Vehicular Transport Safety for the Child With Disabilities

Greg Shaw

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This article reviews transport safety for the child with disabilities in vans, school buses, and automobiles. Because very little research has been done in this area, information about safety for children with disabilities has been extrapolated from information based on the nondisabled population. Commercially available car seats and harnesses, most of which are designed for the nondisabled child, can provide a high level of crash protection. Several available restraint systems are recommended.

A wheelchair user suffered minor bruises and a cut lip when his school bus braked quickly. Had the bus been in a collision, his injuries would have been much worse. This incident concerned the staff at the University of Tennessee Rehabilitation Engineering Program (UTREP). We had modified his wheelchair by adding a special seat and back insert. His injury occurred when the insert's mounts gave way, spilling both the insert and the student onto the bus floor. Two other students were slightly injured in similar situations.

The UTREP staff has been involved in providing technical aids for children since 1974. Most requests are for seating systems with a wheeled base. As part of the clinic evaluation process, the occupational therapist documents the child's family vehicle and school transportation. The answers to these transportation questions not only help determine what type of wheeled base would be most appropriate, but they also alert the clinic team to potential transportation safety issues.

The above incidents prompted us to investigate the issue of wheelchair transport safety. Because parents of other nonambulatory children requiring special seating also asked for suggestions about safety in the family car, we investigated safety restraints for use on vehicle seats. However, we found very little literature specific to transport safety for the child with disabilities.

For the moment, safety data for nondisabled children are the best available. These data unequivocally demonstrate that a child experiences extremely high forces in a vehicle collision. These forces can dash the child against the often sharp edges in the vehicle's interior and possibly eject the child through a window, open door, or windshield. Only properly designed and carefully used restraints can distribute collision forces in a noninjurious manner.

Most states have passed laws requiring that all young children (less than 4 or 5 years old) ride in federally approved safety restraints. In most cases, these commonly available restraints, such as car seats, work well for the young child with disabilities. Other, less publicized commercial options are available for the older and larger child.

Federal and state laws concerning the design of safe school bus interiors exist; efforts to increase the safety level by mandating lap belts are under way. Although a few state and local guidelines specify that buses be equipped with wheelchair restraints, there are no federal standards governing their design or use. Most restraints currently available provide inadequate protection in even moderate collisions. There are, however, an increasing number that have passed laboratory crash tests.

Greg Shaw, MS, is Rehabilitation Engineer, Rehabilitation Engineering Program, University of Tennessee Center for the Health Sciences, Memphis, Tennessee 38163.
Although there are commercial options for most children with disabilities who ride on vehicle seats or in wheelchair buses, these options often must be modified or, in rare cases, discounted in favor of a custom-built device. On the other hand, even a poorly designed restraint is better than no restraint at all. The child with disabilities, whether riding on a vehicle seat or seated in a wheelchair, should be provided a level of safety comparable to that offered children in general.

**Literature Review**

*Transport Safety for Children*

There is little information on accident frequency and the design and selection of safety systems specifically for children who are disabled. There is, however, a comparative wealth of knowledge regarding the transport of children in general, and much of it is relevant to children with disabilities.

More than 1,000 children less than 5 years old are killed annually in auto accidents, which are also the leading cause of death of children 1 to 14 years old (Physicians, 1983). The nature and magnitude of the problem motivated legislators in Tennessee to pass the first mandatory child restraint law in 1978. By June 1983, 41 states had enacted similar laws (Staff, 1983). The mandatory use of safety seats has proved very effective in actual collisions. In some severe accidents in which the driver was killed, the properly restrained child was unharmed (Melvin, Weber, & Lux, 1980).

Research has illustrated the extraordinary forces resulting from a vehicle collision. In a study of adult clasping strength for restraining lap-held infants, Mohan and Schneider (1979) found that even low-speed collision forces were sufficient to tear an infant from a protective embrace. In a severe accident, such as a 35 mi/h head-on collision, a 20-lb infant would fly forward exerting a pull of more than 700 lb on the adult's arms. In the same collision, an 80-lb child would require 2,800 lb of restraining force.

