The spectrum of seat belt syndrome among Canadian children: Results of a two-year population surveillance study

Miriam Santschi MD, Claude Lemoine MD, Claude Cyr MD

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BACKGROUND: Seat belts have been proven to save lives. However, if they are not properly fitted, 'seat belt syndrome' can occur. The aim of the present study was to describe injuries encountered in Canadian children with seat belt-associated injuries.

METHODS: Canadian paediatricians and paediatric subspecialists were surveyed monthly through the Canadian Paediatric Surveillance Program. Children younger than 18 years of age who were restrained in motor vehicles at the time of a collision, with abdominal or thoracolumbar spine injuries, were included. The children may have been restrained in child safety seats, booster seats, or two- or three-point seat belts.

RESULTS: Twenty-eight children, between two and 16 years of age, with injuries compatible with seat belt syndrome were reported in Canada between September 2003 and August 2005. Although 12 children were younger than eight years of age, only one was restrained in a booster seat and only four of the older children were properly restrained with a three-point seat belt. Twenty-four children had abdominal injuries. Of these, 18 had stomach and/or intestinal injuries and 11 had solid organ injuries. Twelve patients had a spinal fracture, including only five Chance-type fractures. Seven patients presented with paraplegia, and none of them recovered.

CONCLUSION: In Canada, over a two-year period, 28 children were reported to have sustained injuries consistent with seat belt syndrome; seven of these children remained paraplegic. These results emphasize the necessity to review restraints in motor vehicles to adequately protect children.

Key words: *Abdominal injuries; Booster seat; Child; Seat belt; Spinal cord injury*

Le spectre du syndrome de la ceinture de sécurité chez les enfants canadiens : Résultats d'une surveillance de deux ans au sein de la population

HISTORIQUE : Il est démontré que la ceinture de sécurité sauve des vies. Cependant, si elle est mal ajustée, il y a un risque de « syndrome de la ceinture de sécurité ». La présente étude visait à décrire les lésions subies chez les enfants canadiens atteints de blessures reliées à la ceinture de sécurité.

MÉTHODOLOGIE : Les auteurs ont interrogé les pédiatres et pédiatres avec surspécialité canadiens tous les mois par l'entremise du Programme canadien de surveillance pédiatrique. Les enfants de moins de 18 ans attachés dans un véhicule automobile au moment d'une collision et qui avaient subi des lésions abdominales ou de la colonne thoracolombaires ont été inclus dans l'étude. Les enfants pouvaient être retenus dans un siège d'auto pour enfant, un siège d'appoint ou au moyen d'une ceinture de sécurité à double ou triple point d'appui.

RÉSULTATS : Vingt-huit enfants de deux à 16 ans ayant subi des blessures compatibles avec un syndrome de la ceinture de sécurité ont été déclarés au Canada entre septembre 2003 et août 2005. Bien que 12 enfants aient eu moins de huit ans, seulement un était retenu dans un siège d'appoint et seulement quatre des enfants plus âgés l'étaient correctement au moyen d'une ceinture de sécurité à triple point d'appui. Vingt-quatre enfants souffraient de lésions abdominales. De ce nombre, 18 avaient des lésions stomacales ou intestinales et 11, des lésions des organes pleins. Douze patients souffraient de fractures lombaires, dont seulement cinq fractures de type Chance. Sept patients étaient paraplégiques, et aucun ne s'est rétabli.

CONCLUSION : Au Canada, sur une période de deux ans, on a déclaré 28 enfants ayant subi des lésions compatibles avec le syndrome de la ceinture de sécurité, dont sept sont demeurés paraplégiques. Ces résultats soulignent la nécessité de revoir les dispositifs de sécurité des véhicules automobiles afin de protéger les enfants correctement.

