Children, automobile restraints and injuries

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Injuries are the most common cause of death for Canadians aged one to 18 years, and 50% of injury deaths in this age group involve an automobile. Evidence suggests that 71% reduction in deaths and a 67% reduction in injuries can be achieved when child safety seats are used properly. This article reviews the recommended restraints for children by weight group and describes the proper position for children. Detailed case examples of car crashes are described to illustrate the dangers of incorrectly used or no restraint.

Key Words: *Child safety seat; Injury; Motor vehicle crash; Seat belt*

Les enfants, les dispositifs de retenue dans les automobiles et les blessures

RÉSUMÉ : Les blessures représentent la principale cause de décès chez les Canadiens de un à 18 ans, et dans ce groupe d'âge, 50 % des décès secondaires à des blessures mettent une automobile en cause. Les données laissent supposer qu'il serait possible d'obtenir une réduction des décès de 71 % et une diminution des blessures de 67 % par une bonne utilisation des sièges d'auto pour enfants. Le présent article passe en revue les dispositifs de retenue recommandés pour les enfants d'après leur groupe de poids et décrit la bonne position des enfants. Des exemples détaillés d'accidents de voiture sont décrits pour illustrer les dangers d'une mauvaise utilisation ou de la non-utilisation du dispositif de retenue.

Injuries are the most common cause of death for Canadians aged one to 18 years (1). In 50% of injury deaths, the automobile is the source of lethal kinetic energy (1). Child pedestrians and cyclists are vulnerable because of their activities near traffic and their undeveloped skills when coping with traffic (2). Child occupants of a vehicle are vulnerable because the restraint systems built in cars are designed for adults. Evidence suggests a 71% reduction in deaths and a 67% reduction in injuries when child safety seats are used properly (3). The rear seating position is safer for children newborn to 12 years of age, with a 35% reduction in death rates compared with front seating, and with a 46% reduction in death rates compared with front seating with an airbag (4). Despite the increasing prevalence of safety seat use in the United States, deaths of child occupants birth to five years of age increased steadily from 1985 to 1989 (5). It has been proposed that children age birth to five years are spending more time in cars, although this is not well measured in either the United States or Canada (6). Another important factor influencing death and injury rates is the misuse of child safety seats among those who have them (7). Correct use of the appropriate child restraint is a complex task for many parents. In a 1997 Quebec survey, only 40% of preschool-aged children were appropriately restrained for travel, even though 80% were seated in an appropriate device (8). In a recent prospective, consecutive series of crashes with injured child occupants, all children were restrained in some way, but the restraint system itself was implicated in 50% of the injuries (9). Use of inappropriate restraints or unintentional misuse of appropriate restraints are common problems in children injured in car crashes in Canada. Parents are already 'buckling up' their children but need more information on how to do it properly.

Lap belts continue to cause severe, preventable injuries to children and adolescents sitting in the back seat. The lap belt injury complex has been described in the medical literature for at least two decades (10), but the general public does not seem to appreciate the dangers. Air bag injuries to children have been described more recently (11,12). Although severe or fatal injuries to children can occur in minor crashes and despite warning labels on car visors and dashboards, many children are still seated in front of an airbag.

All health professionals caring for children can play an

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important role in promoting the correct use of the appropriate child restraints. An American Academy of Pediatrics panel systematically reviewed the literature on injury prevention counselling (13). Eighteen of the 20 articles included information indicating the positive effects of injury prevention counselling on topics such as motor vehicle safety seats. Physicians provided the counselling in 15 of these 18 positive studies (13). A more recent systematic review of health promotion programs to increase motor vehicle occupant restraint use in young children reviewed 18 studies and showed moderate short term effectiveness, with increases in use rates of 12% to 52% (14). The counselling task is simplified for both practitioner and parent by the recent availability of the *Car Time 1234* video from Transport Canada, which is available on request. The American Academy of Pediatrics also has a good online resource describing child safety seat fitting (contact information at end of article).