Safety restraints must be capable of withstanding such forces and distributing them over the child's body to prevent injury. Because a child's physical structure is different from that of an adult, safety restraints must be designed differently for children. For example, because the mass of a child's head is proportionally greater with respect to the body than that of an adult, the potential for whiplash injuries is greater (Amberg, 1978). Head and brain injuries in general are the most severe and common sustained by young children. Melvin and Stalnaker (1978) discovered that a child's pelvis is not developed sufficiently to prevent standard automobile lap belts from riding up and easily damaging abdominal organs.

They also noted that because children vary proportionally much more in size than the general adult population, different sizes of restraint systems are needed.

The following general principles for restraint system design take into account both the extreme collision forces and the child's special anatomical requirements in addition to factors such as user comfort, convenience, and economy, and they apply to both nondisabled children and children with disabilities.

- Children are safer when secured in a restraint system than when riding unrestrained on a vehicle seat or on someone's lap (Insurance Institute, 1983). This is true even when the restraint system is inappropriate used (National Highway, 1979). A small child, protected best by a safety seat, would be safer wearing a standard lap belt than riding totally unrestrained (Melvin et al., 1980).
- Other vehicle passengers are safer when children are restrained (Insurance Institute, 1983). One study reports that 20% of serious injuries are caused by person-to-person collisions (National Highway, 1979). Another study found that disruptive behavior, potentially distracting to the driver, was dramatically reduced when children were required to ride in restraint systems (Christophersen, 1977).
- The safest orientation for the child is rear facing. In autos, the preferred location is the center of the rear seat. The next most effective orientation is front facing. Side facing is usually the most hazardous. In an automobile, the least safe seating position is outboard in the front seat (Melvin et al., 1980).
- When a safety seat is used, it is important that the safety seat be secured to the vehicle seat (usually...
Figure 2
A Typical Child Safety Seat

by the standard lap belts) and the child be secured to the safety seat (usually by means of the safety seat harness). If either step is not observed, the child and the safety seat will fly forward and impact the vehicle interior in a frontal collision (Schneider, Melvin, & Cooney, 1979).

The safest child restraint is the one that is most consistently and properly used (Staff, 1983/1984). No matter how well a particular restraint functions in a laboratory crash test, its real test is in its daily use. To encourage use, the restraint must be comfortable for the child. Restraints that safely raise a small child to window level are also desirable (Turbell & Aldman, 1983). Use and maintenance should be straightforward. Complex systems invariably lead to misuse or disuse. One report found that 75% of the child restraints examined were improperly used and strongly suggested a need for designs that are easier to use (Staff, 1985/1984).

Transportation of Children With Disabilities

At present, there are no U.S. standards regarding methods or devices for transporting a child with disabilities (National Highway, 1979, Dec. 13).

A 1979 report from the University of Michigan Highway Safety Research Institute (UMHSRI) is the most valuable to date (Schneider et al., 1979). It summarized laboratory crash tests of wheelchair tie-downs, safety seats, travel wheelchairs, and harnesses used to restrain children with disabilities on school buses.

Safety restraint considerations specific to the child who is disabled include the following:

- The anatomical differences and differences in physical and mental abilities may preclude the use of standard restraint systems. Severe orthopedic deformity, lack of trunk and head stability, and behavior disorder may render a standard system unusable. The most common problem involves children who have outgrown a car seat yet have not developed sufficient sitting balance to be without its midline support (Turbell & Aldman, 1983). Hydrocephalic children with large, heavy heads are but one example of a population requiring special design effort to produce a safe system.

