Preventing motor vehicle crashes related spine injuries in children

Mohammad R Rasouli, Vafa Rahimi-Movaghar, Radin Maheronnaghsh, Ali Yousefian, Alexander R Vaccaro

Tehran, Iran

Review article

Background: **Spinal cord injury (SCI) is a devastating event that results in permanent disability for injured children. Among all etiologies of SCI, motor vehicle crashes (MVCs) are the leading cause and account for 29% of all traumatic SCIs in children. We tried to evaluate types and mechanisms of MVC-related spinal column and spinal cord injuries, risk factors, safety issues and legislation.**

Data sources: **A literature review was performed using PubMed from 1966 to 12th April 2010 with the following key words: children OR pediatric, spine, injury OR trauma, restraint, seat belt, motor vehicle, road OR traffic, collision OR crash, safety. Cross referencing of discovered articles was also performed.**

Results: **Risk factors for MVC-related SCI include single vehicle crashes, vehicle rollover, and ejection of the passenger from the vehicle. Any anatomic region of the spinal cord may be injured as a result of MVC and may vary according to the type of accident and restraint system usage. Increasing use of three-point seat belts, which are more protective than isolated lap seat belts, has decreased the incidence of MVC-related SCI. There is evidence that airbag use without seatbelt use is associated with an increased risk of cervical spine fractures with or without SCI. Vehicle designers need to give more attention to the prevention of vehicle rollover and to improve occupant protection when rollover occurs.**

Conclusions: **MVC is a common cause of SCI in children; therefore, paying attention to risk factors and modes of prevention is important. As MVC-related SCI can lead to permanent disability, prevention and education play an important role in decreasing childrens' morbidity and mortality. Making behavior, roads and vehicles safer can significantly reduce MVC-related SCI in children.**

World J Pediatr 2011;7(4):311-317

Key words: **children; injury; motor vehicle crash; spinal cord**

Introduction

Spinal cord injury (SCI) is a devastating event that results in permanent disability for the injured child and poses a large financial burden to health care systems.[1-5] Traumatic spinal injuries in children are uncommon, representing only 1% to 10% of all reported spinal injuries. Each year, approximately 1000 new spinal injuries are reported in children. The true incidence of SCI may be underestimated because of scene mortality or death in transport.[6]

Motor vehicle crashes (MVCs) are the second most common cause of spine fractures after falls[7] and are the leading cause of SCI, accounting for 29% of SCIs in children.[6] Road traffic injuries are a leading cause of disability for children. From a young age, boys are more likely to be involved in road traffic crashes than girls.[8] Most MVC-related SCI involves occupants of light passenger vehicles[9,10] and generally the SCI results from injury in the cervical region.[11,12] Usually, SCI results from spine fractures/dislocations in MVC. Cervical spine injury was identified among 176 of 6065 children (age 0-15 years) killed in MVCs.[13] MVCs can cause a diversity of injuries in pedestrians

Author Affiliations: Sina Trauma and Surgery Research Center, Tehran University of Medical Sciences, Tehran, Iran (Rasouli MR, Rahimi-Movaghar V, Maheronnaghsh R, Yousefian A); Research Centre for Neural Repair, University of Tehran, Tehran, Iran (Rahimi-Movaghar V); Department of Orthopaedics and Neurosurgery, Thomas Jefferson University and the Rothman Institute, Philadelphia, PA, USA (Rasouli MR, Vaccaro AR)

Corresponding Author: Vafa Rahimi-Movaghar, MD, Associate Professor of Neurosurgery, Sina Trauma and Surgery Research Center, Sina Hospital, Hassan-Abad Square, Imam Khomeini Ave, Tehran University of Medical Sciences, Tehran, 11365-3876, Iran (Tel: (+98) 915 342 2682, (+98) 216 671 8311; Fax: (+98) 216 670 5140; Email: v_rahimi@sina.tums.ac.ir; v_rahimi@yahoo.com)

