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ABSTRACT

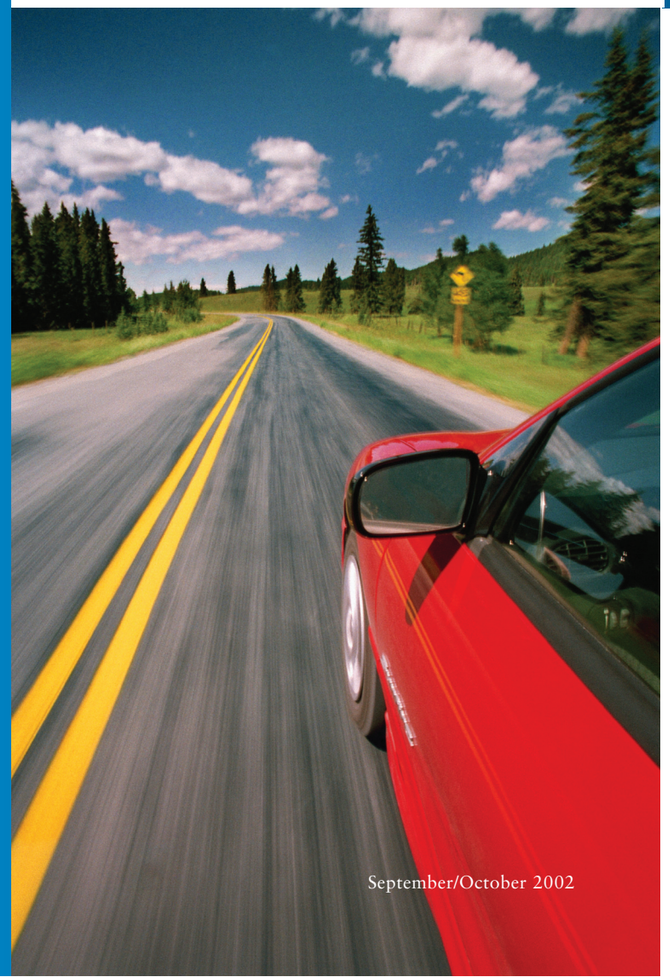
Countless numbers of young lives are lost each year due to motor vehicle crashes. One of the most effective means of reducing the number of children killed and injured as occupants in motor vehicles is through the use of child passenger restraints. Seat belts and child safety seats save lives and reduce the severity of injuries sustained by occupants in motor vehicle crashes. Nurses are in a unique position to educate and influence families on the proper way to safely transport all motor vehicle passengers. Therefore, nurses working with infants, children, and families have a moral and professional obligation to understand the basics of child passenger safety. At the very least, nurses should be able to direct families appropriately for specifics related to child passenger restraints.

The intent of this article is to provide an overview of child passenger safety through a historical, theoretical, and clinical approach. Proper child restraint use is reviewed based on current recommendations for age and size. The potential hazards of child restraint misuse, with an in-depth discussion on airbags, is presented. The discussion on airbags serves to dispel any misconceptions that may be held about airbags. The article includes two case studies that illustrate the injury potential of relatively common misuse patterns. The clinical implications for maternal-child nurses include the recognition that child passenger deaths are primarily due to child restraint nonuse and misuse and the realization of nursing's role in the promotion of proper child passenger restraint.

Key Words: Airbags; Car seats; Child passenger safety; Child safety seats; Occupant safety; Seat belts.

Airbags & Children

Making Correct Choices in Child Passenger Restraints



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Nurses caring for infants and children are in a unique and crucial position to advise families on how to safely transport their children. The expectation is not that all nurses should become experts on child passenger safety, but families should be able to reasonably assume that nurses practicing in maternal-child or pediatric settings have a basic knowledge about the topic. Information that families receive must be current and accurate. With advances in vehicle safety technology as well as improvements in child passenger restraint systems, it is imperative that nurses have a fundamental understanding of proper child passenger restraint and, at a minimum, be able to direct families appropriately for specific information related to child passenger safety.

It is well known and widely accepted that passenger restraints save lives and reduce the severity of injuries sustained by occupants in motor vehicle crashes. From 1975 through 2000, safety belts have saved an estimated 135,102 lives (U.S. Department of Transportation [US DOT], 2000a). During this same time period, an estimated 4,816 lives were saved by child restraints (child safety seats or adult seat belts) (US DOT, 2000b). However, the message of simply "buckling up" is not enough when considering infants and children. Subsequently, the emphasis has appropriately shifted to educating the public on correct child passenger restraint use.

The goal of this article is to address the basics of proper child passenger restraints within a theoretical framework of passenger safety. In addition, the potential hazards associated with child passenger restraint misuse, with a focus on children and airbags, are presented. The intent of a thorough discussion of children and airbags is so nurses can dispel any myths, misconceptions, and fears associated with airbags when counseling families.

