

# Automobile restraints for children: a review for clinicians

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## Abstract

MORE CANADIAN CHILDREN DIE OF ROAD TRAFFIC INJURIES than of any other cause. Nonuse and misuse of child restraints is common and leads to preventable severe injuries or deaths. This article, intended for clinicians interested in injury prevention counselling, advocacy, research, and treatment of child occupants in car crashes, reviews current knowledge about child safety seats and discusses controversies related to their use. Children should sit in the back seat of a vehicle and should be properly restrained in a current age- and size-appropriate device (rear-facing infant seat, child safety seat, booster seat, or lap and shoulder seat belt) that is properly adjusted. The centre rear seat is safer than side positions, but a lap belt alone should be avoided. The age at which children should start sitting in a forward-facing position is controversial. Children should be seated away from air bags. Resources to aid in patient counselling are described.

**M**ore Canadian children die from road traffic injuries than from any other cause.<sup>1</sup> Non-use of child restraints is common among those killed or injured.<sup>2-4</sup> In addition, misuse of child restraints is common<sup>5-9</sup> and can lead to severe injury.<sup>10</sup> Yet death and disability of children involved in motor vehicle crashes can be prevented. Discussing safe travel with parents may be a clinician's most important child health promotion activity. It is known that clinicians can engender short-term behaviour change by counselling about use of child safety seats,<sup>11</sup> even though the optimal means of ensuring protection of children in vehicles over the long term remains unknown.

In addition to counselling, clinicians may be involved in treatment of injuries, advocacy, public education campaigns, legislation and research. This paper reviews current knowledge about and controversies related to child restraint in vehicles and directs readers to resources to aid in counselling.

## Current knowledge about restraints

Four types of child restraint are recommended by Transport Canada,<sup>12</sup> depending on the child's size. Infants up to 10 kg (22 lb) should be seated in a rear-facing infant carrier. Toddlers from 10 kg to 18 or 22 kg (22 lb to 40 or 48 lb) should be seated in a forward-facing child safety seat, the upper weight limit depending on the seat model. Children from 18 or 22 kg to 27 kg (40 or 48 lb to 60 lb) should be seated in a booster seat. The recommended upper weight limit for booster seats is 36 kg (79 lb) in the United States<sup>13</sup> and the United Kingdom.<sup>14</sup> Larger children should use a lap or shoulder seat belt in the rear seat.

## Seating position and restraint effectiveness

The rear seat of a vehicle is the safest seat. Braver and associates<sup>15</sup> estimated that rear seating reduced the risk of death by 36% for children involved in fatal crashes, regardless of whether the child was restrained (Table 1). Berg and colleagues<sup>16</sup> demonstrated that children in rear seats were 1.7 times less likely (95% confidence interval [CI] 1.6-2.0) to suffer a fatal or severe injury than front seat occupants. These studies included children up to 12 or 14 years respectively, so they encompass ages when child safety seats and seat belts are recommended.

Kahane<sup>17</sup> estimated that correctly used child safety seats reduced the risk of fatal-

*Review*

*Synthèse*

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### Transport Canada: current recommendations for child seating in vehicles<sup>12</sup>

Children up to 12 years of age should sit in the rear seat  
 Use rear-facing infant seat until 10 kg (22 lb) (approximately 1 year)  
 Use forward-facing child seat from 10 kg (22 lb) to 18 or 22 kg (40 or 48 lb) (approximately 4½ years); upper weight limit depends on specific seat model  
 Use booster seat from 18 or 22 kg (40 or 48 lb) to 27 kg (60 lb) (approximately 8 years)\*  
 Use lap and shoulder belt in the rear seat for older children

\*An upper weight limit for booster seats of 36 kg (79 lb) (approximately 11 years) is recommended in the United States and the United Kingdom.<sup>13,14</sup>

ity by 71% and the risk of serious injury by 67%. Isaksson-Hellman and collaborators<sup>18</sup> concluded that large, rear-facing child restraints for children up to 3 years old (a design used in Scandinavian countries) reduced injuries by 96%. Miller and associates<sup>19</sup> estimated that each dollar spent on a child seat in the United States saved \$2 in medical care, \$6 in other tangible costs and the equivalent of \$25 in quality of life (based on insurer payouts for pain and suffering).