doi: 10.1007/s12519-011-0327-z

and vehicle occupants. Fatal and nonfatal trauma to the spine can occur from the craniocervical region to the lumbosacral junction. The different types of injuries result from the specific mechanism of injury and the type of disruptive forces applied, including flexion, extension, distraction, compression, lateral bending, and shear.[14] Alker et al[15] performed a radiographic examination of 312 victims of MVC with respect to cervical spine injuries. Most fractures/dislocations involved the craniocervical junction and the upper cervical area. Over half of them were flexion injuries, and one-fifth were caused by extension. Winslow et al[16] showed that there is a high rate of non-contiguous cervical spine and thoracolumbar fractures after blunt MVC, and the chance of thoracolumbar fracture is doubled in the presence of cervical spine fracture. Not surprisingly, injuries that severely narrow the spinal canal are more likely to cause complete SCI. Flexion-rotation injuries in the thoracic and lumbar spine and bilateral facet dislocations in the cervical spine are more likely to cause complete injuries.[17] Ersmark and Lowenhielm[18] suggested that a wider upper cervical spinal canal diameter, measured at the atlas, helped protect against SCI at this level.

Common types and mechanisms of MVC-related spinal column and SCI

Cervical spine fracture/dislocation

The cervical spine is considered to be the most frequently injured part of the spine following MVC in children, particularly in those younger than 8 years of age.[19] Among children with spine fractures, the incidence of cervical spine fractures is 20%-35% in the birth to 8-year-old groups, while it is 70%-80% in children over 13 years old.[20] Cervical spine injury was identified among 176 of 6065 child MVC fatalities.[13]

However, the type and distribution of spinal injuries in young children are different from those in adolescents.[21] The larger inertial mass of the head in the infant and young child shifts the axis of rotation rostrally (to the region around C2-C3), which increases the susceptibility of the upper cervical spine and craniovertebral junction to extreme flexion and extension forces.[19,22] After the age of 9 years, injuries tend to be in the middle and lower portions of the cervical spine, similar to adults.

A common mechanism of cervical spine injury in a belted passenger with a head-on collision is head flexion, with the trunk relatively restrained by the seat belt.[23] In contrast, the upper cervical spine is forced into extension relative to the lower vertebrae during rear-end collisions.[24] In side impacts, Maak et al[25] demonstrated that multiplanar injuries occur at C3-C4 through C7-T1 and result in significantly greater injury at C6-C7 compared to a rear impact with the head facing forward.

Upper cervical injuries

Upper cervical and craniovertebral junction injuries in children younger than 3 years of age are two to three times as frequent as that in children of 10-17 years old.[20] Cirak et al[6] reported that 46.2% of spinal cord injuries occurred at the levels of O-C4 .

Jefferson fracture (C1 lateral mass fracture)

Classically, a Jefferson's fracture is produced by simple and symmetric compression of the neck, which is very uncommon in children.[20]

Lower cervical fracture/dislocation

Injuries to the cervical spine (C3-C7) occur frequently from MVC and sports activities. According to Cirak et al,[6] 15.2% of SCIs occurred at the levels of C5-C7. Lower cervical and thoracic injuries occur with equal frequency in the birth to the 9-year-old groups and the 10-17 year age groups since maturation at these joints occurs much more gradually with age than at the upper cervical articulation.[20]

Thoracic spine fractures

Injury to the thoracic vertebral column or spinal cord occurred in 9.7% of 145 children who had SCI or vertebral column injuries.[6] In a study of 2416 children with vertebral fracture and/or neurological injury, regardless of gender or mechanism of injury, the thoracic spine (T2-T10) was the most common region of fracture in pediatric trauma patients.[26]

Thoracolumbar junction injuries (flexion-distraction, fracture-dislocation, and compression/burst fracture)

Injury to thoracolumbar junction represented 6.2% of spine injuries in children with vertebral column injuries.[6] MVC is one of the most common causes of thoracolumbar junction (TLJ) injury.[27,28]

Lumbar and lumbosacral spine fracture/dislocation

Lumbar injuries are primarily lesions of adolescence.[20] Injury to the lumbosacral vertebral column represented 22.8% of vertebral column injuries in children.[6] In a cohort of pediatric patients, Dogan et al[29] reviewed 89 patients with thoracic, lumbar, or sacral injuries. Their results showed that the L2-L5 region was the most frequently injured region, and MVC was the most common mechanism of trauma.