Children as Passengers in Motor Vehicle Crashes

Statistics released by the Centers for Disease Control and Prevention (CDC), the Insurance Institute for Highway Safety (IIHS), and the National Highway Traffic Safety Administration (NHTSA) have clearly established that motor vehicle-related injuries are the leading cause of death among children at every age after the first birthday. Although motor-vehicle crash data include child pedestrian and bicycle deaths, the greatest number of children affected are those who are passengers in motor vehicle crashes (67% of child motor vehicle deaths in 2000 were passenger vehicle occupants) (IIHS, 2001). In 1998, nearly 2,000 children <16 years of age were killed and over 300,000 were injured as passengers in motor vehicle crashes in the United States (CDC, 2002). These injuries and deaths were potentially preventable because many of these children were either unrestrained or incorrectly restrained at the time of the crash.

It is important to consider risk factors for motor vehicle occupant injuries. For example, in looking exclusively at infant injury mortality related to motor vehicle crashes, predictors of higher risk included: young maternal age, low maternal education, increased number of other children, and marital status of mother (unwed) (Scholer, Hickson, & Ray, 1999). These socioeconomic markers can be used to identify the highest risk population for targeted prevention efforts.

Historical Background of Passenger Restraint Systems

Seat belts have been the most basic and profoundly effective pieces of passenger safety equipment in vehicles. Hendey and Votey (1994) furnished a concise history of passenger safety in their review of injuries sustained in restrained motor vehicle accident victims. Passenger restraints were introduced in the early 1920s in aircraft and

Use it right and make it tight! Child passenger restraint basics include determining the proper restraint and the correct direction, followed by secure seat installation and snug harnessing.

racing cars, and a few early automobiles were equipped with a seat belt primarily to keep passengers from falling out of their vehicles. By 1964, most cars produced in the United States were equipped with lap belts, and by 1968, lap and shoulder belts were required on all U.S. produced cars. Although the importance of shoulder straps for upper body restraint was recognized, the belts at that time often had separate lap and shoulder components making them confusing and challenging to use. By 1974, the three-point seat belt with the lap and shoulder component joined at the buckle became (and continues to be) the industry standard. In the 1970s, airbags were introduced to further improve vehicle safety. This safety feature was first introduced as an option on select GM cars, but safety was notably not a major selling point in the '70s, and few actually were purchased. Fortunately, the next 20 years marked a monumental change as public opinion shifted and people became increasingly concerned about passenger safety. By 1993, federal law mandated that passenger cars (starting with model year 1998) be required to have manual lap and shoulder belts as well as dual airbags. Airbags are found in over 120 million cars and light trucks in the United States (58%), and over 98 million of these vehicles (46.3%) also have passenger airbags (IIHS, 2002a). The numbers will continue to increase as new cars with airbags, approximately 1 million per month, are sold. It is anticipated that improved passenger safety technology incorporated into the fleet of vehicles on U.S. highways will prove to increase the number of lives saved and injuries prevented.

The Safety Mechanics and Benefits of Airbags

The basic premise of passenger safety technology is to restrain the passengers within the vehicle, to diffuse energy generated from a crash away from the passengers, and to prevent the passengers from contacting hard surfaces within the vehicle. Seat belts, long highly regarded as a crucial safety device, simply prevent ejection, limit the contact the crash victim has with the interior of the vehicle, and spread the force of a sudden deceleration over a greater area and time (Hendey & Votey, 1994). Airbags supplement seat belts by further reducing the impact the passenger has with the hard surfaces inside the vehicle.

Airbag sensors are designed to detect the rapid deceleration associated with a crash. The response from crash detection to airbag deployment is almost instantaneous. A rapid response ensures that the airbag is fully deployed to cushion and appropriately protect the vehicle occupant. The seat belt keeps the occupant from moving too far forward so that the airbag is fully deployed when the occupant makes contact.

Multiple studies have demonstrated the life-saving and injury-reducing capabilities of airbags. Studies of airbag efficacy conducted at NHTSA were summarized within a report to Congress on the effectiveness of occupant protection systems and their use (NHTSA, 1996). Within this report, NHTSA concluded that driver and passenger-side airbags are 31% effective in reducing fatalities in pure frontal or direct head-on crashes, 19% effective in all frontal crashes, and 11% effective in all crashes. Furthermore, in an analysis of real-world data, the combination of lap-shoulder seat belts and airbags was found to be 75% effective in preventing serious head injuries and 66% effective in preventing serious chest injuries. Thus not only do airbags reduce fatalities, they also decrease nonfatal injuries. Specifically, airbags minimize the risk of life-threatening injuries to the head, neck, face, chest, and abdomen.

Fatality reductions seen with airbags are over and above those seen with seat belt use alone. NHTSA credits airbags with saving approximately 7,585 lives on the nation's highways from the late 1980s through October 1, 2001 (NHTSA, 2001). As more data become available over time, these numbers will continue to increase.

Child Passenger Restraints

As healthcare providers working with children and their families, we have a moral and professional obligation to accurately educate our patients/families on the importance of proper child passenger restraint use. Although it is not feasible for nurses to know the many specifics of the hundreds of models of child safety seats available, nurses should become familiar with several central principles.

The first basic rule of passenger safely is that all passengers should be properly restrained at all times, during every ride. This seems elementary, yet the U.S. seat belt usage rate based on state surveys is only 71% (US DOT—NHTSA, 2001). Although US DOT further reports that 91% of children under 5 are restrained, the percentage does not appropriately reflect the number of children who are improperly restrained in a seat belt instead of a child safety seat.