Although restraint use in motor vehicles has clearly decreased mortality in motor vehicle collisions (1), a spectrum of injuries have been described in restrained victims of motor vehicle collisions. The so-called 'seat belt syndrome' was first described by Garrett and Braunstein (2) in 1962, and referred to injuries to the intestinal viscera and to the lumbar spine associated with seat belt restraints. The first cases were described in adults. However, in the 1980s, reports of children with seat belt syndrome appeared with the increased use of rear seat belts (3).

Typically, seat belt syndrome involves a tear or perforation of the intestine and its mesentery accompanied by fracture, distraction or dislocation of the midlumbar spine (4). The mechanism of the lumbar spine injuries appears to be a hyperflexion of the spine around the lap belt, subjecting the vertebrae to tension stress and distraction (5). Children are especially vulnerable to these injuries due to their physical and behavioural characteristics (4,6). The children's immature pelvis cannot anchor the lap portion of the belt properly, and they have a tendency to slide forward in the seat so that their knees are flexed at the seat edge; these two characteristics allow the lap belt to ride up over the abdomen. Therefore, during rapid deceleration, the belt can cause mesenteric tears and bowel contusions owing to the direct compression of these organs between the belt and the spine (7).

Department of Pediatrics, Centre Hospitalier Universitaire de Sherbrooke, Université de Sherbrooke, Sherbrooke, Québec
Correspondence: Dr Miriam Santschi, Département de pédiatrie, Faculté de Médecine et des Sciences de la Santé, Université de Sherbrooke, 3001, 12e avenue Nord, Sherbrooke, Québec J1H 5N4. Telephone 819-820-6868, fax 819-564-5398, e-mail Miriam.Santschi@USherbrooke.ca
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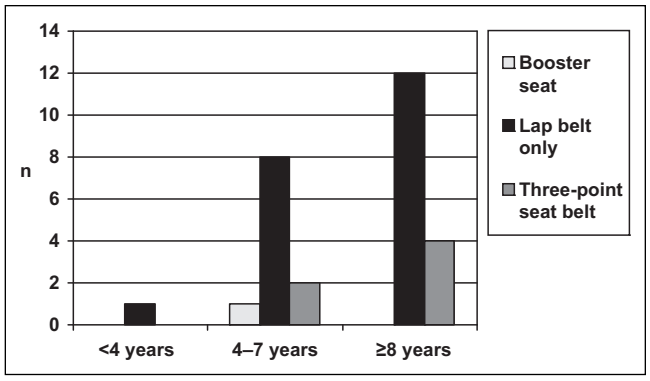

Figure 1) *Seat restraints used per age group*

Few population-based studies on seat belt syndrome have been undertaken. Therefore, it is difficult to obtain a reliable estimate of the incidence of seat belt syndrome in children who are victims of motor vehicle collisions, and to have a clear idea of the exact pattern of injuries associated with seat belt syndrome in children.

The aim of the present study was to describe the frequency and the pattern of injuries encountered in Canadian children with seat belt syndrome.

METHODS

Study design

The present study was undertaken through the Canadian Paediatric Surveillance Program (CPSP) between September 2003 and August 2005. The CPSP is a national surveillance program based on the voluntary reporting of 2400 actively practising paediatricians and paediatric subspecialists. The response rate during the two years of the study was 82%. A 'check-off' form was mailed monthly to all participants to find cases of 'seat belt syndrome'. For those physicians who reported a case, a detailed questionnaire was sent to collect case-specific information. Duplicate reports were identified through non-nominal patient information, such as the date of birth and sex. The institutional ethic review board of the Centre Hospitalier Universitaire de Sherbrooke (Sherbrooke, Quebec) approved the study.

Case definition

Every child (younger than 18 years of age) restrained in a motor vehicle at the time of a collision, with either an abdominal injury or a thoracolumbar spine injury, was reported. Restraints were defined as child safety seats, booster seats, lap-belt only, or lap and shoulder belts. The reporting physicians were asked to describe the child's injuries in the different body locations (head and neck, face, thorax, abdomen, extremities and spine). Abdominal injuries were determined by operation, ultrasound or abdominal computed tomography scan. Reported injuries included injuries involving the small intestine and colon, spleen, kidney, liver, pancreas, mesentery, bladder, uterus and any vascular structure within the abdominal cavity.

