Talking points for CIREN Presentation
Current Issues in Pediatric Motor Vehicle Trauma
October 20, 1997

MV crashes are still the #1 killer of children aged 6-14 years.
In 1996 there were 1,340 deaths to MV occupants < 12.
MV crashes are responsible for one-third of all injury deaths to kids < 12
In the US the death *rate* per 100,000 population is greatest for children < 12
Every day 8 children die in MV crashes.

Fortunately, there are a number of restraint systems designed to protect children in crashes:

Infant safety seats reduce the risk of fatal injury by 69%

Seats designed for toddlers reduce the risk of fatal injury by 47%

If 100% of children < 5 were correctly restrained, NHTSA estimates that 560 lives would be saved each year

The problem is getting people to use appropriate restraints and to use them correctly.

While great strides have been made in child occupant protection, there is still a long way to go -- total child motor vehicle *occupant* deaths have decreased only 3% since 1975 versus a 9% decline for the general population. (Note: this is *total* deaths, not death *rate*)

There are many inherent difficulties in studying child MV safety:
Tremendous diversity in occupant environment for children:

Infant seats, convertible seats, shield booster seats, belt-positioning booster seats, lap belts, lap/shoulder belts ... All of which can be (and frequently are) misused, and all of which may interact with air bags

NSKC check-up: misuse rate > 90%

Incompatabilities with vehicle seats and safety beltsfurther complicate matters

Superimposed on all of this are developmental differences

We have enrolled > 170 cases of restrained children < 12 years who were injured in MV crashes

Other CIREN centers also beginning to collect pediatric cases
Because occupant environment is more diverse for children, the need for multi-center study is greater, can establish broader case base

In addition, CIREN has the ability to target specific restraints:
ALL child-air bag interactions, or
specific types of child restraint and restraint misuse.

Today we will look in detail at two injury mechanisms we have seen among restrained children:
(1) non-fatal air bag interactions and
(2) injuries to children in correctly worn lap/shoulder belts.

Airbags and children:
To date, there have been more than 45 child deaths from air bag deployments:
12 infants in rear-facing seats and 33 older children, most of whom were unbelted.

Extraordinary high level of attention from media.

Important to keep AB injuries in the larger context of pediatric MV trauma:

In 1996 there were 1,340 child MV occupant deaths -- fewer than 30 resulted from AB deployment

Recent CPSC study for NHTSA estimated that in 1996 there were 657 deployment injuries to children <= 12 which were treated in hospital EDs (but not necessarily admitted)

However, this represents only 3.5% of the 18,950 childhood MV injuries treated in Eds

CPSC further estimates that only 5% of these air bag injuries result in hospital admission

Many groups (NSKC, NHTSA, AAP, et al.) recommend that children < 12 not sit in R/F seat of vehicle with passenger air bag. This is not always possible due to car pools, large families, small rear seats, etc. Who, then, should sit in front?

Definitely not infant in rearward facing seat (12 deaths)
Our limited data suggest that outcomes are better for belted children than children restrained in forward-facing safety seats:

5/6 children in L/S belts sustained facial abrasions only, but
2/3 children in FFCSS sustained serious brain injury AIS $\geq$ 4)

The following case illustrates potential dangers to children in correctly used forward facing safety seats when contacting passenger air bags.

Before we begin, I'd like to familiarize you with the occupant kinematics for toddlers restrained in forward facing safety seats in frontal crashes.

FMVSS 213 limits the total amount of head excursion allowed. All approved seats must conform to this requirement, in practice performance is considerably worse, as parents essentially never have safety seats belted in as tightly as stipulated in the 213 sled tests.

Now, we'll examine what happened in a real crash when a passenger air bag deployed in front of a child restrained in a forward facing child safety seat.

The case occupant is a 17-month old, 26-lb, 22-inch female who was seated in the right front seat of a 1995 Chevrolet Geo Metro. She was restrained by a forward facing child safety seat correctly anchored by the manual lap/shoulder belt. Evidence of restraint use included the worn apolstery on the seat indicating regular safety seat use, a mark on the passenger air bag presumably resulting from contact with the air bag, and the locking of the right front belt retractor with enough slack in the belt to anchor the seat. At the time of inspection, the right front seat was adjusted just forward of the center track position.