Any health professional seeing casualties in the emergency department may occasionally care for children injured in car crashes. Misdiagnosis and diagnostic delay are still common with lap belt injuries. Air bag injuries are a newer phenomenon, and the mechanism of injury is less familiar to some practitioners.

This paper is organized by child's weight group and discusses the recommended restraint for each weight group and the evidence supporting its use. A case example or two from a recent Children's Hospital of Eastern Ontario/Transport Canada series of crash studies is presented for each weight category. The cases are used both to illustrate the importance of promoting the best practices in restraint use, and to highlight the clinical pitfalls common in caring for child crash victims. A summary of injury prevention opportunities and diagnostic issues related to lap belt and air bag injuries is also provided.

After reading this paper, the practitioner should have the knowledge and tools to promote effectively the correct use of the appropriate child restraint and have improved awareness of restraint-related injuries when caring for children injured in car crashes.

WEIGHT GROUP – UNDER 9 KG (20 LBS)

Infants are transported in a rear facing seat with a three- or five-point harness. The seat must face the rear because of the weight of the child's head and the weakness of the neck. It seems sensible to keep a child rear facing for as long as the child will tolerate it. There is no safety advantage to facing forward. Catastrophic neck injuries with cord damage are reported in cases where infant seats have been incorrectly installed, facing forward (15).

Significant danger from airbag inflation requires that an infant be placed in the rear seat. Parents may prefer to see their infant while driving (possibly a dangerous distraction in itself), and many seem not to appreciate the danger airbags pose, despite warning labels. An airbag is not a cushion; the initial phase is a chemical explosion which has been compared with a 300 km/h impact (12). If the child is in the zone of inflation of the bag while it inflates, then inflation of the bag can cause injury. Adults are held well back and out of the zone by the seat belt, but the rear facing infant carrier placed on a front seat puts the child in the zone of inflation of the bag. Severe head and neck injuries or fatalities can occur at any time that the airbag is deployed, even in crashes at very modest speed (16). Despite this, many children in rear facing carriers are still placed in front of an airbag in an at risk position.

As well as being in the rear seat and rear facing, the infant must also be strapped into the carrier properly. Over 40% of infants were improperly strapped into infant seats in a 1997 Quebec survey (8). Loose straps can result in excess injury or in ejection from the vehicle.

Case example: A 1996 Suzuki Sidekick was struck on the driver's side by a 1988 Jeep Cherokee which ran through a stop sign. Following the initial impact, the Sidekick rolled onto its right side. The maximum crush to the Sidekick was 32 cm. The equivalent barrier speed was estimated as 37 km/h. The 29-year-old female driver of the Sidekick was fully restrained and sustained a fractured clavicle, fractures to the left humerus and wrist, and a laceration to the scalp.

The right front passenger was a three-and-a-half-month-old infant who was restrained in a rear facing infant carrier, which was attached to the vehicle by a lap belt. Despite warnings to the contrary, the child restraint was placed in front of the right front airbag. Because the collision forces were primarily lateral, the infant carrier was translated towards the driver's side of the vehicle. This motion took place at the time that the air bag was deploying such that the air bag inflated around the passenger side of the infant carrier instead of behind it.

The infant received a right parietal skull fracture with a subdural haematoma and contusions over the left frontal bone, above and lateral to the left brow. The right-sided skull fracture and underlying subdural haematoma were created by a combination of collision impact forces and airbag forces. The collision impact from the driver's side (right side of the rear facing child's head) pushed the vehicle interior towards the head. The deployment of the airbag around the passenger side of the restraint (left side of the child's head) actually accelerated the child and seat towards the collision, adding, perhaps significantly, to the injury force. The lateral forces in this crash may have protected this child from a worse airbag deployment injury by allowing the bag to inflate around the passenger side of the infant seat rather than interact directly with it. However, the airbag did not provide any protective advantage to the infant, and probably contributed to the severity of the injuries received.

In this case, an appropriate restraint was used inappropriately. When counselling parents about child restraint use, it is necessary to go into sufficient detail to ensure the correct use of any device.