### Rates of restraint use

Rates of restraint use fall as children grow older. In Canada in 1997, the rates were 96% for infants, 91% for children 1 to 4 years old and 85% for those 5 to 15 years old.<sup>20</sup> Corresponding rates of restraint use in the United States for 1996 were 85%, 60% and 65%.<sup>21</sup> Only 56% of children (under 10 years of age) involved in fatal crashes in the United States in 1994 were restrained.<sup>2</sup> The strongest predictor of use of a child restraint in fatal crashes was the driver's use of a restraint.<sup>2</sup>

### Rates of restraint misuse

Parents must select an appropriate device for each child, secure it properly to the car and adjust it properly to fit the child as he or she grows. Thus, it is not surprising that misuse of these important but complex devices is the norm. Misuse rates have ranged from 44% to 81% for child safety seats and 33% to 50% for booster seats in different jurisdictions.<sup>5-9</sup>

### Age for forward-facing seating

The American Academy of Pediatrics has recently advised that children should be seated facing the rear of the vehicle for as long as possible and at least until 1 year of age.<sup>22,23</sup> Facing rearward is intrinsically safer, provided the head is supported, and the reasons for seating a child in the

**Table 1: Child's risk of dying in a fatal crash, by seating position and restraint use\***

Seating position	Use of restraint; risk of death, % of children in fatal crashes	
	Restrained	Unrestrained
<b>Front seat</b>	22	39
<b>Rear seat</b>		
Outboard position	14	25
Centre position	11	22

Note: Each percentage is based on the total number of children in the given restraint category and seating position involved in a crash in which at least one person died; the percentage represents the proportion of those children who died. For example, of all unrestrained children seated in the front seat at the time of a fatal crash, 39% died.  
 \*Source: Braver and associates.<sup>15</sup>

opposite position relate to convenience, not safety.<sup>24,25</sup> With heavy heads and weak necks, children are vulnerable to catastrophic traction injuries to the cervical cord,<sup>26-29</sup> and children older than 1 year retain this vulnerability.<sup>26,28,30,31</sup> In contrast, there are no reports of catastrophic neurologic injury for children in the rear-facing position.<sup>24,25</sup> Both Transport Canada<sup>12</sup> and the US National Highway Traffic Safety Administration<sup>13</sup> currently suggest having children face forward from about 1 year of age or once they reach 10 kg (22 lb). Nonetheless, many currently available child safety seats are designed for rear-facing use until the child reaches 14 kg (31 lb),<sup>22</sup> which prolongs the period that children can be kept safer by facing rearward.

### Premature graduation

Children are commonly "graduated" to inappropriate restraints too early. In one observational study 21% of toddlers (9 to 18 kg [20 to 40 lb]) and 75% of preschoolers (18 to 27 kg [40 to 60 lb]) were restrained by a seat belt only.<sup>7</sup> In another study 28% of 4-year-olds, 36% of 5-year-olds and 70% of 6- to 8-year-olds were restrained by a seat belt only.<sup>32</sup> More than 50% of parents owned the appropriate device but believed, incorrectly, that their children were large enough for a seat belt.<sup>32</sup> Children 2 to 5 years of age who crashed wearing a seat belt had a relative risk (compared with children in child seats) of significant injury of 3.5 (95% CI 2.4-4.2) and a relative risk of significant head injury of 4.2 (95% CI 2.6-6.7).<sup>10</sup>

### Current knowledge about injuries

#### Lap belt injuries

Lap belt injuries are a well-described clinical entity. The full triad includes bruising of the abdominal wall, abdominal viscus injury and vertebral fracture.<sup>33-39</sup> Lap belt use in a frontal crash should trigger a careful search for clinically inapparent injury, since diagnostic delays remain common.<sup>36-38</sup> Children are prone to lap belt injuries because they often slouch with the belt loose and across the ab-

domen (rather than the hips). A booster seat corrects these problems by lifting the child up and forward, allowing better fit of both the lap and the shoulder belts. Recommendations for booster seat use extend to 27 kg (60 lb) or 8 years in Canada<sup>12</sup> and to 36 kg (79 lb) or 11 years in the United States<sup>13</sup> and the United Kingdom.<sup>14</sup> However, actual use is very low in most countries, and preventable lap belt injuries continue to occur.

### Ejections

Children in loose seat belts or loose child safety seat harnesses are at risk of ejection from a vehicle, especially if it rolls over.<sup>40,41</sup> Although specific data for children are not available, ejection carries an 8-fold increase in fatality risk for adults,<sup>42</sup> and a similar factor might be expected for children. Loosely fitting (i.e., improperly fitted) child safety seat harnesses are endemic.<sup>5,6,8,9</sup> Thus, even though rollovers are rare — 1% to 2% of crashes — they account for 29% of child crash fatalities in the United States.<sup>41</sup> Optimizing protection of children against ejection injuries requires universal use of restraints and better understanding of how restraints can prevent ejection.

### Side impacts

Side impact crashes are dangerous for children and represent a challenge to prevention efforts. Agran and colleagues<sup>43</sup> found that significant injuries occurred in 41% of side impact crashes, 15% of frontal impacts and 3% of rear impacts involving restrained school-age children.<sup>43</sup> Braver and associates<sup>15</sup> reported a child fatality rate of 30% for side impact crashes and 17% for frontal impact crashes. Restraints did not significantly influence the likelihood or severity of injury for children on the struck side in side impact crashes.<sup>44</sup> The best advice is to seat the child in the centre position whenever possible and to ensure that age-appropriate restraints are used. Particular care must be taken to tighten straps to limit the lateral mobility of the child's head.