TABLE 1
Mechanisms of impact (n=28)

	Results
Type of motor vehicle, n (%)	
Passenger car	13 (46)
Minivan	10 (36)
Light truck	3 (11)
Unknown	2 (7)
Type of impact, n (%)	
Head-on	17 (61)
Side	4 (14)
Roll-over	3 (11)
Unknown	4 (14)
Approximate speed at impact (km/h), mean ± SD	87±22
Position in the vehicle, n (%)	
Back seat	23 (82)
Front seat (passenger)	2 (7)
Front seat (middle)	3 (11)
Death of another passenger	6 (21)

Thoracolumbar spine injuries were classified in major spinal injuries (compression fractures, burst fractures, Chance-type fractures and fracture dislocations) and minor spinal injuries (fracture of transverse process, fracture of articular process, spinous process fractures and pars intercularis fractures) (8).

Optimal restraint use was defined for every age group – child younger than four years of age restrained in a child safety seat, child four to seven years of age restrained in a booster seat, and child eight years of age and older restrained with a three-point seat belt. Suboptimal restraint use was defined as a child younger than eight years of age not restrained in a child safety seat or a booster seat, or a child eight years of age and older restrained with a lap-belt only or a three-point seat belt worn incorrectly (behind back or under arm).

RESULTS

Twenty-eight children with seat belt syndrome were reported in Canada over a two-year period.

The children's ages ranged from two to 16 years. Fourteen were boys. Patients have been reported evenly throughout the different seasons of the two years of the study. However, some regions reported a higher number of patients. There were 11 patients from Quebec, seven from Ontario and 10 from western Canada. No patient was reported from the Atlantic provinces, and the territories.

The only child who was younger than four years of age was not restrained in a child safety seat, but was restrained with a lap-belt only. Only one of the 11 children between four and seven years of age was restrained in a booster seat (with the seat belt worn incorrectly behind the back). Furthermore, four of the 16 children eight years of age and older were properly restrained with a three-point seat belt (Figure 1). The mechanisms of the impact are described in Table 1.

Twenty-four patients had abdominal injuries (Table 2). Eighteen had stomach and/or intestinal injuries. Of these, 10 had small bowel perforations or mesenteric lacerations, three had colon or sigmoid perforations and three had duodenal perforations. One patient presented with a stricture of the small intestine and another with a small intestine infarct. Two patients had a mesenteric laceration, with one of these presenting with a massive mesenteric hemorrhage and devascularization of the midgut, needing surgical resection. Additionally, three patients had renal injury, five had splenic laceration and three had liver laceration. Sixteen of these patients needed exploratory laparotomy.

Twelve patients had a spinal fracture, all except one were at the lumbar level; one patient had a fracture-dislocation of the thoracic spine (T2-T3 level). Five patients had the classically described seat belt-associated spinal fracture (Chance-type), three patients had a compression fracture of a vertebrae, two patients had a fracture-dislocation, one patient had a comminuted fracture of a vertebra and one child had a fracture of the pedicle of L3. Six of these patients had a spinal cord injury and all of them remained paraplegic. Only two patients with paraplegia had a Chance-type spinal fracture. Also, one patient presented with complete paraplegia at the T11-T12 level, without any radiological abnormality to the spine (Table 2).

Other body sites injured are described in Table 2. Fourteen patients presented with an ecchymosis or abrasions over the abdomen, lower thorax or anterior iliac crests.