When used properly, child safety seats are effective in preventing fatalities and reducing the incidence of major and minor injuries associated with motor vehicle crashes. Child safety seats reduce the risk of fatal injury in passenger cars by 71% for infants (<1 year old) and by 54% for toddlers (1–4 years old); furthermore, they reduce the need for hospitalization by 69% for children ages 4 and under (National SAFE KIDS Campaign, 2001).

Legislation exists in all 50 states in the United States requiring the use of restraint systems for infants and children. However, most of these laws are inadequate in that they do not reflect the current safety recommendations, and frequently allow for substitution of seat belts for child safety seats and booster seats at too early an age. Furthermore, although all 50 states and the District of Columbia have primary or standard child restraint laws (meaning police may stop vehicles solely for child restraint violations), this only holds true for 19 states with regard to belt use laws (IIHS, 2002b). Overall shoulder belt use data obtained from observational survey of moving traffic in states with primary enforcement seat belt laws is estimated to be 13% greater than those without such laws (77% vs. 64%) (US DOT—NHTSA, 2001). These gaps in child restraint and safety belt laws reinforce and perpetuate confusion and inconsistencies in child passenger restraints. Stronger restraint use laws and active enforcement of such laws are ultimately indicated to improve restraint compliance.

Finally, adults need to be strong positive role models for children. Agran, Anderson, and Winn (1998) demonstrated that driver restraint use was the strongest predictor of child restraint use, with a restrained driver being three times more likely to restrain a child. This study of fatal car crashes furthermore reported that just 56% of children under 10 years of age were either buckled up or in child safety seats at the time of the crash.

Correct Child Passenger Restraint Use

Increased emphasis is clearly needed on educating the public on the proper use of child safety restraints. It is important to provide up-to-date, appropriate information to parents regarding car safety seat choices and proper use (American Academy of Pediatrics, 2002). Key points are to first determine the right seat to use and direction of placement. This is followed by tight attachment of the safety seat in the vehicle and snug harnessing of the child in the seat itself. The seat should not move more than 1 inch in any direction and the harness strap should be snug against the child's body (Bull & Sheese, 2000).

Every effort should be made to secure the child in the rear seat of the vehicle because it is significantly safer than the front seat. Children younger than 13 years of age are 36% less likely to die in a crash if seated in the rear seat of a passenger vehicle (National SAFE KIDS Campaign, 2001). The rear center position is the ideal occupant seating position as it is furthest away from any crash forces, but all rear seat positions are safer as compared to the front seat. When a driver has no other option than to place a child in the front seat of a passenger vehicle, the child should be properly placed in the restraint device that offers the maximum protection for the child's size and age. The seat should be moved as far back as possible from the dashboard and a rear-facing child safety seat should *never* be placed in front of a passenger-side airbag.

Parents need to carefully read and familiarize themselves with the safety seat manufacturer's instructions and keep them readily available, preferably with the seat itself. Reference to the vehicle owner's manual is also necessary to ensure proper child safety seat installation. What follows is a basic synopsis of child restraints (see Table 1). Information on transporting children with special needs such as premature infants or those with special healthcare requirements can be found by searching the Web sites of the American Academy of Pediatrics and SafetyBeltSafe U.S.A. (The addresses of these organizations are provided at the conclusion of this article.)

Infant or Rear-Facing Convertible Seat

A rear-facing position is indicated until a child is both at least 1 year of age and 20 lbs. (due to the poorly developed musculoskeletal support of the head). This seat must always be placed in the back seat of vehicles equipped with passenger-side airbags. As with all child restraint harnesses, the straps are adjusted to fit snugly and the harness clip is placed at the armpit level.

Forward-Facing Seat

Once a child reaches 1 year of age and weighs >20 lbs., he or she may be placed in the forward-facing position. Children are maintained in this seat and position until they weigh 40 lbs or exceed the weight requirement for the seat. When changing a convertible seat from the rear- to forward-facing position, attention must be paid to the specific adjustments that need be made to the seat incline, the internal harness system, and the path of routing the vehicle seat belt to properly secure the child safety seat to the vehicle (Bull & Sheese, 2000). Reference to the child safety seat manufacturer's specifications is necessary.

Booster Seat

Once a child weighs >40 lbs. or is too tall for the child safety seat he or she is ready for a booster seat. Booster seats are designed to accommodate children until the lap-shoulder belt fits properly. Current recommendations are to use a booster seat until a child weighs 80 lbs unless they are ≥4'9". Parents need to understand the importance of booster seat utilization. Because ours is a highly mobile society, many young school-age children are unnecessarily being placed at risk by not being placed in booster seats.