Spinal cord injury without radiological abnormality (SCIWORA)

The definition of SCIWORA has evolved with advances in imaging. One definition of SCIWORA is an injury with positive neurologic findings and negative plain X-ray and computed tomography scan but with SCI demonstrated on MRI. According to this definition, 6% of pediatric SCI patients in one series had SCIWORA.[6] SCIWORA is thought to occur mostly in children under 10 years of age.[6,30-33]

Risk factors

To prevent MVC-related injuries and fatalities, safe vehicles, safe traffic behavior, and safe roads are needed.[34-36] In single vehicle rollover MVC, the chance of SCI was nearly three times higher in non-sedans compared with sedans, and the probability of SCI was nearly five times higher for sport utility vehicles (SUVs) than for sedans.[10] According to these results, O'Connor[9] suggested that attention should focus on eliminating single vehicle crashes involving rollover of non-sedan type cars.

Different factors may affect the risk of injury following a rollover, including seat belt use, seat position with respect to the roll direction, the presence of other occupants, and the number of rolls.[37] Bahling et al[38] performed several rollover and drop tests and concluded that augmented roof strength did not reduce neck loads for belted or unbelted models. Viano et al[37] showed that the presence of another occupant may decrease the risk of serious injury to far-seated occupants, i.e., passengers seated opposite from the side of impact. Ejection from the vehicle involves significantly higher risks for severe injury in all MVC types.[39]

Seat position

Three aspects of MVC mechanisms are associated with more severe symptoms of whiplash: rear-end collision, any subsequent frontal impact, and rotated or inclined head position at the moment of collision.[40] Lap belts, fixed to the centre seats of old cars, provide some protection, but significantly less than three-point belts. Seat belt syndrome, consisting of injury to abdominal viscera and/or lumbar spine, has been mainly associated with lap belts.[41] It has been reported that severe injuries to the transverse ligament and the posterior atlanto-occipital membrane are more frequent in front-end than in rear-end MVC.[42] Seat belt use has been more effective in preventing severe injury to far-side occupants than near-side occupants in <25 mile/hour chance in velocity (Delta V) impacts.[43] In the pediatric age group, the side impacts resulted in more injuries to the head, cervical spine, and chest than frontal impacts.[44]

The Centre for Accident Research and Road Safety-Queensland (CARRS-Q), which analyzed over 30 000 Victorian crash records from 1993 to 2004, concluded that in a traffic crash, the risk of fatality for children aged 0-12 years was twice as high for children in the front seat compared to children in the back seat.[45]

In contrast to forward-facing car seat (FFCS), a rear-facing car seat (RFCS) supports the child's head, preventing the relatively large head from loading the proportionately smaller neck. Regardless of the age group, RFCS use resulted in a lower risk of injury than FFCS use for crashes of all directions.[46]

Restraint use

The rate of use of appropriate child restraints in motor vehicles varies considerably across countries from over 90% in the United States to almost zero in Oman.[8] Johnston et al[47] reported that the rate of incorrect use of restraints was substantially higher in children. It has been suggested that the elevated rate of high cervical spinal injuries in children is due to the lack of top tethering because these injuries are rarely seen in Australia where top tethers are mandatory.[48] Car manufacturers appear to give a higher priority to the effectiveness of adult restraint rather than restraint of children. Currently, seat belt anchorage points are being moved further forward to place the lap strap across adult thighs rather than the stomach. This makes it more difficult to secure child seats safely.[49]

The effectiveness of seat restraints in preventing injury is reduced when these are used incorrectly. For example, certain serious injuries, such as high cervical spine fractures in children and lumbar spinal dislocations ('seat belt syndrome') have become more common in recent years. Adult lap belt use in children has been associated with an increased rate of bowel and lumbar spine injuries.[48]