All reported patients survived. Patients were admitted to the hospital for a median of 10 days (range three to 155 days); 18 patients were admitted to the intensive care unit and the median intensive care unit stay was five days (range zero to 21 days). The course of two patients was complicated by delay in diagnosis. One patient presented with a stricture of the small bowel two weeks after the initial accident, and another patient was initially admitted and operated for a small bowel perforation, but was readmitted for a missed fracture of L4. Twenty-three patients had a surgical intervention, and 10 needed two or more interventions. All seven patients presenting a spinal cord injury on admission remained paraplegic.

TABLE 2
Abdominal, spinal and other organ injuries

Injuries	n (%)
Abdominal*	
Stomach and/or intestine	18 (64)
Kidney	3 (11)
Spleen	5 (18)
Liver	3 (11)
Pancreas	1 (4)
Bladder	1 (4)
Other	13 (46)
Total	24 (86)
Spinal*	
Chance-type fracture	5 (18)
Compression fracture	3 (11)
Dislocation fracture	3 (11)
Comminuted fracture	1 (4)
Fracture pedicle	1 (4)
Spinal fracture, total	12 (43)
Spinal cord injury	7 (25)
Other body sites*	
Head and/or neck	7 (25)
Face	9 (32)
Thorax	9 (32)
Extremities	7 (25)
Others/external	15 (56)

**Total adds up to more than 100% because some children had more than one type of injury*

DISCUSSION

The present study reports 28 children with seat belt syndrome through a national surveillance program. The patients reported in the present study had significant injuries requiring prolonged hospitalizations and, in almost all cases, at least one surgical intervention. One-quarter of the patients remained paraplegic as a consequence of spinal cord trauma.

The minimal incidence rate can be estimated at 0.5 per 100,000 children younger than 14 years of age, and one child per 1000 children 14 years of age and younger injured in a motor vehicle collision in 2004. The incidence rate of seat belt syndrome was estimated as the number of individuals 14 years of age and younger with seat belt syndrome divided by the total population of Canadian children 14 years of age and younger at that time, and defined as the midpoint during the study period (2004). The incidence of seat belt syndrome can also be calculated as the number of children 14 years of age and younger with seat belt syndrome during 2004 divided by the total number of Canadian children 14 years of age and younger involved in a motor vehicle collision during the same time period (9,10). These results are consistent with previous studies (11,12).

Abdominal injuries described in the present study go beyond the classically reported hollow viscus injuries described in seat belt syndrome. Our patients not only presented with intestinal injuries, but over one-third of them (11) had solid organ lacerations or contusions. The spectrum of abdominal injuries in children with seat belt syndrome seems to be wider than what is described in adult victims. Health care professionals caring for restrained children who were victims of a motor vehicle collision need to have a high level of suspicion for seat belt-associated abdominal injuries, with special attention to solid organ injuries. Because 64% of patients presented with a bowel perforation, great attention must be given to abdominal symptoms in these patients because computed tomography scans and echographical evaluations can initially miss an intestinal perforation (13). Many of these injuries come to the attention of physicians by increasing abdominal tenderness over time. The presence of an abdominal wall ecchymosis or contusion should heighten the suspicion of

TABLE 3
Booster seat recommendations

- Children younger than eight years of age
- Weighing between 18 kg and 36 kg
- Measuring less than 145 cm

seat belt-associated abdominal injuries (7). These patients should be hospitalized for serial abdominal examinations, even if the initial diagnostic workup is negative.

Spinal cord injuries are reported in 43% of patients in the present study. The spectrum of reported fractures is wider than the classically described Chance-type fractures. More than one-half of the patients with a spinal fracture had complete paraplegia. Results of case series (14,15) of children with Chance-type fractures published since 1990 suggest that long-term neurological deficits owing to spinal cord injury are relatively uncommon after Chance-type fractures. In these series, only two of 18 patients (11%) reported with Chance-type fractures remained paraplegic. In our cohort, two of five patients (40%) with Chance-type fracture remained paraplegic. As described in previous studies (16,17), injuries in our study mainly affected the lumbar spine; only one patient had a thoracic spine injury. Paraplegia in these age groups has lifelong implications for the patients, their families and also the society. Life expectancy is reduced in spinal cord-injured patients (18); they have greater health care needs and fewer working opportunities.