Lap-Shoulder Belt

Children are ready to use the vehicle's lap-shoulder belt when they are tall enough so the shoulder strap fits across their shoulder while the lap belt simultaneously fits across the bony pelvis. The child's legs also must be long enough

Table 1. Recommendations for Correct Choices in Child Passenger Safety

Age and Weight Factors	Recommendations
Infants:	
≤20 lbs. **and** ≤ 1 yr *(at least!)*	Rear-facing position only in infant or convertible child safety seat. *Never place safety seat in the front seat of a vehicle that has a passenger-side airbag.*
Infant/Child:	
>20 lbs. to 40 lbs. **and** > 1 yr	May face forward in convertible child safety seat or forward-facing car seat.
Child:	
> 40 lbs. (or exceeds height requirements of child safety seat)	Belt-positioning booster seat with the vehicle's lap-shoulder belt.
Older child:	
• > 80 lbs or 4'9".	Lap and shoulder seat belt. Lap and shoulder belts fit low on hips over upper thigh **and** across shoulder.
• lap and shoulder straps fit	*Never place shoulder strap under arm or behind back.* If the lap-shoulder belt does not yet fit, use a booster seat.
• tall enough to sit with knees bent over the seat's edge.	

to bend over the front of the seat when the child's back is against the back of the seat. Otherwise, the child will assume a position of comfort by slouching down in the seat making the shoulder strap cut across the neck and the lap portion ride up on the abdomen. Never place the shoulder strap behind the child's back or under his or her arm as serious injury may result in the event of a crash. As a general rule, if the lap-shoulder strap does not fit properly, the child still belongs in a booster seat.

LATCH: A New Standardized Child Safety Seat System

Anyone who has ever attempted to install a child safety seat in a vehicle is aware of the installation challenges to obtain an appropriately tight fit. Incompatibilities between vehicle and child safety seat designs make this a difficult if not impossible feat. It is vitally important that consumers review both their child safety seat instruction manual as well as their vehicle manual in order to ensure proper fit.

Fortunately, recent technologic advances have been implemented to address this problem. LATCH is a new standardized child safety seat system that will simplify child safety seat installation and thereby enhance child passenger safety. As of September 1, 1999, most new passenger vehicles are equipped with top tether anchors, and by September 1, 2002, all new passenger vehicles (i.e., cars, minivans, and light trucks) will be equipped with lower, child seat anchorage points between a vehicle's seat cushion and seat back. Corresponding adaptive changes to child safety seats will be implemented according to the same time frame. Although the vehicle's belt system will continue to be capable of securing a child safety seat, this latest installation system is entirely independent of the vehicle's belt system and will provide a more secure and easy installation.

Child Restraint Misuse

Not only must children be restrained; they must be *properly* restrained to maximize the protective properties of the passenger restraint system. Child safety restraints used incorrectly have been associated with injuries, primarily to the head (Graham, Kittredge, & Stuemky, 1992). Child restraint misuse includes consideration of the type of child restraint used as well as the installation of the seat in the vehicle and the harnessing of the child into the seat. Factors contributing to child restraint misuse include: a variety of age and size requirements, incompatibility between car seat and vehicle design, improper seating position, and gaps in child occupant protection laws (National SAFE KIDS Campaign, Taft, Mikelade, & Taft, 1999). Child restraint misuse reduces the effectiveness of the device and places the child at a much greater risk for serious or fatal injury should a severe crash occur.

In assessing child restraint type selection alone, inappropriate use is widespread. The National SAFE KIDS Campaign (Cody, Mickalide, Paul, & Colella, 2002) conducted the largest interactive, observational survey of restraint use among children ages 14 and under in the United States and reported that nearly 33% of children were using the wrong restraints for their size and age. Moreover, >63% of children who should have been in booster seats were inappropriately restrained, most often in adult safety belts.

An examination of the use of child restraints reveals more concerning data. In a national study on car seat misuse, the National SAFE KIDS Campaign (Taft et al., 1999) reported misuse patterns that were revealed at car seat check ups held across the nation involving thousands of families. In this motivated population of families that self-selected to participate in a car seat check-up event, 85% of the car seats observed were misused. The most commonly found misuses were the safety belt not securing the seat tightly (63%) and the harness straps not snug (33%). Gross misuse reported in this study included children placed in a forward position before being both 1 year of age and 20 lbs. and rear-facing infants placed in front of an active airbag. Other previously reported forms of obvious misuse include utilization of an improper restraint device and failure to either secure the child safety seat in the vehicle or the child in the seat itself (Graham et al., 1992).

Another frequently encountered problem is early graduation from car seats to seat belts, entirely bypassing booster seats. In a study specifically assessing premature graduation to seat belts in young children, few children between ages 4 and 8 were properly restrained due to their failure to use a booster seat (Winston, Durbin, Kallan, & Moll, 2000). Less than 1% of the children >5 years of age were restrained in booster seats. This study further demonstrated that young children prematurely restrained with a seat belt rather than a child safety seat are at greater risk for sustaining significant injury, particularly brain injury.

When children are placed in a seat belt before they are big enough, the lap portion of the belt rides up over the abdomen and the shoulder belt crosses the neck or face. To improve the comfort of an ill-fitting lap-shoulder belt, parents (or children themselves) commonly place the shoulder strap under the arm or behind the back. These actions seriously compromise safety by allowing for excessive forward movement in the event of crash. The rapid flexion against a fixed poorly positioned lap belt places the child at risk for intraabdominal and spinal cord injuries (seat belt syndrome), and brain injury due to impact of the head with the child's knees or the vehicle interior (Winston & Durbin, 1999).