Safety seat use, specifically use of booster seat, is uncommon in children of 4-8 years. One national survey found that the rate of safety seat use was only 6.1% in this age group, with 75.3% using lap belts prematurely.[50] A study by the National Highway Traffic Safety Administration (NHTSA) found critical misuses (meaning one or more errors in seat installation or usage that could affect seat performance in a crash) in 72.6% of all child restraint systems studied.[51]

Safety issues

Safe traffic behavior

Risky driving is an important cause of MVC, but there

Review article

is a lack of good epidemiological data in this field.[36] Risky driving behaviors include "speeding, passing violations, tailgating, lane-usage violations, right-of-way violations, illegal turns, and control signal violations, among others".[52] Bina et al[53] showed that the most frequent offenses were speeding and failure to maintain a safe braking distance. Speeding is the most common cause of MVC.

It has been shown that the risk of spine injury is associated with higher speeds, being involved in a head-on crash or a rollover, and not wearing a seat belt.[53] Public education, combined with police enforcement, increases compliance with laws. Education and enforcement change the attitudes of the public due to efforts against high-risk driving behavior.[53] Health education alone has generally been an ineffective means of changing behavior and decreasing the rate of occurrence of injuries.[50]

Safe roads

Making roads safer has done more to decrease MVC fatalities and injuries than exhortations to drive carefully.[36] Identification of hazardous locations and the creation of policies to improve high-risk sites including the extension of median barriers to prevent passing in hazardous stretches, the creation of lanes for passing along rural roads, and building pedestrian passageways at crossings have helped to reduce the incidence of MVC injuries and fatalities.[35] The same recommendations will likely help to reduce the rate of MVC-related vertebral column injuries and SCI.

Navin et al[54] reported that road safety engineering can play an integral part in the prevention of whiplash injuries. Several road safety engineering countermeasures specifically targeted at rear-end collisions have been researched and deployed. These countermeasures include simple and affordable solutions such as signal visibility enhancements, as well as complex and expensive solutions such as intersection geometry upgrades.

Safe vehicle

Safety standards for the design of motor vehicles have focused on protecting the occupants from contact with hard objects or surfaces in the interior of the vehicle. Perhaps the most important improvement was the introduction of seat belts in passenger vehicles.[41]

Given the small stature of children, poor vehicle design is an important risk factor for child road traffic injury. The standard design of a vehicle can have a major effect on the risk and severity of injuries sustained by a child pedestrian, particularly if the child's head makes contact with the rigid windshield.[8]

Vehicle configuration

Based on the study of Hu et al,[55] the roof has been identified as the major source for head and neck injuries. However, changing the roof design alone has not been shown to improve rollover safety. Instead, the belt restraint systems and passive airbags need to be considered to increase rollover occupant protection.

Recent studies suggest that it may be possible to improve the kinematics of rear seat occupants in frontal MVC using a three-point belt system with a shoulder belt retractor equipped with a two-stage force-limiter and pretensioner.[56]

Seat belt, airbag and booster seat

Airbags and safety belts are viewed as complements to one another for occupant protection in MVCs.[57,58] Enhanced protection against vertebral column injury is needed for high energy MVCs with large changes in velocities (Delta V). The Delta V levels that airbag and seat belt use can protect against are higher in frontal MVCs than lateral MVCs.[59]

Seat belts

Although the effectiveness of three-point seat belts in reducing MVC injuries is well known, restraints cannot eradicate all deaths and injuries in MVCs. When all MVC types are considered, belt restraints are effective in reducing the frequency of injuries and deaths.[23] It has been shown that three-point lap and shoulder belts, child seats, and booster seats have an even greater ability to reduce morbidity and mortality than the two-point lap belt. Durbin et al[60] showed that belt-positioning booster seats eliminated injuries to the spine and abdomen, therefore age-appropriate restraint is essential. Although cervical strain or neck pain is more frequently seen in occupants using shoulder belt than those do not use,[23] it has been shown that using three-point lap-shoulder belts will reduce the severity of MVC-related SCI.[23,61] It is well documented that the frequency of severe injuries in front seat occupants is reduced by using three-point belts compared to those who do not use seat belts.[23] In summary, the use of both seat belt and airbag is associated with decreased risk of spine fracture.[62]