The crash occurred when the case vehicle, which was traveling at an estimated speed 25-30 mph, struck a Cadillac (model around MY 1988) which had entered the path of the case vehicle while its driver was attempting to make a left turn. The result was a frontal collision with a total Delta-V of 11 mph and a maximum crush of 5 in the induced damage width was 54 inches. At impact, the case occupant moved forward and slightly to the left, contacted the passenger's air bag and rebounded back hitting the back of the safety seat. [Typically there is only about 1/4 to 1/2 inch of foam padding between the back of a child's head and the hard plastic frame of a safety seat.] These contacts resulted in an occipital subarachnoid hemorrhage with tracking into the sulci, though no evidence of parenchymal bleeding, a concussion, a contusion/abrasion to the right cheek, swollen, abraded lips, a central forehead abrasion just above the eyebrows, nasal ecchymosis and bilateral periorbital edema. None of the other three passengers in the case vehicle was injured.

The child was transported by helicopter to a regional pediatric trauma center. She arrived awake, alert and crying with reported waxing and waning en route. She presented with a large contusion/abrasion to her forehead as well as abrasions to her right cheek and lips and left periorbital swelling. She had a blood pressure of 131/100, pulse rate of 110 and a respiratory rate of 39. Her chest and pelvis films were negative; a cervical X-ray was not done due to her waning level of consciousness. The child was marginally responsive during a head CT which revealed right occipital subarachnoid hemorrhage. Although her initial admission Glasgow Coma Scale was 14, the GCS had dropped to 7 an hour after arrival and by 2 hours post admission she was arousable only to noxious stimuli. She was admitted to the ICU. Her level of consciousness gradually increased over the next 24 hours. Her C-spine was cleared the next day by fluoroscopy and she was transferred to a regular unit. There was no further deterioration in the child's condition overnight and she was discharged home the third day post injury.

The occipital brain hemorrhage sustained by this child is a typical contre coup injury similar to injuries seen in children who strike their foreheads after falling from playground equipment; it is rarely caused by rotational forces alone.

It is important to broaden our understanding of nonfatal interactions between air bags and children. With the advent of de-powered air bags and smart air bags it is increasingly important to develop policies that are based on the full spectrum of cases involving children and air bags. For this reason, CIREN investigators are investigating all crashes involving air bags and child right front seat passengers, regardless of whether the interaction resulted in injury to the child.

We will next consider the interactions between the anatomy of a young child and vehicle safety belts in frontal crashes.

We at CNMC, along with researchers at other centers, have published many papers on the "so-called "lap-belt syndrome."

We found that children restrained with lap belts in frontal crashes exhibited a characteristic injury pattern:
 Abdominal ecchymosis, or belt marks frequently at umbilicus level or higher perforations/ruptures of the hollow viscus, fractures of the lumbar spine (both vertebral body compression and Chance fractures), sometimes minor to moderate brain injury

There are anatomical and behavioral considerations that predispose children to these injuries
 Small AP diameter (obesity seems to be protective)
 lack of anterior superior iliac crest
 Kids never sit still, slouch in seats: belt rides cephalad

While these injuries have been well characterized, the injury patterns of children in lap/shoulder belts is less well understood. Recent review of cases reveals an emerging pattern, similar, yet different, from the lap belt syndrome. The following case illustrates this injury pattern.

Child injured in correctly worn L/S belt

The case occupant is a 5-yr-old, 40 lb, 56" little boy who was seated in the right front seat of a 1990 Ford Escort restrained by a manual lap belt and automatic shoulder belt. The Ford struck a 1994 Cheverolet Cavalier that had "run" a stop sign resulting in an angled, frontal crash with a PDOF of 5 degrees and a delta-V of 24 mph. The maximum crush was 26.8 inches with a damage width of 51 inches along the left frontal plane.

When medics arrived, the child was found lying supine on the grass. He had abdominal ecchymosis and complained of head pain. He was brought by helicopter to a regional pediatric trauma center with an admission Trauma Score of 11.