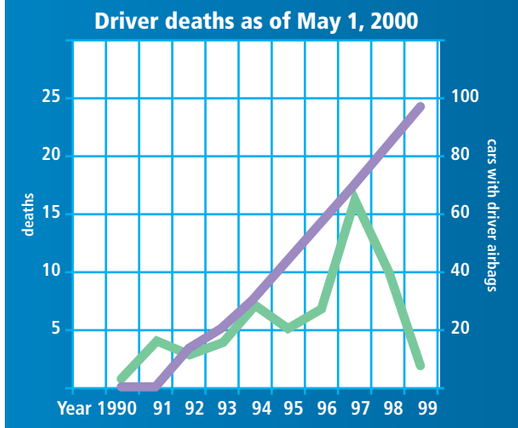
Injuries Associated With Airbag Deployment

The exposure of children to airbags may result in severe injury and death. Over the last several years, much media attention has focused on children killed by airbags. These cases, for some, have replaced logic and scientific evidence with skepticism and fear. A more in-depth discussion of airbags helps to dispel any myths that may perpetuate unnecessary fears about them.

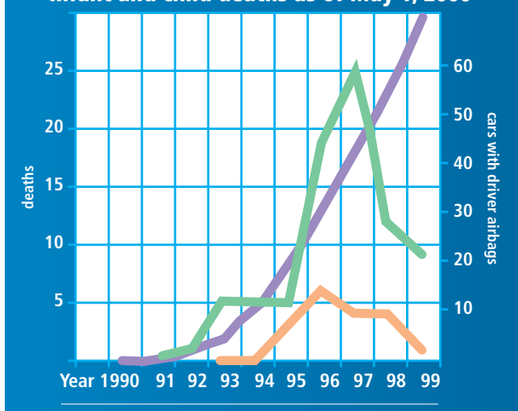
As previously stated, airbags deploy almost immediately after crash sensors detect the rapid deceleration associated with a crash. In order for airbags to deploy quickly enough to cushion the vehicle occupant, the speed of airbag inflation must be commensurate. Airbags deploy at a speed of 140 to 200 MPH. It is the speed and force of deployment that poses the greatest potential danger to the occupant and is the causal factor of airbag-related injuries.

Unfortunately, technologic advances in passenger safety are not without drawbacks. Airbags, like seat belts, have been associated with a variety of injuries. Injuries may occur from contact with the rapidly inflating bag or with the by-products of combustion released during the deployment process (Hendey & Votey, 1994). Airbag injuries are directly related to the position of the occupant in relation to the deploying airbag. The force of the deployment is greatest in

Confirmed deaths from inflating airbags



Confirmed deaths do not include 12 driver deaths under investigation by the National Highway Traffic Safety Administration.



Confirmed deaths do not include 20 child and 3 infant deaths under investigation by the National Highway Traffic Safety Administration.

Source: Insurance Institute of Highway Safety. (2000). Special issue: New federal airbag rule. *Status Report, 35*(6), 5.

The primary cause of child passenger injury and death is child restraint nonuse and misuse.

the first 2 in. to 3 in. from the airbag module. In fact, the recommended distance from an airbag to avoid serious injury on deployment is 10 in.

Early studies evaluating the effectiveness of airbags attributed few and relatively minor injuries to airbag deployment. Because driver-side airbags were widely instituted prior to the federal requirement for dual airbags, these studies only reflected driver-side airbags and, therefore, only reflected adult data analysis. For example, Antosia, Partridge, and Virk (1995) conducted a retrospective review of data collected by the NHTSA from 1980 to 1994. They found that an overwhelming majority (96.1%) of the reported occupant injuries related to airbag deployment were minor. Injuries reported in order of frequency included abrasions, contusions, and lacerations, followed by burns, fractures, and retinal injuries.

As data became available on the effectiveness of passenger-side airbags, startling and unanticipated results became apparent in regard to children. The first documented case of an infant fatality resulting from a passenger-side airbag deployment occurred in 1995. Previously reported in the literature (Hollands, Winston, Stafford, & Lau, 1996), the death of this infant led to an in-depth investigation and crash reconstruction as the potential lethal effects of airbags were suddenly realized.

Winston and Reed (1996) subsequently described the results of a series of children who sustained serious or fatal injuries attributed to passenger-side airbag deployment. This report was based on the results by the Special Crash Investigation Program of the National Highway Traffic Safety Administration. The biomechanical study of occupant kinematics revealed that the study sample of affected children could be divided into two categories: infants in rear-facing safety seats and unrestrained children over 1 year of age. The rear-facing child in a safety seat was in dangerously close proximity to the airbag module. This resulted in rearward displacement of the safety seat upon contact with the airbag module flap or cover and frequently caused cracks in the casing of the seat itself. These babies were essentially crushed between the child safety seat and the vehicle seat.

The unrestrained forward-facing children in this series were similarly in close proximity of the airbag, but in these cases it was due to avoidance braking that commonly occurs prior to a crash. Avoidance braking is a phenomenon that occurs as the driver steps on the brakes in an effort to avoid a crash. As the car quickly decelerates, the unrestrained child passenger continues to move forward toward the airbag. When the airbag deploys, the force of deployment was shown to accelerate the child forcibly upward and then rearward resulting in cervical spine and brain injuries.