- Restraint requirements for children transported while seated in wheelchairs reflect the same principles for children riding in safety seats. Both the wheelchair and the child must be secured (Schneider et al., 1979). If the child's wheelchair has been modified by the addition of a seating system, this too must be secured. The wheelchair can weigh as much or more than the child and requires its own restraint (i.e., wheelchair tie-down). The total restraining forces for a child in a wheelchair exceed those of a child transported on the vehicle seat. This is due to the added weight of the wheelchair. Even in a moderate (20 mi/h head-on) collision, the restraining force can exceed 4,000 lb (see Figure 1).

Discussion

This study was prompted by the realization that if three local children had not been sufficiently secured for a rapid braking maneuver, their injuries would have been much more severe if collision forces had been involved. Our fears were confirmed by the University of Michigan laboratory crash tests. However, further investigation revealed that the chances for injurious school bus collisions occurring are slim (Schneider et al., 1979). Therefore, although the potential for severe injury to children with disabilities riding school buses is great in the event of a collision, the probability that such a collision will occur is very low.

Despite the low probability of collision, steps are being taken to reduce the injury risk. Barbara Tebbit of the Suffolk County Transportation Office, Long Island, New York, reports that the county has passed a law mandating school bus seat belts and that the New York State legislature passed a similar law in January 1985 (personal communication, March, 1985). Efforts are under way to pass similar laws in other states. We encourage safety-conscious states to provide comparable restraint systems for their students with disabilities who are unable to use standard seat belts. Short of advocating collision protection, we urge that all children with disabilities be protected in normal vehicle maneuvering and braking.
For children with disabilities riding in private vehicles, the majority of whom ride on automobile seats, we must assume that the chance for injury is the same as that for children in general, although this assumption is not verifiable by the crash statistics. We feel that children with disabilities should have access to restraint systems that will ensure the same level of safety that nondisabled children have.

The occupational therapist has a unique opportunity at the time of the evaluation and the equipment provision to discuss the importance of safe transportation with the parents of children who are disabled. Occupational therapists working in special education settings can help school transportation officials meet the parents' demand for safe transportation.

Our contention that disabled children should enjoy the same level of safety afforded nondisabled children is in the spirit of existing U.S. legislation regarding disabled people's access to public buildings and educational programs. The following are our recommendations for devices to transport disabled children. Since we have not conducted crash tests, we lean heavily on the data and opinions regarding device safety judgments from the Schneider report (Schneider et al., 1979). Our 9 years of experience in providing seating systems for children with disabilities enable us to address the anatomical and usability considerations.

**Restraints Used on Vehicle Seats**

This category includes child restraint seats, booster seats, and harnesses.

**Figure 3**

A Safe and Simple Modification to Provide Increased Lateral Head Control

**Figure 4**

A Bobby Mac Deluxe Car Seat Modified to Provide Support for the Child With Disabilities

*Note. This car seat is manufactured by the Questor Juvenile Furniture Company, 1801 Commerce Drive, Piqua, Ohio 45353.*

*Child restraint seats.* Restraints that meet Federal Motor Vehicle Safety Standard (FMVSS) 213 are the most desirable (National Highway, 1979, Dec. 13). The proper use of such restraints has provided a very high level of crash protection.

Good child restraint seats that meet FMVSS 213 are widely available for children weighing up to 50 lb (see Figure 2). In most cases, children with disabilities can also use these seats.

If problems involving side-to-side, trunk, or head balance are encountered, simple modifications might be required (see Figure 3). Simple modifications may be done by a therapist and technician.

Extensive modifications require that the therapist work closely with the manufacturer or a qualified engineering facility. Any modifications to the restraint belts or arrangement to fasten the unit to the vehicle seat made by even qualified people will likely change a restraint's effectiveness. Only a series of prohibitively expensive crash tests could confirm the effects each modification would have on the restraint's performance. Although a manufacturer or engineering facility cannot usually guarantee a significantly modified restraint, their knowledge and experience will maximize the chances for a safe system.