WEIGHT GROUP – 9 TO 18 KG (20 TO 40 LBS)

The toddler and smaller child should be carried in a forward facing or convertible (rear or forward facing) car seat with a three-point or five-point harness. These seats must be used in the rear, away from airbags. A 70% reduction in fatality risk compared with unbelted children has been reported for this type of seat, making it potentially more effective than adult seat belts (2). Parents tend to discontinue the use of this type of seat long before they have to, because they feel that the child has outgrown the seat (7). However, because this is the safest type of seat in a car, parents should be strongly encouraged to continue using it as long as the child fits into it. The straps can be adjusted to accommodate tall or large frames, and the seat fits for as long as the headrest ends at or above the ear canal. This degree of head support is needed to protect the neck in the event of a rear impact.

It is recommended that this style of seat be installed with a seat belt plus a tether strap, which passes over the top of the automobile seat to a tether bolt attached to the frame of the car. The seat belt that holds the child seat to the car must be made snug and must remain snug during motion.

The straps that hold the child into the restraint must have less than 2.5 cm (one inch) of slack. In three point or t-shield strap designs, a sliding chest clip will prevent the shoulder straps from spreading. If the shoulder straps spread apart, the child may be ejected from the seat and the vehicle.

It is demanding for parents to anchor correctly the seat to the car and the child to the seat, each and every time. The new universal child restraint anchor (introduced in some 1999 cars) is aimed at making securing the seat to the car more straightforward. This device is a horizontal bar between the seat cushions, which is grasped by locking clips on the child seat. It holds the child seat to the car securely without using the car's seat belt. However, the tether strap and the child's harness must still be properly installed and tightened by the parent. When small children are wearing bulky snowsuits, parents often knowingly leave straps quite loose. In the 1997 Quebec survey, over 40% of children in child seats were strapped in too loosely (8). In his clinical practice, the author has seen this result in ejection from the vehicle.

In many communities, organizations such as the fire department, police department or the children's hospital offer child seat clinics where the installation and use of the seats can be assessed. In addition, parents can use the Transport Canada *Car Time* video or the American Academy of Pediatrics website to obtain information on the correct installation and use of child seats.

Case example: A 1995 Saturn SL2 was traveling in the passing lane of a four-lane urban road when the driver fell asleep and the vehicle drifted to the right. The driver was awakened by her passengers, but she struck a 1997 Dodge Neon parked in the curb lane. The equivalent barrier speed for the Saturn was estimated at 25 km/h. Both front airbags in the Saturn deployed upon impact.

The 58-year-old female driver of the Saturn was properly restrained by the three-point seat belt. She sustained minor contusions across the hips and upper torso, and to the right hand, plus a minor facial abrasion and muscle strain.

A four-year-old male was in the right front seat. He was 107 cm tall, had a mass of 16 kg and was wearing the lap belt with the shoulder belt positioned behind his back. At the time of the collision, his head was turned to the left, towards the driver. This child sustained a 20% gross hyphema of the right eye and a small corneal abrasion as a result of contact with the deploying air bag. There was edema and abrasion of the periorbital tissues, with no underlying fracture. Visual acuity was 20/50 right and 20/30 left on the day following the injury. The hyphema resolved, and visual acuity returned to 20/30 on the right side within two weeks.

This boy's eye injury occurred because his head was in the zone of inflation when the airbag deployed. Children are more mobile than adults within the motor vehicle and are often out of position in some way even when belted. Shoulder belts designed for adults do not keep the children away from the zone of airbag deployment. Children's injuries from airbag inflation may be severe or even fatal. This boy would still have fit into a standard forward facing child seat, but like many four-year-olds he had not used one for many months.

WEIGHT GROUP – 18 TO 27 KG (40 TO 60 LBS)

The weight group 18 to 27 kg (40 to 60 lbs) is most often inappropriately restrained. Infants are routinely placed in rear facing carriers, and most toddlers at least start out with a forward facing child seat. However, booster seats for the middle-aged child (age three to six years) are much less widely used. In Quebec, the use rate was 64% in 1997 (8).