The severity of the airbag-associated injuries in children in this early series was in sharp contrast to the primarily minor injuries reported in the adult population. This was further supported by subsequent research. Braver, Ferguson, Greene, and Lund (1997) assessed the effectiveness of passenger airbags in reducing the risk of death in frontal crashes for right-front passengers. They reported that the risk of frontal crash death for right-front passengers in cars with dual airbags was reduced 14% among those reported to be using belts and 23% among belt nonusers. However, children <10 years old in cars with dual airbags were found to have a 34% increased risk of dying in frontal crashes. This study demonstrated that more children were being injured rather than saved by passenger-side airbags. It again should be emphasized that almost all infants and children injured or killed by airbags were either unrestrained or improperly restrained at the time of the crash. Consequently, they were out of position and, therefore, perilously close to the airbag when it deployed. NHTSA (2001) estimates that as of October 1, 2001, 119 children have been killed by airbags that impacted with them in low-speed crashes that might have otherwise been survivable.

The CDC (1997) cite additional factors inherent in the physical and behavioral qualities of children that place them at increased risk of sustaining serious or fatal injuries from a deploying passenger-side airbag. A child as a front seat passenger is more likely to move forward or out of position than his or her adult counterpart. Due to their smaller stature, children's legs are unlikely to be long enough to touch the floor preventing any bracing during preimpact braking, and their head/neck rather than chest is likely to contact a deploying airbag. As previously noted, children are also more likely to place an ill-fitting shoulder strap behind their back or under their arm eliminating upper body protection. In all cases, the child is improperly positioned in relation to the deploying airbag.

Side airbags also pose a potential threat to the out-of-position child, although they too clearly provide additional supplemental protection to adults involved in side-impact crashes. A serious or life-threatening injury is possible if a child's head, neck, or chest is in close proximity to the airbag at the time of deployment. This concern prompted NHTSA (1999) to issue a consumer advisory on side airbags and child safety. As part of this advisory, NHTSA asked vehicle manufacturers to ship the vehicles with rear side airbags to dealers with these airbags deactivated unless deemed otherwise safe by the manufacturer. Once informed, the consumer can request to have these airbags switched "on" by their dealer.

Airbag Advances

Efforts are being undertaken to reduce the potential dangers of airbags for those most at risk. Until the technology of "smart airbags" is refined, consumers have the option of installing an airbag cut-off switch in their vehicles. A ruling was made by NHTSA in November 1997 allowing airbag on-off switches under specified circumstances (NHTSA, 1997). A cut-off switch is designed to allow consumers to temporarily deactivate the driver- or passenger-side airbag if they meet one of the following criteria: the vehicle is used to transport infants in the rear-facing mode or forward-facing children ages 1 to 12 years of age in the front passenger seat; the driver is unable to maintain the minimum recommended 10 in. distance from the steering wheel; and driver's medical condition prohibits him or her from maintaining a safe sitting distance from the airbag. In actuality, few people need an airbag cut-off switch. Permission for a cut-off switch is obtained through a self-certification application process whereby permission for installation is thereby granted by NHTSA. Once NHTSA authorization if obtained, the consumer must find an automobile dealer or repair shop willing and able (specialized training is required) to install the switch. A cut-off switch is key-activated with dash notification in an effort to limit misuse and promote thoughtful consumer consideration of appropriate airbag deactivation.

As technology advances, smart airbags are being developed and ultimately will be available in all new vehicles. These airbag systems will tailor deployment based on crash severity, occupant size and position, and seat belt use. The goal of advanced airbag systems is to markedly reduce, if not entirely eliminate, the risks produced by the current airbag designs. Fortunately, we are already seeing a decrease in airbag-related injuries and deaths. Newer airbag designs and the intense public education of motorists have already made an impact. The number of airbag deaths appears to be shrinking even as the number of airbag-equipped vehicles increases (see Figure 1).

The IIHS (2000) recently released a status report on the new federal rules to make airbags safer for out-of-position occupants while continuing to prevent deaths and injuries in serious crashes. A major improvement is the requirement for government airbag tests to more accurately represent the true spectrum of motorists. One of the problems inherent to the original design of airbags is that they were developed to protect the average-size unbelted adult male. Federal safety standard testing until recently only reflected the 50th percentile adult male. The lack of comprehensive crash testing data and the resultant absence of evidence across size variables thereby made it extremely difficult to accurately predict the potential dangers inherent in airbag deployment. However, real-life situations have since demonstrated otherwise and made the need for expanded dummy testing clear. Federal regulations now mandate testing on dummies designed to represent a small woman, a 3- and 6-year-old child, and an infant. Crash tests have been improved to more accurately examine, and therefore predict, the results of crashes on properly positioned occupants as well as the potential airbag risks for out-of-position occupants.

Another component of the new ruling addresses airbag sensors to modify deployment for children and short stature adults. Specifically, the new rule allows manufacturers either to suppress airbags whenever children are present or to deploy with diminished force to decrease the risk of airbag-related injury. Airbag systems will be required to demonstrate appropriate activation, suppression, or deactivation for adults and children in various occupant positions with and without the use of proper passenger restraints.

