always clear and to clarify that it is often, that the information provided in the accident files is not clear or obviously wrong. Once there is a false statement in the accident report, it is often not noticed and the accident will be reconstructed under circumstances with false assumptions. Therefore it is necessary to determine the child's seating position with the other indications, following the investigation of the vehicle. If this is not possible, the search for other evidence is needed, which makes another seating position more likely.

Information on the Child and on the Child seat

How old is the child, how tall is it, how heavy is it?

This information can be extracted normally quite simple from the accident records. If the child was examined in the hospital or has even died and an autopsy report is available, then this information can be found there. Information on age is also available in the police's accident report.

Which child seat was in use?

The question about the child seat is very easy to answer, if there are pictures of it, or if witnesses can be interviewed directly. If this is not the case, there remains the possibility that the child seat was taken into custody by the police, or that it is still in the accident vehicle. If there is no reliable information about the child seat available, it is nearly impossible to reconstruct the accident useful. In a similar seat of the same class, at best, basic kinematic investigations can be conducted.

How was the Child seat installed in the Car?

The correct answer to this question is as difficult as important. Statements of witnesses in this context are usually not available or of limited reliability. Apart from cases in which there was an obvious misuse that stand out even to the layman, it is not very likely that first responders pay attention on the installation of the child seat in an accident situation. Fundamental issues such as the installation direction or the possible use of ISOFIX attachment may be answered. Since the seat is often removed from the vehicle directly from the first responders the installation can be reconstructed retrospectively only with the help of traces in the car and on the child seat. The questioning of persons, who have secured the car seat in the vehicle, can provide valuable information. If there are any assumptions

about misuse it might be useful to ask whether these assumptions could be true. However, previous studies show that parents normally believe that they are securing their children correctly. Following that it is likely that this impression leads the answers.

How was the Child secured in the Seat?

Here, too, it does only makes sense to reconstruct an accident if reliable facts about this question are available. As mentioned above, it is usually difficult to get this information. It remains to questioning the people who have seated the child in the CRS or the child itself, but especially the examination of the vehicle and the car seat for possible traces.

Information about the Injuries of the Child

Which injuries suffered the Child?

Detailed information about the injuries of the child can be very helpful for accident reconstruction. With the help of the report from the hospital it is possible to get information about the securing situation based on the described injuries.

Injuries to the skull are usually caused by a contact between the head and the vehicle or some other hard object. Because the child seat is usually designed in a way that it cannot cause head injuries, it can be excluded as a cause of injuries. This is true at least for frontal impacts. A direct contact of the head with the vehicle, however, can occur only under two circumstances: either the child was saved incorrectly, so it was due to a large slack in the seat belt or in the vehicle belt or due to a wrong routing of the harness or car belt which has led to a large forward displacement, or because of intrusion of vehicle parts in the interior, to which the child has had contact. Depending on the location of the injury to the head of the child, the contact point in the car may be narrowed down more precisely. If a head injury because of an intrusion can be excluded, a mistake in securing the child is likely. In cases of very small cars with less space on the rear seat it is also possible, that there is a head contact with the backrest of the front seats even if the CRS was installed correctly. In addition it is possible, that head injuries occur because of a high deceleration, even if there was no head contact.

Injuries in the neck, especially for small children, point to less support for the head. If such injuries occur for babies in baby shells, it would be necessary to determine whether or not it was used in incorrect direction (i.e. forward facing instead of rear facing). For children using a forward facing CRS the question is whether or not the child was premature for this type of CRS. In both cases in the event of a severe frontal impact neck injury are very likely. Moreover most of these neck injuries in the analysed and reconstructed accidents were caused by this misuse. Neck injuries are usually very severe, and especially for babies and very young children often fatal because of their anatomy.

Injuries in the thoracic area can occur due to many reasons. A direct contact with other objects can be generally seen from the injury. There is also the possibility that the vehicle belt or the harness of the child seat caused injuries, which leads also to typical injuries. As a result it can lead to broken ribs, bruising of the lungs or other internal organs. If the child was properly secured and if the vehicle deceleration was not very high, it can be assumed that described injuries would not occur. This means, conversely, that the presence of (severe) chest injuries is the result of misuse. It may come from a large belt slack or a wrong path of the vehicle belt as a possible cause. If for example in a class 2/3 seat the shoulder belt is routed under the arm and not over the shoulder so there is a significant load to the upper body, which may cause the injuries described above. In severe accidents the location of injuries can be considered as an indication for the actual belt routing – e.g., fractures of lower ribs at the outboard side indicate that the three point belt was worn below the arm pit.