There is a significant risk of the lap belt injury complex from the poor fit of an adult lap and shoulder belt. The lap belt injury complex results when a loose lap belt directly loads the abdomen and lumbar spine during rapid deceleration. Flexion-distraction injuries of the lumbar spine commonly result, although anterior wedge compression patterns are also seen. Paraplegia is commonly reported, and occurs because of a stretching injury of the thoracic cord. The level of neurological damage is commonly proximal to the fracture level because of the stretching mechanism (17). Abdominal organ injuries are frequent, but may initially present with subtle findings. Solid and hollow organ injuries occur. Mesenteric tearing may result in small bowel ischemia and delayed rupture.

Children in this weight group do not fit into adult lap belts for three reasons. The belt is often held too high off the seat by stiff plastic stalks. The belt width between the stalks is often too great, forcing the belt to be loose. Finally, the seat is too long relative to the child's femur, and it is natural for the child to slouch forward to have his or her knee to bend over the front of the seat. These me-

chanical problems can be corrected by the use of a booster seat, which allows correct positioning of the lap belt over the iliac crests anteriorly.

Both low and high back boosters exist. The high back booster is recommended if the low back booster lifts a child high enough that the ear canals are above the seat or head restraint. In this case, a high back booster provides improved neck protection in the event of a rear impact or recoil. Either design of booster seat can be used with a shoulder belt. The shoulder belt needs to fit across the shoulder and not the neck or face. Many high back booster designs have clips that facilitate correct placement of the shoulder belt.

Case example: A 1998 Nissan Maxima was westbound on a two-lane undivided rural highway. An eastbound 1988 Honda Accord crossed the centre line and struck the Maxima head on. Both vehicles were extensively damaged, and both front seat occupants of the Accord died at the scene. The maximum crush to the Maxima was 124 cm. The equivalent barrier speed was 82 km/h.

The driver of the Maxima was a fully restrained, 34-year-old male. His air bag deployed in the crash. The driver sustained fractures of the left tibia and right arm, primarily due to the extensive intrusion of the firewall and dashboard.

The left rear passenger was a six-year-old female, with a mass of 30 kg, who was restrained by only the lap portion of a lap shoulder belt. She experienced a flexion-distraction type (Chance) fracture of the second lumbar vertebra. She had a pulseless left lower extremity due to an intimal tear of the iliac artery and compression from a retroperitoneal haematoma. She sustained a perforation of the jejunal portion of the small intestine. She was paraplegic below the T12 level. Her hospital course included two abdominal operations and a posterior spinal fusion.

The right rear passenger was a four-year-old male, with a mass of 20 kg, who was restrained by only the lap portion of a lap shoulder belt. He sustained periumbilical seat belt bruising marks, and a flexion-distraction (Chance) fracture at the first lumbar vertebra. He had a small bowel perforation and adhesions treated by abdominal surgery, and developed a subphrenic abscess. He was paraplegic below the T12 level. He had a bilateral sixth cranial nerve palsy, which recovered spontaneously. This was related to stretch or contusion from a deceleration injury of the head. There was posterior cervical ligamentous injury, but no bony instability. He also required posterior lumbar fusion.

In this very severe but survivable crash, the adult occupant was well served by the three-point seat belt and air bag combination. The children both suffered paraplegia as well as abdominal organ injuries and unstable lumbar spine fractures. A poorly fitting lap belt is suboptimal protection, yet it is often what Canadian children use in modern 'safe' cars. Parents should be told that this weight group should use a booster seat in the back seat. Parents should ensure that the lap belt is snug and low over the hips, and the shoulder belt is crossing the chest and shoulder. Crash performance of low and high backed boosters is not yet fully assessed, but they offer strong theoretical advantages to this age group.

Case example: A 1995 Ford Windstar minivan passed by a vehicle that struck and pushed it into a snowy ditch. The van rolled over completely. A five-year-old female with a height of 110 cm and a weight of 20.5 kg was seated in a two-point lap belt with a low booster seat. She was wearing a bulky snow suit, and the lap belt was known to be loose. When the vehicle came to rest, she was found outside the vehicle, having been ejected through the broken left rear window.