Advanced airbags meeting the new requirements will be phased in by the 2004 model vehicles and will be required in all new vehicles after August 2006. Even with the development of more advanced airbag systems, one can expect that many years will pass before the technology is widely infiltrated in passenger vehicles on the road. Furthermore, although the risks of airbag injuries to out-of-position occupants will be reduced, they will still exist.

Case Studies in Child Restraint Misuse

Improperly Restrained School-Aged Child

A 6-year-old boy was involved in a low-speed motor vehicle crash as a front seat passenger in which both the driver and passenger-side airbags deployed. The boy was restrained with a lap-shoulder strap, but his mother had placed the shoulder strap behind his back because it otherwise cut across his neck. His mother was restrained with a lap-shoulder restraint at the time of the crash and escaped uninjured. However, the child was immediately unresponsive with a Glasgow Coma Score (GCS) of 3. The GCS assesses level of consciousness by assigning points in three categories: eye opening, verbal response, and motor response, with score totals ranging from 3 to 15. A score of 3, as in this case, indicates no eye opening, verbal response, or motor response to verbal or painful stimulation.

The child experienced cardiopulmonary arrest at the scene requiring CPR and intubation. The primary hospital's resuscitation was aggressive including multiple doses of epinephrine, atropine, and sodium bicarbonate. A heart rhythm was restored after approximately 20 minutes of resuscitative efforts, and he was thereupon transferred to a Level I Pediatric Trauma Center.

The child's injuries were further delineated upon arrival to the pediatric trauma center. A brain CT revealed diffuse

Despite the life-saving properties of airbags, airbags may cause injury or death to the out-of-position occupant.

subdural hemorrhage, subarachnoid hemorrhage, and cerebral edema. The CT was also consistent with a severe anoxic brain injury. In addition to the brain injury, he was found to have a fracture with separation of C_1 from C_2. Externally, only minor facial abrasions were present. His clinical exam as well as a cerebral perfusion scan were consistent with brain death, and he was declared dead.

The airbag, not the crash itself, caused the child's fatal injuries. Without upper body restraint, preimpact braking brought the child's head and upper body in close proximity to the deploying airbag. The mother of this child was understandably overwrought with guilt as she was well aware that she had disregarded warnings on her vehicle and from her friend, a nurse, regarding the hazards of placing her child in the path of a deploying airbag. Had the mother not surrendered to the child's pleas to sit in the front seat and had she, instead, placed him in a booster seat in vehicle's rear seat, the child would have survived.

Improperly Restrained Infant in Forward-Facing Position

An 11-month-old girl was restrained in a forward-facing convertible car seat in the rear seat of a passenger vehicle that struck a pole head on. The driver, the infant's mother, was wearing a lap-shoulder belt and sustained only minor injuries. At the scene the child was found to be apneic and flaccid. Resuscitative efforts included prompt airway control through endotracheal intubation and ventilation. A methylprednisolone infusion for treatment of a spinal cord injury was begun at the primary hospital prior to transfer to a Level I Pediatric Trauma Center.

Diagnostic evaluation of the brain and cervical spine was completed by CT and MRI. The baby was found to have a C_1-C_2 distraction injury with complete spinal cord transection as well as a diffuse axonal injury to the brain. Despite the severity of the injuries, the only external sign of trauma was a small bruise on the right shoulder and some soft tissue swelling on the left side of the neck and occiput.

Clinically the baby grimaced to pain and had occasional spontaneous eye opening. She had intact cough/gag, pupillary, and corneal responses. Over the course of her 3-day hospitalization, no neurologic improvement was noted and increasing ventilatory support was required. Several multidisciplinary family meetings were held to discuss the infant's injuries, prognosis, and treatment options. The family chose to withdraw life support, and the baby died peacefully in her mother's arms soon after her endotracheal tube was pulled and comfort measures provided.

In this case, the mother had clearly made strong efforts to keep her child safe. However, despite the baby's weight in excess of 20 lbs., the baby was prematurely moved into a forward-facing position. Infants have large heavy heads and poor musculoskeletal support. The primary reason an infant should remain rear-facing is due to neck bone rigidity and ligament strength (Sachs & Tombrello, 2000). Lax cervical ligaments put them at risk for a cervical spine injury in a high-energy crash such as the one described. In actuality, a child should remain rear-facing as long as possible but at least until he or she is both 1 year of age and weighs 20 lbs. (Sachs & Tombrello). Had this baby been properly placed in the rear-facing position, the energy of the frontal crash would have been more evenly distributed, the child better protected, and the injury likely avoided.

Clinical Implications

The primary cause of child passenger deaths is more highly related to child restraint nonuse and misuse than with the dangers of airbag deployment (Winston & Durbin, 1999). It is the maternal/child nurse's professional obligation to advise families about family restraint use and to educate and/or guide them on the proper use of child restraints. Misconceptions families may have about airbags must be clarified during this process. Special efforts should be made for populations at risk for injury at the earliest possible point of intervention. Infants at high risk for infant injury mortality can be identified using the easily obtainable characteristics of maternal education, age, number of other children, marital status, and infant birthweight (Scholer et al., 1999). These demographic factors can be used for targeting children and families at greatest risk.