In one study, 81% of children with SCI were either unrestrained or inappropriately restrained, whereas only 25% of those children who died were restrained appropriately.[30]

Thoracic or lumbar spine injuries happen in lap-shoulder belted occupants in frontal-type MVC. When the body is decelerated by the lap-shoulder belt, the pelvis can rotate beneath the lap belt, flexing the lumbar spine. This "submarining" of the pelvis can cause lumbar or lower thoracic injuries.[23]

Airbag

Airbag use without the simultaneous use of a seat belt is associated with a higher incidence of cervical spine fractures with or without SCI. Airbag misuse is also associated with higher injury severity score, lower Glasgow coma scale, and longer intensive care unit and total hospital stays.[63]

It is well established that a child occupant who is unrestrained or who is too close to an airbag may actually be at an increased risk of injury. In fact, due to closed head injury, airbag deployment may contribute to pediatric occupant mortality even at very low vehicle speeds.[13]

Booster seat

Rivara et al[50] reported perceived positive aspects of booster seats. These positive aspects were that they were easily portable from one vehicle to another, allowed the child to see out of the window more easily, and helped children get in and out of the car independently.

Legislation

Legislation and enforcement have partially improved seat belt and child safety seat usage for the country as a whole, but large gaps in usage still remain.[51]

In a vulnerable population, there was no significant increase in self-reported appropriate booster seat usage, and one must be cognizant of the negative side effect of premature graduation to booster seats after the law was enacted. In addition, findings showing that poor urban children remained sub-optimally restrained despite legislation will encourage states to develop targeted educational, law enforcement, and economic programs directed at this group.[64]

Also, strict laws on drunk-driving should be introduced and enforced. Methods include setting lower blood alcohol concentration limits for young drivers, undertaking sobriety checks or selective breath testing, undertaking random breath-testing and raising the legal drinking age.[8]

Conclusion

MVC is a common cause of SCI in children; therefore paying attention to risk factors and methods of prevention is important. There are various factors that can increase the risk of MVC-related SCI in children. These factors include incorrect use of restraints in children and ineffectiveness of seat belts.

As MVC-related SCI can lead to permanent disability, prevention and education have an important role in decreasing morbidity and mortality in children. Making behavior, roads, and vehicles safer can significantly reduce MVC-related SCI in children.

Vehicle designers and regulators need to give more attention to the prevention of vehicle rollover and to improve occupant protection in the event of rollover. It is recommended to evaluate more precisely the role of different seat positions, types of seat belts, airbags, vehicle design including roof structure, and other new innovations to help prevent MVC-related vertebral column injury.

Finally, we believe that legislation can play an important role in the adoption of the above factors.

Funding: This study was supported by Sina Hospital Trauma and Surgery Research Center.

Ethical approval: Not needed.

Competing interest: None.

Contributors: Rahimi-Movaghar V, Rasouli MR and Vaccaro AR contributed to design of study. Rahimi-Movaghar V, Rasouli MR, Maheronnaghsh R and Yousefian A contributed in data gathering and writing the draft of the manuscript. Rahimi-Movaghar V and Vaccaro AR contributed to the manuscript editing. All authors read and approved the final version of the manuscript.

References

1 Rahimi-Movaghar V. Efficacy of surgical decompression in the setting of complete thoracic spinal cord injury. J Spinal Cord Med 2005;28:415-420.

2 Rahimi-Movaghar V, Saadat S, Vaccaro AR, Ghodsi SM, Samadian M, Sheykhmozaffari A, et al. The efficacy of surgical decompression before 24 hours versus 24 to 72 hours in patients with spinal cord injury from T1 to L1—with specific consideration on ethics: a randomized controlled trial. Trials 2009;10:77-84.