Her injuries included a type 3 supracondylar fracture of the right distal humerus produced by an elbow hyperextension force. She had an abrasion over the right cheek, and two small lacerations above and just lateral to the left eye.

This case brings out two important points. The first is that vans, which are replacing passenger cars for many families, roll over more commonly than cars do. Rollover collisions are potentially highly lethal, particularly to unrestrained occupants. Second, the use of an appropriate restraint does not offer children protection if that restraint is not properly tightened. Loose straps are the most common problem identified in the use of child restraints for all age groups. Ejection from a rolling van resulted in relatively mild injuries in this case, but it can be lethal.

WEIGHT GROUP – 27 KG (60 LBS) AND OVER

The safest position for older children and adolescents is in a three-point belt in the back seat. Adolescents are often placed in two-point belts in the back seat in older cars. There is clear evidence that a three-point belt is superior at the 27 kg (60 lbs) and over weight group. Given the risk of lap belt injury, the passenger capacity of a car should be judged by the number of three-point belts and not by the number of seats.

Three-point seat belts in the outboard rear positions have been mandatory since 1990. The rear centre position, however, still has only a lap belt in most cars currently on the market. Some 1999 model year cars (Toyota Corolla, Honda Accord) are designed with three-point belts in all the seating positions. It is even possible to produce minivans and sport utility vehicles (Honda Odyssey, Landrover Discovery) with three-point belts in all seating positions, despite the engineering challenges of anchoring these belts in an open cargo volume. More manufacturers will upgrade to three-point belts in all seating positions if the public directs their buying to proven safety features. Detailed information on car safety features by model is available online (18).

Case example: A 1993 Honda Accord was rounding a highway curve to the right. The Accord crossed over the centre line and came into an offset head-on collision with a 1994 Suzuki Swift. The Accord sustained a maximum

crush of 48 cm at its left front corner. The equivalent barrier speed was estimated at 26 km/h.

There were five occupants in the Accord. The four outboard occupants were all fully restrained; they sustained minor injuries and required no medical attention. The centre rear passenger had only a lap belt available. She sustained a seat belt-induced abdominal injury and was admitted to hospital for treatment.

The centre rear occupant was a 17-year-old female. She was 157 cm tall with a mass of 48 kg. She had a lap belt bruise just above the umbilicus, and a flexion-distraction (Chance) fracture of the second lumbar vertebra. A bowel injury was initially treated nonoperatively, but, after several days, she developed a complete bowel obstruction and required an abdominal operation with resection of a jejunal stricture and primary anastomosis. She did not have any damage to her spinal cord or nerve roots. Her fracture was initially treated in a cast, but she ultimately required a posterior spinal fusion with instrumentation from L1 to L3.

Had there been a three-point seat belt available to this adolescent, she would likely have had minor injuries similar to her companions. It is possible to buy vehicles with three-point belts in all seating positions. The centre rear lap belt should be considered appropriate only for securing an infant or child seat (in combination with an appropriate tether bolt). It should not be considered adequate restraint for a larger child or adolescent. Only seating positions with three-point belts should be used.

The female's clinical course is instructive. A large lap belt bruise and painful lumbar spine were present, but the patient was discharged from the initial emergency room in which she was examined. Review of lumbar spine films taken there showed the Chance type lumbar flexion-distraction fracture, but the displacement was small, making radiographic changes subtle. Often the fracture is confined to posterior elements and is difficult to see radiographically; sometimes the injury is entirely through ligament. There is kyphosis of the lumbar spine at the injured level. Local pain, tenderness and boggy swelling over the posterior lumbar spine are often present clinically. Abdominal organ injury commonly accompanies this fracture (up to 60% of the time), but diagnosis is often delayed (19). Similarly, in some cases, the abdominal organ injury is treated but there is delay in diagnosing the spinal fracture. With a history of lap belt use and a findings of either abdominal or spinal bruising, pain or tenderness, a spinal fracture and an abdominal organ injury should be assumed to be present until they can be ruled out.