Child passenger restraint information should be readily provided in primary care settings as part of well-child care education and injury prevention; it should be included in outreach endeavors throughout the community as well. Knowledge of local safety belt and child restraint laws serves as a starting point for legislative efforts so that the laws will one day mirror the current recommendations. Actively support legislation to strengthen child passenger restraint requirements, the enforcement of such requirements, and the penalties to violators. Nurses can help to accomplish these goals by joining forces with community organizations such as local chapters of the National SAFE KIDS Campaign, local Departments of Health and Departments of Transportation, and day care centers, schools, hospitals, and clinics. On an individual level, nurses can be positive role models by properly restraining themselves, your family members, and all passengers. As with all practice guidelines, nurses should continuously seek scientific evidence to support legislative, technologic, and educational advances to improve child passenger safety. The time and money involved in injury prevention is well spent when one considers the emotional and financial ramifications of even one child needlessly injured. ✣

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ONLINE

Information related to child passenger safety, product specific information, and related Internet links:

The American Academy of Pediatrics
www.aap.org

The Insurance Institute for Highway Safety
www.iihs.org

Centers for Disease Control and Prevention
www.cdc.gov

National Highway Traffic Safety Administration
www.nhtsa.dot.gov

National SAFE KIDS Campaign
www.safekids.org

SafetyBeltSafe U.S.A.
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Questions

1. **A strongly predictive risk factor for infant injury mortality from motor vehicle crashes is**
   a. few or no other children in the family.
   b. low level of maternal education.
   c. smaller vehicle size.
2. **It is a federal law that beginning with model year 1998, passenger vehicles must have**
   a. manual lap belts only.
   b. manual lap and shoulder belts.
   c. manual lap and shoulder belts and dual airbags.
3. **Together, lap-shoulder seat belts and airbags have been**
   a. 75% effective in preventing serious head injuries resulting from crashes.
   b. 75% effective in preventing mortality resulting from head-on crashes.
   c. 66% effective in preventing mortality resulting from head-on crashes.
4. **Of the following, the strongest predictor of child restraint use is**
   a. a newer vehicle.
   b. driver restraint use.
   c. multiple children in the family.
5. **Of the following, the safest vehicle occupant seating position is**
   a. the driver's seat.
   b. the front passenger seat.
   c. a rear center seat.
6. **In a vehicle equipped with dual airbags, a 6-month old infant should be placed in**
   a. a rear-facing infant seat in the front passenger seat.
   b. a rear-facing infant seat in a rear passenger seat.
   c. a front-facing infant seat in a rear passenger seat.
7. **A child who weighs 60 lbs. should sit in the rear seat of the vehicle using**
   a. a rear-facing convertible seat.
   b. a booster seat.
   c. a lap and shoulder belt without an additional seat.
8. **Children are ready for a lap-shoulder belt without a special seat when**
   a. they are 6 years old and at least three feet tall.
   b. they will no longer agree to sit in a booster seat and weigh a least 60 lbs.
   c. their knees bend over the edge of the vehicle's seat when they sit against the back of the seat and the shoulder strap fits across their shoulder.
9. **LATCH is**
   a. a new campaign to encourage child-restraint use.
   b. a new type of seat belt designed to secure children without using safety seats.
   c. a new system that incorporates properly positioned child seat anchorage points.
10. **According to the 1999 National SAFE KIDS Campaign, what percentage of the car seats observed in use by the families who voluntarily participated were actually misused?**
    a. 63%
    b. 75%
    c. 85%
11. **When a child is placed in a lap-shoulder belt prematurely, the risk of which of the following combinations of injuries increases dramatically?**
    a. intraabdominal, spinal cord and head injuries.
    b. chest and spinal cord injuries
    c. intraabdominal and head injuries
12. **What is the recommended distance necessary between a vehicle's occupant and an airbag to avoid serious injury upon deployment?**
    a. 10 inches
    b. 12 inches
    c. 24 inches
13. **Prior to 1995, safety data related to airbags reported the most common type of airbag-induced injuries to be**
    a. concussion.
    b. abrasions.
    c. fractures.
14. **During avoidance braking, a deploying passenger-side airbag accelerates an unrestrained forward-facing child**
    a. downward and then rearward.
    b. upward and then rearward.
    c. rearward and then downward.
15. **Which of the following individuals would meet criteria for permission to have an airbag cutoff switch installed on a personal vehicle?**
    a. a person who chooses not to risk airbag injury to any passenger.
    b. a person who considers airbags a violation of their rights to choose their own safety precautions
    c. a person whose physical or medical condition makes it impossible to maintain the minimum required distance from the steering wheel

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2. a ❑ b ❑ c ❑	7. a ❑ b ❑ c ❑	12. a ❑ b ❑ c ❑
3. a ❑ b ❑ c ❑	8. a ❑ b ❑ c ❑	13. a ❑ b ❑ c ❑
4. a ❑ b ❑ c ❑	9. a ❑ b ❑ c ❑	14. a ❑ b ❑ c ❑
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