Abdominal injuries mainly occur in children who were saved in a class 2/3 seat. If the lap belt is not routed by an appropriate belt guide, which was either not used or which is not available for this child seat, the belts penetrates into the abdominal area in case a forward displacement due to an accident. This effect is supported by the so-called submarining. Significant internal injuries are the result. If such injuries could be found, it can be assumed, that the child was secured incorrectly, unless it is an unusual severe accident.

Injuries to the extremities allow usually no conclusions about the securing of the child in the car. Due to a high deceleration arms and legs can have contact with the car or the child seat which can lead to injuries. Independent from a correct or incorrect securing of the child broken bones are possible.

Investigation of the Child Seat

What traces can be found on the child seat?

The CRS itself can provide valuable information about its installation in the vehicle. First of all the seat class shows whether or not it is a suitable seat for the child according to its weight. Furthermore, the adjustment of the harness indicates whether or not it was properly adjusted to the size of the child – however, it may have changed during the crash. The next step would be to check whether or not all components of the child seat are available. If this is not the case, they may be lost during the removal of the seat, but it is also possible that they were not at the seat during the accident and thus a proper installation of the seat was not possible. If damage can be found on the child seat, it is important to determine the cause for the damage. There may be parts of the vehicle, which may be the reason for it. Also, the loads due to the deceleration of the child may have damaged the seat (Figure 2). Damages in the area of the belt guides can be caused by the safety belt itself, which indicates a correct belt routing. On the other hand belt-typical abrasion can occur at points at which the belt should not be guided. That would be a clear indication of a wrong installation. Due to the low mass of the children stretch indicators on the harness of the child seat can usually not be found, even in serious accidents. Nevertheless, other traces of loads can be found in the belt system. Conspicuous kinks suggest points at which the belt was diverted. Under certain circumstances it is possible to see with this traces how tight the belt was tightened and whether or not slack existed.

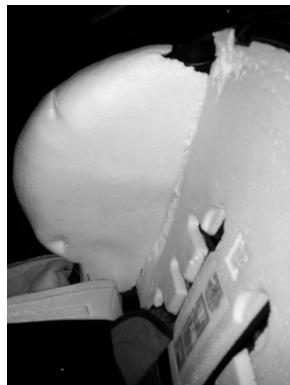


Figure 2: Broken head protection after head contact in side collision

If the seat was fastened by ISOFIX in the vehicle, the connection points should be investigated. Deformations indicate a force, if it is present only on one side, it is possible that one hook was not properly engaged. If a top tether is present, this may also be examined for traces of a kink. That can be an indicator how tight it was and moreover if it was in use. If a support leg was in use it would be to investigate whether the length setting matches with the height of the vehicle seat, or whether the support leg was set too short or too long.

At all points relating to the child seat, it should be noted that the seat may be changed or damaged when it was removed from the car and no longer needs to comply with the condition that it had at the moment of the accident.

Investigation of the Car

What traces can be found in the car?

Also inside the vehicle there is possibly a variety of information that gives clues to the securing situation of the child. The first step is to verify that the child seat was actually installed at the designated seating position. In some situations, imprints in the seat cushion or in the door panels are

hints of a contact with the child seat. Also, the vehicle belt show signs that indicate that it was used with a child seat.

If such traces can be found on the belt, then they should be compared with the belt guides on the child seat. It can possibly tell if the belt was properly routed and how the vehicle belt was tightened. It is important to note that the belt elongates while it absorbs energy. An apparent slack in the belt does not mean automatically a real slack in the original set-up.

In Figure 3 abrasion marks on a vehicle belt can be seen. They were caused by the belt clamp of the CRS. The mark with its typical diagonal pattern in Figure 4 was caused by the upper belt deflection (d-point). Figure 5 is an example for belt marks in the CRS harness, caused by the buckle after high deceleration force.