SUMMARY

Children continue to be injured or die in car crashes in Canada. Many of these deaths and injuries are preventable. All children should be optimally restrained in cars, and most are not. Health care practitioners can be leaders in promoting the appropriate use of child restraint in cars. After weighing a child in the office, it is a natural time to inquire as to what type of automobile restraint is used, and determine whether it is appropriate for the child's size.

As well as ensuring that the child is in the correct restraint, it is important to ensure that the restraints are installed and used properly. The most common errors include failing to tighten properly the straps that hold the child into the restraint or placing children in the front seat near an airbag. No more than 2.5 cm of slack in the straps is the rule of thumb. Second-hand restraints may be missing parts or instructions, and should be generally regarded as unsafe. A child restraint bed may be necessary for premature infants. Children with casts can be held in a larger seat with a five-point harness, which can be rented or borrowed from most children's hospitals. Children with developmental disabilities can often use a wheelchair insert and restraint straps fitted into a special frame. Assistance with special needs seating as well as regular car seats is provided online by the American Academy of Pediatrics. Children must not be left unsupervised in safety seats. Falls of infants in seats from unsafe surfaces (eg, car roofs, trunks, kitchen tables) are common and should be avoided.

When children do present to the emergency department after car crashes, details of the restraint used and the crash events must be sought specifically. The index of suspicion for lumbar spinal injury and occult abdominal injury must be very high for lap belt users. Closed head injury, upper cervical spine injury, ocular injuries, facial fractures and hyperabduction injuries to the upper limbs can result from children occupying the zone of airbag deployment during the time that the airbag inflates explosively.

Most injured children who present to the emergency department have minor injuries, even if they have come from a car crash. In fact, 20% of children attend the emergency department annually for some form of minor injury (20). It is appealing to use a minor injury visit to promote specific injury prevention measures, although this is perhaps not as commonly practised as medical preventive modalities.

Health care professionals can reduce substantially children's injury morbidity and mortality by promoting specific preventive measures. For Canada's children, this means making sure that they are using an appropriate child restraint correctly each time that they travel by automobile.

RESOURCES

- Transport Canada *Car Time 1234* video. Available from Transport Canada at the road safety information centre. Telephone 1-800-333-0371 or 613-998-8616 from the Ottawa area (EST 8:00 am to 16:30 pm), web site www.tc.gc.ca/roadsafety/
- Useful 'how to' website for practitioners and parents, including regular car seats and special needs children on the American Academy of Pediatrics web site at www.aap.org/family/mncrseat.htm

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All Internet addresses are accurate at the time of publication.

Children, automobile restraints and injuries – Quiz

Answer the following questions by circling the letter of the correct answer(s). Answers can be found on page 49.

1. Regarding child restraint fit, which of the following is false?
   a) one inch of slack is permissible in straps.
   b) the head and neck should be supported up to the level of the external auditory meatus in forward facing designs.
   c) self tensioning belts guarantee good fit.
   d) a properly positioned chest clip is necessary to prevent shoulder straps from spreading.
2. Airbag deployments have been implicated in the following types of injuries in Canadian children:
   a) fatal occipitocervical dislocations.
   b) ocular injuries and chemical and/or friction burns to the face.
   c) closed head injuries.
   d) all of the above.
3. The purpose of a booster seat for children 18 to 27 kg (40 to 60 lbs) is to :
   a) position the lap portion of the seat belt over the pelvis and not the spine.
   b) allow the shoulder belt to be worn in the correct position.
   c) prevent slack in the lap belt and 'submarining' beneath it.
   d) all of the above.
4. When a lap belt injury to the spine is diagnosed, injury to the abdominal organs:
   a) is rarely present.
   b) is very obvious clinically if present.
   c) presents with subtle findings, and is often diagnosed after some delay.
   d) is so common as to mandate exploratory laparotomy in all cases.
5. Three-point seat belts in the mid-rear position:
   a) cannot be adequately anchored to the vehicle frame.
   b) confer no advantage over lap belts alone when used in this inboard and protected position.
   c) are available in passenger cars, but are not technically feasible for minivans or sport utility vehicles.
   d) are currently available on the Canadian market in certain minivans and sport utility vehicles as well as passenger cars.