3 Rahimi-Movaghar V, Yazdi A, Karimi M, Mohammadi M, Firouzi M, Zanjani LO, et al. Effect of decompression on complete spinal cord injury in rats. Int J Neurosci 2008;118:1359-1373.

4 Saadat S, Javadi M, Divshali BS, Tavakoli AH, Ghodsi SM, Montazeri A, et al. Health-related quality of life among individuals with long-standing spinal cord injury: a comparative study of veterans and non-veterans. BMC Public Health 2010;10:6.

5 Taghipoor KD, Arejan RH, Rasouli MR, Saadat S, Moghadam M, Vaccaro AR, et al. Factors associated with pressure ulcers in patients with complete or sensory-only preserved spinal cord injury: is there any difference between traumatic and nontraumatic causes? J Neurosurg Spine 2009;11:438-444.

6 Cirak B, Ziegfeld S, Knight VM, Chang D, Avellino AM, Paidas CN. Spinal injuries in children. J Pediatr Surg 2004;39:607-612.

7 Leucht P, Fischer K, Muhr G, Mueller EJ. Epidemiology of traumatic spine fractures. Injury 2009;40:166-172.

8 Peden M, Oyegbite K, Ozanne-Smith J, Hyder AA, Branche C, Rahman AF, et al. World report on child injury prevention. Peden M, eds. Geneva: World Health Organization, 2008.
9 O'Connor P. Injury to the spinal cord in motor vehicle traffic crashes. Accid Anal Prev 2002;34:477-485.
10 O'Connor PJ, Brown D. Relative risk of spinal cord injury in road crashes involving seriously injured occupants of light passenger vehicles. Accid Anal Prev 2006;38:1081-1086.
11 Fife D, Kraus J. Anatomic location of spinal cord injury. Relationship to the cause of injury. Spine 1986;11:2-5.
12 Thurman DJ, Burnett CL, Beaudoin DE, Jeppson L, Sniezek JE. Risk factors and mechanisms of occurrence in motor vehicle-related spinal cord injuries: Utah. Accid Anal Prev 1995;27:411-415.
13 Stawicki SP, Holmes JH, Kallan MJ, Nance ML. Fatal child cervical spine injuries in motor vehicle collisions: analysis using unique linked national datasets. Injury 2009;40:864-867.
14 Shkrum MJ, Green RN, Nowak ES. Upper cervical trauma in motor vehicle collisions. J Forensic Sci 1989;34:381-390.
15 Alker GJ Jr, Oh YS, Leslie EV. High cervical spine and craniocervical junction injuries in fatal traffic accidents: a radiological study. Orthop Clin North Am 1978;9:1003-1010.
16 Winslow JE 3rd, Hensberry R, Bozeman WP, Hill KD, Miller PR. Risk of thoracolumbar fractures doubled in victims of motor vehicle collisions with cervical spine fractures. J Trauma 2006;61:686-687.
17 Waters RL, Sie I, Adkins RH, Yakura JS. Injury pattern effect on motor recovery after traumatic spinal cord injury. Arch Phys Med Rehabil 1995;76:440-443.
18 Ersmark H, Lowenhielm P. Factors influencing the outcome of cervical spine injuries. J Trauma 1988;28:407-410.
19 Osenbach RK, Menezes AH. Pediatric spinal cord and vertebral column injury. Neurosurgery 1992;30:385-390.
20 Muzumdar D, Ventureyra EC. Spinal cord injuries in children. J Pediatr Neurosci 2006;1:43-48.
21 Cattell HS, Filtzer DL. Pseudosubluxation and other normal variations in the cervical spine in children. A study of one hundred and sixty children. J Bone Joint Surg Am 1965;47:1295-1309.
22 Papavasiliou V. Traumatic subluxation of the cervical spine during childhood. Orthop Clin North Am 1978;9:945-954.
23 Huelke DF, Mackay GM, Morris A. Vertebral column injuries and lap-shoulder belts. J Trauma 1995;38:547-556.
24 Kaneoka K, Ono K, Inami S, Hayashi K. Motion analysis of cervical vertebrae during whiplash loading. Spine 1999;24:763-769.
25 Maak TG, Ivancic PC, Tominaga Y, Panjabi MM. Side impact causes multiplanar cervical spine injuries. J Trauma 2007;63:1296-1307.
26 Reddy SP, Junewick JJ, Backstrom JW. Distribution of spinal fractures in children: does age, mechanism of injury, or gender play a significant role? Pediatr Radiol 2003;33:776-781.