Figure 3: Belt abrasion marks from the CRS belt clamp

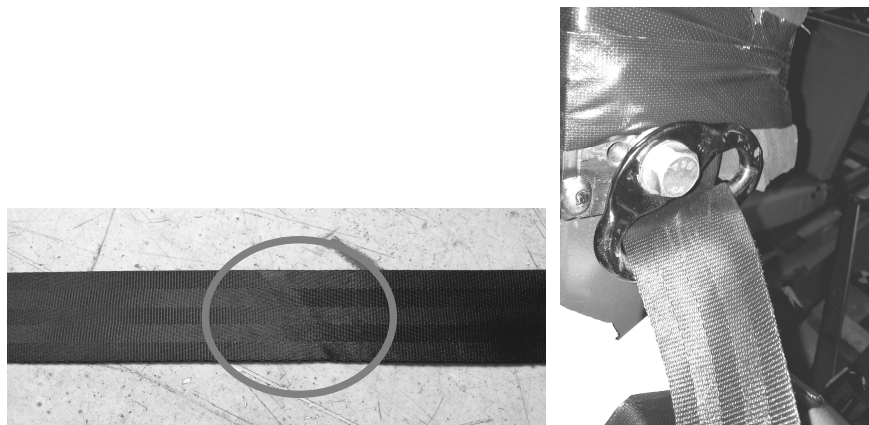


Figure 4: Belt marks from the upper belt deflection



Figure 5: Belt marks caused by the CRS buckle

With the help of marks on the vehicle belt, it is possible to reconstruct how the belt was guided and tightened on the CRS. In Figure 6 a comparison test with two CRS is shown. On the left side the belt

was guided correctly, on the right side, the belt was guided above the lower belt guide points. The belt guides should prevent the vehicle belt from penetrating into the abdominal area of the child.



Figure 6: Sled test with group 2/3 CRS; Left: correct installation; Right: Installation with wrong belt guide

With the belt marks the belt was guided in the CRS like it probably was in the moment of the crash. The comparison shows, if the belt was guided correctly, there is a normal belt slack which is matching with a child in the CRS (Figure 7, left). In Figure 7 right, a big belt slack can be seen. This is a clear hint for a misuse. Either the child was secured with this belt slack and probably with a correct belt guided belt, or, as it was in the test, there was an incorrect belt routing. With the comparison of belt marks and corresponding points at the child seat it is possible to get information about the belt routing. Photos of this configuration are very helpful for later accident research.

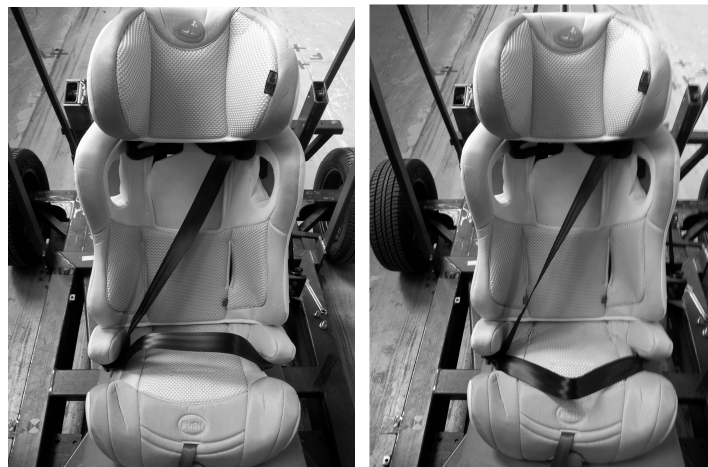


Figure 7: Comparison of reconstructed belt routing; Left: Routing was correct; Right: Routing with slack or wrong belt path

In Figure 8 a comparison test is shown, where on the left side the CRS was installed correctly, on the right side it was installed with some belt slack. Again, with the matching of belt marks with corresponding points on the child seat it was possible to reconstruct this slack after the test.