All paediatric age groups are represented in the present study. However, the majority of patients (82%) were between four and 12 years of age. These children seem to be especially at risk for seat belt syndrome.

Children between four and eight years of age have outgrown their child safety seats and are restrained in seat belts designed for adults, often without the use of booster seats (19). A previous study (20) showed that children between four and eight years of age are at the highest risk of inappropriate restraint use. In this large surveillance study (20), 74% of the children between four and eight years of age were not properly restrained, compared with 9.5% of children younger than four years of age, and 9.1% to 12.9% of older children. In our study, only one child was restrained in a booster seat. Booster seat use seems to correct the biomechanical vulnerability for seat belt syndrome (19), and decreases the risk of injury by 59% (21). Despite being highly effective devices, booster seats are underused in Canada. In one study (19), only 4.5% of children five to nine years of age were using booster seats. The main barriers to booster seat use are that parents do not believe that they are necessary (22,23) or do not correctly identify the age at which it becomes safe to use a seat belt (24). But most alarmingly, only 25% of Toronto community paediatricians could identify the recommended age for transition to three-point seat belts (25).

Children between eight and 12 years of age are also at increased risk of seat belt-associated injuries, probably because of inappropriate use of seat belts (use of lap-belt only or three-point seat belts worn behind the back or under the arm). Furthermore, children have characteristics putting them at risk of seat belt-associated injuries. Their intra-abdominal organs are less protected by the thorax and pelvis, their posterior ligaments of the spine are less well developed and more easily torn, and their iliac crests are less developed than those of adults, allowing the belt to ride up over the abdomen (4,6).

The risk of injury to inappropriately restrained children is nearly twice as high, compared with appropriately restrained children (OR 1.8; 95% CI 1.4 to 2.3); whereas unrestrained children are at more than three times the risk of injury (OR 3.2; 95% CI 2.5 to 4.1) (20).

These results are an estimate of the true incidence and spectrum of seat belt-associated injuries in Canadian children. All these patients were seen by a paediatrician, a paediatric emergency physician or a paediatric intensivist at some point during their care. We believe that some patients with less severe injuries might have been seen only by a surgeon and, therefore, not reported. Furthermore, severe cases of seat belt-associated injuries leading to a rapid death after the collision could have been missed because these patients died before all their injuries could be identified. Older teenagers could have been taken care of in adult centres, even if Canadian paediatric intensive care units care for patients up to 18 years of age. However, before the actual study was undertaken, a survey was performed among CPSP participants to ensure that they would see patients with seat belt syndromes. Eighty-seven per cent of the paediatricians believed that these children would be seen either by a paediatrician or a paediatric intensivist (participants of the CPSP) at some point during their care.

The present study could potentially display a response bias. However, during the study period, the response rate of paediatricians completing the initial 'check-off form' was 82%; therefore the vast majority of patients with seat belt-associated injuries seen by a paediatrician during these months have been reported.

CONCLUSION

Seat belt syndrome is a known complication of suboptimal restraint use in motor vehicles. Important complications are associated with paediatric seat belt syndrome – need for emergency surgical intervention for abdominal injuries and paraplegia secondary to spinal cord trauma. Knowledge of the current recommendations for age- and/or size-appropriate restraint for children would help to lessen the number of injuries among young children. Preventive strategies (use of booster seat [Table 3] and three-point seat belts) can decrease the incidence of these injuries. Some automobile manufacturers have already banned two-point seat belts in new cars. These results emphasize the necessity to review restraints in motor vehicles to protect children adequately, and the urgent need for aggressive education efforts aimed at adequate child restraint use in motor vehicles. We believe that efforts aimed at parental and health care professionals'

education for optimal child restraint use should be supported by reinforcement of legislations on booster seat and three-point seat belt use.

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