Modified child restraint seats can be very convenient for children with certain disabilities. We have modified the Bobby Mac car seat to function as a
contoured body support seating system with headrest and footrest (see Figure 4).

For children weighing more than 50 lb and less than 80 lb the Britax car seat offers similar multiple uses with its available wheeled base option. Lumbar and trunk side supports are available. Also available for larger children is Preston's Tumble Forms car seat (see Figure 5). It is designed for children who weigh more than 50 lb, are less than 60 in. tall, and measure less than 13 in. in pelvic width. The molded-foam, high-backed seat has straps for trunk support. The vehicle's three-point seat belt system provides collision restraint. Both the Britax and the Tumble Forms car seat have passed FMVSS 213 tests.

Caution should be observed by people using the popular travel chairs as car seats. These convenient devices incorporate a folding stroller that allows the child to be placed in the front seat. Unfortunately, some travel chairs are not designed for crash safety (Schneider et al., 1979). The chair's design positions the child forward on the vehicle seat, thereby increasing the chances that the head will impact the dash-

Figure 5
Tumble Forms Car Seat

board or windshield. The commonly used vinyl/velcro belts lack the strength to restrain a child in a collision.

Recently, efforts have been made to improve the chair's safety. Ortho-Kinetics travel chairs produced after October 1983 meet FMVSS 213 standards, and chairs produced before this date can be retrofitted to meet the standards (Dill, 1984). Safety Travel, Inc., is presently investigating ways to improve the crash safety of its chair.

Child booster seat and harness combinations. Child booster seat and harness combinations might offer the required seating stability needed by disabled children with fair to good sitting balance. Proper booster seats are firmly padded and usually have slots for the vehicle seat belt. In addition to assisting in the proper placement of the lap belt (low across the pelvic bones), the booster seat raises the child so that he or she can see out of the vehicle (see Figure 6) (Molnar & Rodwell, 1979).

Restraint Harnesses

Of the available stand-alone restraint harnesses, only the Rupert harness can provide a measure of trunk support for the child with severe disabilities (see Figure 7) (Kelleher, 1983). This harness is available in sizes to fit both children and adults. It can be used in conjunction with a booster seat if a firm, stable sitting surface is needed. The manufacturer is receptive to customization requests and indicates that the harness can be modified to allow a child to lie down. This capability may aid in the transportation of people with severe disabilities.
Although we urge people to use caution when modifying the restraints used on vehicle seats, we acknowledge that without such modification some children would be without a restraint of any kind—unquestionably a dangerous situation.

**Wheelchair Restraint Systems**

Many of the wheelchair restraint systems on the market are not effective in crash situations (Schneider et al., 1979). This is not to say that these systems, widely used on school buses and in private vans, are worthless. The better ones do a good job of restraining wheelchairs during panic braking or rapid lane-changing maneuvers. If the wheelchair occupant is also wearing a lap belt attached to the chair frame or to the vehicle, he or she will likely remain in the wheelchair.

Some of the systems that fail a 20 mi/h crash test might restrain a light wheelchair and small child in low-speed collisions. Systems capable of restraining manual and the heavier, powered wheelchairs (tested in simulated impacts of 20 mi/h) are as follows (Schneider, 1981):

**Aeroquip.** The Aeroquip system uses four cargo tie-down straps to secure the four corners of the wheelchair to two floor-mounted metal tracks. Advantages include (a) low cost, (b) adaptability to different wheelchairs, and (c) no need for wheelchair modifications. Disadvantages are that (a) the system requires careful attachment to the wheelchair (overtightening the straps can cause wheel damage, and improper attachment to weak wheelchair frame members reduces effectiveness) and (b) a seat belt for the wheelchair occupant is not available.

Two other four-belt wheelchair restraints similar to the Aeroquip have passed similar crash tests. Both the Q-straint, a Canadian system (see Figure 8), and the Australian Safe-N-Sound provide belts for occupant restraint.