Admission the child's GCS was 15, his blood pressure was 127/63, his heart rate was 125, and his respiratory rate was elevated at 40; he had a Trauma Score of 11. The child's capillary refill was brisk, but his abdomen was tender and he was guarding it. He complained of nausea and vomited once (approximately 30 cc). An abdominal CT showed free fluid in the abdomen and the child was taken to surgery where he underwent exploratory laparotomy which revealed a ruptured duodenum, a mesenteric hematoma, and a retroperitoneal hematoma with bile. The child's stomach, liver, and spleen were found to be intact. The child's duodenum was resected and repaired, and a JP drain was placed to suction the right lower abdominal quadrant. In addition to his internal injuries, the child sustained abdominal ecchymosis and a left side hip abrasion.

After surgery, the child was admitted to the floor in stable condition, with an ISS of 26. He was groggy, but arousable. He was monitored closely for pain and for drainage from the abdominal incision. On the second night post surgery, the child woke up inconsolably crying. He had small amounts of serosanguinous fluid abdominal drainage from the incision as well as moderate amounts of bilious secretions from his nasogastric tube. The child's abdomen was soft and non-distended; his pain was controlled with

MSO4 and he returned to sleep. On post op day 5, the child was allowed out of bed to the playroom. His staples were removed from the abdominal incision on day seven post-op, and he was continued on tube feeds. He was encouraged to spend time out of bed and his bowel function was closely monitored. On day 9, the child was started on a clear liquid diet, which he tolerated well. He was advanced to a regular diet on day 10 and discharged home on day 12.

While this child ideally should have been restrained in a belt-positioning booster seat, he is typical of the vast majority of children who go from forward-facing child safety seats directly to adult safety belts. Both the driver (mother) and the child independently reported that the shoulder belt had not been placed behind the back or under the arm. Because of the angled impact of the crash, the child moved forward and to his left immediately after the impact, perhaps coming out from under the shoulder belt. The small stature of young children makes it difficult to obtain proper belt fit even in the absence of overt belt misuse. In this case, the lap belt was riding cephalad of the anterior iliac crests contributing to abdominal injury while the child's short stature allowed him to slip free of the automatic shoulder belt which might otherwise have provided some measure of protection.

The role of the shoulder belt both in protecting the child from injury and perhaps contributing to solid organ injury is not fully understood. The shoulder belt does seem to provide some protection from extreme hyperflexion, as we lumbar fractures are rare among these children, whereas in children restrained with a lap belt only lumbar fracture is the most common injury excluding abdominal ecchymosis. NASS CDS data indicate that the rates of intestinal injury for children in 3-point belts and children in lap belts only are nearly identical.

The greater likelihood of solid organ injury to children in lap/shoulder belts versus children in lap belts only is suggested both by our data and data from the NASS CDS which indicate that the incidence of solid organ is may be more than three times as high for children in three-point belts than for children in lap belts only. Not surprisingly, NASS data clearly show that the incidence of these injuries is dramatically increased in frontal crashes with a delta-V > 15 mph (vs. < 15 mph).

We are currently investigating whether the principal direction of force may factor in to this equation. Several of our lap/shoulder restraint cases with intestinal injury were injured in offset crashes where the principal direction of force was on the side opposite the upper anchor point for the child's shoulder belt. In these cases the child may indeed slip free of the shoulder belt, rendering the restraint less protective that for adults. Nevertheless, the presence of some protective effect of the shoulder belt, especially in preventing hyperflexion around the lap belt is suggested by the lack of lumbar fractures in children with three-point restraints.

NASS data also suggest that there may be a significantly higher incidence of brain injury to children restrained in 3-point belts compared to children in lap belts only. We are currently investigating the nature of brain injury by belt restraint type and considering differences in occupant kinematicsandespecially in rotational forces to the head generated in frontal crashes. We hope to report these findings at a later meeting.

In the mean time, these two cases illustrate the importance of continued and renewed efforts to properly restrain children in motor vehicles.

Educate parents to use appropriate restraints
Give Kids a Boost
Continue to collect accurate data and analyze rigorously