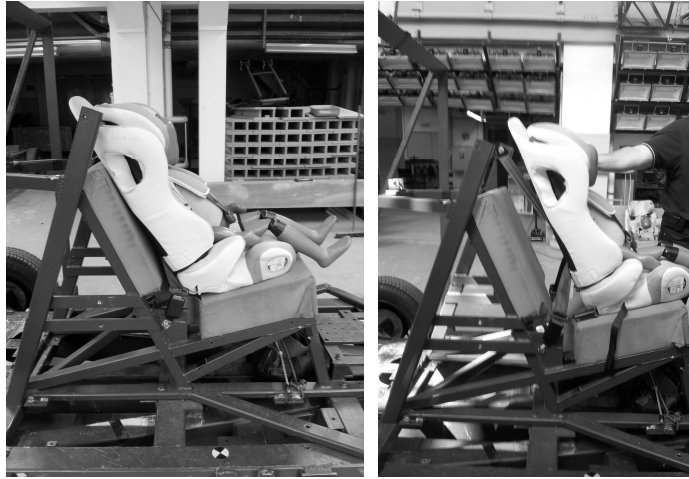


Figure 8: Sled test with group 1 CRS; Left: correct installation; Right: Installation with belt slack

According to the impact direction by the child or the child seat it should be looked for any signs of contact in the car. Here is to check whether the possible occupant kinematics match with the contact points. Furthermore, it is important to note whether or not the airbag at this seat position has been triggered. It would be interesting especially for the airbag in the front passenger seat, but also thorax and head airbags can lead to interaction with the child seat or the child and may cause injuries. Additionally, it must be considered whether the vehicle is equipped with a belt tensioner on the appropriate place and whether or not it has prevented a possible belt slack. Also of importance is the question of the position of the vehicle seat, on which the child was seated. In the case of the passenger seat it is adjustable in several directions. It should be noted, however, that the seat was adjusted in connection with rescue operations and must be no longer in its original position. If the child was sitting in the back seat, then the distance to back rest of the front seat is important because there was also the possibility of a head contact.

If an ISOFIX seat was in use, it would be necessary to have a look at the anchorage points in the car. Possibly, the hooks are deformed, if this is on one side only the case, it could indicate that only one anchorage point was in use. It is also possible that deformation could be found at the top tether anchorage point. Otherwise, perhaps another attachment point in the boot was in use. It may be that the top tether was cut from a firefighter and is still in the vehicle. In case of the use of a support leg impact points may be found on the vehicle floor, pointing to its use.

Questioning of People who have secured the Child

What information can be given by people who have secured the child?

Questioning of people who have saved the child in the vehicle may, ideally, bring precise information about the securing situation. Although if it cannot be reliably described how tight the belt of the seat or the vehicle were tightened, but possibly the belt routing can be described, as well as the installation direction of the seat or the way how ISOFIX has been used. Also important is the question whether or not the child has secured itself and if it was checked by the driver.

As already mentioned, it should be noted that information coming from people directly involved, may differ greatly from reality. This can happen knowingly or unknowingly.

Questioning of Witnesses

What information can be given by witnesses or other involved people?

Witnesses can give very important information for finding out how a child was secured in the vehicle. Although if the focus of the first responders is certainly not how or whether the child is secured in the car seat, they can later answer questions from memory and give important information about the securing situation. Witnesses may not only be first responders, but also firefighters and medical

doctors who were involved in rescue operations, as well as employees of the police, who are charged with the accident record. Especially the policemen may have a special look at the situation that may be helpful for certain issues.

It may also be that there was already a substantial effort by the police during the recording of the accident and there are for example detailed sketches and photos. It happens not infrequently that even long time after the accident policemen can answer detailed questions from memory. Last but not least the police can possibly make contact with other witnesses for a helpful questioning.

Summary

The procedure described above for the reconstruction of accidents in which children were involved as passengers, shows a variety of options that can be used. However in very rare cases, it will be possible, to use all described ways. Rarely, the vehicle can be examined in detail long time after the accident, and in general it is difficult to obtain reliable testimonies during the procedure of accident reconstruction.

As a result, this will always mean that certain assumptions must be made.

In the end a decision has to be made, whether a reconstruction makes sense with the given information.

It may be relatively unimportant if the collision velocity is determined accurately in an accident, where a baby sat in a forward-facing baby seat and suffered serious neck injuries, while the exact determination of impact angle and the collision point in a side impact with a tree contact which had led to serious head injuries can be fundamental.

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