**Master-Lok (Creative Controls, Inc.).** The Master-Lok system is quite different from the Aeroquip restraint. Instead of belts it uses metal brackets to hold the wheelchair. One set of brackets attaches to the vehicle floor; the other set attaches to the wheelchair. Securing the wheelchair involves locking the two sets of brackets together with a steel bar.

The Master-Lok system has three advantages: (a) The wheelchair can be secured and released easily and rapidly and is foolproof; (b) the rigid bracket system prevents the wheelchair from folding in crash situations and reinforces the wheelchair frame; and (c) the occupant restraint belt has an optional shoulder harness available.

The disadvantages are that (a) it is suitable only for standard wheelchair frame construction, (b) the two sets of brackets must align closely (minor variations among standard wheelchairs prevent the common use of any one floor bracket without adjustment), and (c) wheelchair-mounted brackets add over 10 lb to the wheelchair's weight, and a transverse steel bar must be removed before the wheelchair can be folded.

The University of Michigan's Highway Safety Research Institute praises the Master-Lok's test performance. For situations where only one wheelchair or only identical wheelchairs are transported, the Master-Lok should be considered. Because of the heavy wheelchair-mounted brackets and the transverse bar, this system is less attractive for children who propel their own wheelchairs or for parents who may have to fold and handle the chair.

The above restraint systems proved safe when the wheelchair is facing forward in the vehicle. The common practice of securing a wheelchair in the side-
Q-straint Wheelchair Restraint System

This system, like the Aeroquip and the Safe·N·Sound, uses four belts to secure the wheelchair. A special feature is the three·point harness system (points 3, 4, and 5) for the wheelchair occupant. Reprinted with permission from Queen's University, Mechanical Engineering Department, Kingston, Canada K7L3N6.

Figure 8

Facing position is the most hazardous (Schneider et al., 1979).

Conclusions

The child with disabilities should enjoy a level of transport safety comparable to that legislated for children in general. Occupational therapists involved in the provision of technology have an excellent opportunity to recommend commercially available systems to both families and school systems. In special cases requiring judiciously modified restraints the therapist can work closely with engineering professionals to ensure a workable solution. The successful application of restraint technology requires an appreciation of the extreme forces involved in a collision. General design principles developed to minimize the injurious effect of these forces helps in the design, selection, and use of restraint devices. In all cases, a less than optimum restraint is safer than no restraint at all.

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Appendix 1

Restraints for Children With Disabilities

A. Restraints Used on Vehicle Seats

Child restraint seats for infants weighing up to 50 lb. Local department stores, store catalogs (e.g., Sears, J.C. Penney’s), $20–$60.

Child restraint seats for children weighing more than 50 pounds. Britax Handicapped Child Safety Seat, BRTAX, Chertsey Road, By Fleet, Surrey KT14 7AW, England (Telephone: 093-23-41121) or Sears Home Health Care Local catalog sales, $400.

Tumble Forms Car Seat. J.A. Preston Corporation, 60 Page Road, Clifton, New Jersey 07012 (Telephone: 800-631-7277), $150.

Child booster seats/harness combinations. Local department stores, store catalogs (e.g., Sears, J.C. Penney’s), $20–$40.


B. Wheelchair Restraint Systems

Aeroquip Series E/A Four Point Attachment System. Aeroquip Corporation, 1225 West Main Street, Van Wert, Ohio 45891 (Telephone: 419-238-1190), $90 plus installation.

Q-straint. Girardin, 33 Highridge Court, Cambridge, Ontario, Canada N1R 7L3 (Telephone: 519-622-0666), $200 (?) plus installation.

Safe-N-Sound Wheelchair and Occupant Restraint System. Safe-N-Sound, PO Box 545, Gosford, NSW 2250, Australia, $65 (Australian) plus installation.


Note. Estimated prices are as of January 1984.

References


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