### Air bag injuries

Children occupying the front seat have been killed or severely injured by front passenger air bags, even in minor crashes.<sup>45-49</sup> The bag inflates quickly from a chemical explosion likened to a collision at 300 km/h.<sup>47,50</sup> Children in the zone of inflation can suffer fatal injuries to the head and cervical spine. Several factors contribute to this problem. Children are poorly held by large seat belts (such as those available in the front seat), they move around while the vehicle is moving, and child safety seats (particularly rear-facing seats, which hold the head within the zone of air bag inflation) are often erroneously used in the front seat.<sup>50</sup> Current air bag systems have higher thresholds for deployment than those initially marketed, but they are still unsafe

### Controversies

#### Age for forward-facing seating

Officially recommended for 1 year (10 kg or 22 lb), but safest to consider this as a minimum and continue rear-facing seating as long as possible, provided head is supported. Many currently available seats are designed for rear-facing use until child reaches 14 kg (31 lb) or larger; check the manufacturer's instructions.

#### Rear-seat air bags

No real-world experience has been reported yet, but crash testing shows potential danger to out-of-position child occupants. Use centre seat for children or deactivate rear-seat air bags (or both).

#### Special needs

Children whose weight, height or physical development differs significantly from norms for their age group require individual consideration. Avoid "premature graduation," aim for good belt fit, with only 2.5 cm (1 in.) of slack, and ensure that shoulder belts do not come from below shoulder level. Modified seats, vests and car beds are available for children with special needs. See the Web site of the American Academy of Pediatrics ([www.aap.org/family/cps.htm](http://www.aap.org/family/cps.htm)).

for children. Children under 13 years of age must be seated in the rear, away from the air bags.

Side air bags in the rear seat are currently available in only a small number of luxury vehicles. There is little crash experience of their effect on child occupants. Transport Canada found that rear-seat air bags could cause injury — sometimes serious — to out-of-position 3- and 6-year-old child dummies.<sup>51</sup> Since most children are out of position for portions of any journey, it is wise to avoid rear-seat air bags in cars where children are the intended passengers. Current US policy is that cars with rear air bags be sold with the bags deactivated, to avoid injury to children.<sup>52</sup>

### New anchorage systems

New systems that simplify the installation of child safety seats are currently available and are required in all new cars sold in Canada as of September 2002. Clips on the child safety seat attach to fixed horizontal bars between the seat cushions. These bars (referred to as isofix or LATCH systems) provide an easier and more secure means of attachment than vehicle seat belts but will be available only in new vehicles. A top tether strap anchor point will also be provided in rear seating positions. Older vehicles without tether anchor points can be retrofitted by dealers. The standards for these systems are similar in North America<sup>53</sup> and Europe.<sup>54</sup> Real-world crash experience will be needed to confirm the expected benefits of lower rates of misuse and more limited movement of the child safety seat during

## Resources for parents and clinicians

### Transport Canada

Information about restraint types, rationale for use and instructions on proper use

Ordering information for a 13-page booklet for parents and a free video, *Car Time 1-2-3-4: Safe Seating in the "Kid Zone"*

800 333-0371

[www.tc.gc.ca/roadsafety/childsafe/cindex\\_e.htm](http://www.tc.gc.ca/roadsafety/childsafe/cindex_e.htm)

### Safe Kids Canada

Tips on car seat safety and other injury prevention topics

[www.safekidscanada.ca/English/SKW/SKW\\_RoadSafety/SKW\\_Carseat.html](http://www.safekidscanada.ca/English/SKW/SKW_RoadSafety/SKW_Carseat.html)

### American Academy of Pediatrics

Information about seat types, a shopping guide by brand and model, installation tips, counselling information for clinicians and information about transporting children with special needs

Policy statement on child safety seat counselling

published in *Pediatrics*, March 2002 issue<sup>23</sup>

[www.aap.org/family/cps.htm](http://www.aap.org/family/cps.htm)

### National Highway Traffic Safety Administration (US)

Information about seat types and a checklist for safe use

[www.nhtsa.dot.gov/people/injury/childps/](http://www.nhtsa.dot.gov/people/injury/childps/)

crashes. Simplification of the belt harness for children, while optimizing crash performance, will be the next challenge in the design of child restraints.

## Conclusions

Children should sit in the rear seat of a vehicle. Each child should be restrained in a current age- and size-appropriate device (rear-facing infant seat, child safety seat, booster seat, or lap or shoulder seat belt) that is properly adjusted. They should be seated away from air bags.

Children are routinely weighed and measured during regular health visits to clinicians. The greatest health benefit of this information could be realized if it is used to ensure that children travel safely in cars. An optimal counselling intervention has not yet been defined, but the resources listed in the sidebar provide detailed and practical information for clinicians and families.

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Note: A table providing a more detailed literature review is available at eCMAJ at [www.cmaj.ca](http://www.cmaj.ca) (see Table 2 of this article).

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