27 Inamasu J, Guiot BH. Thoracolumbar junction injuries after motor vehicle collision: are there differences in restrained and nonrestrained front seat occupants? J Neurosurg Spine 2007;7:311-314.
28 Inamasu J, Guiot BH. Thoracolumbar junction injuries after rollover crashes: difference between belted and unbelted front seat occupants. Eur Spine J 2009;18:1464-1468.
29 Dogan S, Safavi-Abbasi S, Theodore N, Chang SW, Horn EM, Mariwalla NR, et al. Thoracolumbar and sacral spinal injuries in children and adolescents: a review of 89 cases. J Neurosurg 2007;106:426-433.
30 Brown RL, Brunn MA, Garcia VF. Cervical spine injuries in children: a review of 103 patients treated consecutively at a level 1 pediatric trauma center. J Pediatr Surg 2001;36:1107-1114.
31 Buldini B, Amigoni A, Faggin R, Laverda AM. Spinal cord injury without radiographic abnormalities. Eur J Pediatr 2006;165:108-111.
32 Ferguson J, Beattie TF. Occult spinal cord injury in traumatized children. Injury 1993;24:83-84.
33 Betz RR, Mulcahey MJ, D'Andrea LP, Clements DH. Acute evaluation and management of pediatric spinal cord injury. J Spinal Cord Med 2004;27:S11-S15.
34 Rahimi-Movaghar V, Zarei MR, Saadat S, Rasouli MR, Nouri M. Road traffic crashes in Iran from 1997 to 2007. Int J Inj Contr Saf Promot 2009;16:179-181.
35 Rasouli MR, Nouri M, Zarei MR, Saadat S, Rahimi-Movaghar V. Comparison of road traffic fatalities and injuries in Iran with other countries. Chin J Traumatol 2008;11:131-134.
36 Shams M, Rahimi-Movaghar V. Risky driving behaviors in Tehran, Iran. Traffic Inj Prev 2009;10:91-94.
37 Viano DC, Parenteau CS, Edwards ML. Rollover injury: effects of near- and far-seating position, belt use, and number of quarter rolls. Traffic Inj Prev 2007;8:382-392.
38 Bahling GS, Bundorf RT, Moffatt EA, Orlowski KF. The influence of increased roof strength on belted and unbelted dummies in rollover and drop tests. J Trauma 1995;38:557-563.
39 Viano DC, Parenteau CS. Ejection and severe injury risks by crash type and belt use with a focus on rear impacts. Traffic Inj Prev 2010;11:79-86.
40 Sturzenegger M, DiStefano G, Radanov BP, Schnidrig A. Presenting symptoms and signs after whiplash injury: the influence of accident mechanisms. Neurology 1994;44:688-693.
41 Himmetoglu S, Acar M, Bouazza-Marouf K, Taylor AJ. Energy-absorbing car seat designs for reducing whiplash. Traffic Inj Prev 2008;9:583-591.
42 Kaale BR, Krakenes J, Albrektsen G, Wester K. Head position and impact direction in whiplash injuries: associations with MRI-verified lesions of ligaments and membranes in the upper cervical spine. J Neurotrauma 2005;22:1294-1302.
43 Viano DC, Parenteau CS. Severe injury to near- and far-seated occupants in side impacts by crash severity and belt use. Traffic Inj Prev 2010;11:69-78.
44 Orzechowski KM, Edgerton EA, Bulas DI, McLaughlin PM, Eichelberger MR. Patterns of injury to restrained children in side impact motor vehicle crashes: the side impact syndrome. J Trauma 2003;54:1094-1101.
45 Lennon A, Siskind V, Haworth N. Rear seat safer: seating position, restraint use and injuries in children in traffic crashes in Victoria, Australia. Accid Anal Prev 2008;40:829-834.
46 Henary B, Sherwood CP, Crandall JR, Kent RW, Vaca FE, Arbogast KB, et al. Car safety seats for children: rear facing for best protection. Inj Prev 2007;13:398-402.
47 Johnston C, Rivara FP, Soderberg R. Children in car crashes: analysis of data for injury and use of restraints. Pediatrics 1994;93:960-965.
48 Campbell H, Macdonald S, Richardson P. High levels of incorrect use of car seat belts and child restraints in Fife—an important and under-recognised road safety issue. Inj Prev 1997;3:17-22.
49 Bull MJ, Stroup KB, Gerhart S. Misuse of car safety belts. Pediatrics 1988;81:98-101.
50 Rivara FP, Bennett E, Crispin B. Booster seats for child

passengers: lessons for increasing their use. Inj Prev 2001;7:210-213.
51 Martin M, Holden J, Chen Z. Child passenger safety for inner-city Latinos: new approaches from the community. Inj Prev 2006;12:99-104.
52 Karlsson G, Halldin J, Leifman A, Bergman H, Romelsjö A. Hospitalization and mortality succeeding drunk driving and risky driving. Alcohol Alcohol 2003;38:281-286.
53 Bina M, Graziano F, Bonino S. Risky driving and lifestyles in adolescence. Accid Anal Prev 2006;38:472-481.
54 Navin F, Zein S, Felipe E. Road safety engineering: an effective tool in the fight against whiplash injuries. Accid Anal Prev 2000;32:271-275.
55 Hu J, Lee JB, Yang KH, King AI. Injury patterns and sources of non-ejected occupants in trip-over crashes: a survey of NASS-CDS database from 1997 to 2002. Annu Proc Assoc Adv Automot Med 2005;49:119-132.
56 Forman J, Lopez-Valdes F, Lessley D, Kindig M, Kent R, Ridella S, et al. Rear seat occupant safety: an investigation of a progressive force-limiting, pretensioning 3-point belt system using adult PMHS in frontal sled tests. Stapp Car Crash J 2009;53:49-74.
57 Viano DC. Restraint effectiveness, availability and use in fatal crashes: implications to injury control. J Trauma 1995;38:538-546.
58 Zaglia E, De Leo D, Lanzara G, Urbani U, Dolci M. Occipital condyle fracture: an unusual airbag injury. J Forensic Leg Med 2007;14:231-234.
59 Smith JA, Siegel JH, Siddiqi SQ. Spine and spinal cord injury in motor vehicle crashes: a function of change in velocity and energy dissipation on impact with respect to the direction of crash. J Trauma 2005;59:117-131.
60 Durbin DR, Elliott MR, Winston FK. Belt-positioning booster seats and reduction in risk of injury among children in vehicle crashes. JAMA 2003;289:2835-2840.
61 Burke DC. Spinal cord injuries and seat belts. Med J Aust 1973;2:801-806.
62 Wang MC, Pintar F, Yoganandan N, Maiman DJ. The continued burden of spine fractures after motor vehicle crashes. J Neurosurg Spine 2009;10:86-92.
63 Donaldson WF 3rd, Hanks SE, Nassr A, Vogt MT, Lee JY. Cervical spine injuries associated with the incorrect use of airbags in motor vehicle collisions. Spine 2008;33:631-634.
64 Brixey S, Ravindran K, Guse CE. Legislating child restraint usage—its effect on self-reported child restraint use rates in a central city. J Safety Res 2010;41:47-52.

Received November 10, 2010
Accepted after revision June 14, 2011

Review article

Correction

In the article entitled *Dying with parents: an extreme form of child abuse* by Kam Lun Hon (World J Pediatr 2011;7(3):266-268): the order of sex lane from the bottom of the table should have been F, F, M, F, M, F, M……