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Pediatric cervical spine fracture case report: Best practice to delay transition to rear-facing restraint

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ABSTRACT

Pediatric physicians and motor vehicle safety experts have been advocating for change in child passenger restraint practices for decades. As professional recommendations evolve to support extended rear-facing restraint, actual practices remain disparate. We report a case of pediatric cervical spine fracture due to motor vehicle collision, an uncommon, yet predictable, pattern of injury for which prevention education is undoubtedly preferable to managing the consequences of premature forward-facing in vulnerable pediatric patients. Currently, 9 kg is a minimum legal standard for forward-facing child restraint system use in Ontario, rather than a recommended transition time. We advise that parents should be counselled on the benefits of rear-facing as long as possible and discuss realistic transition times using their child restraint system manual as a reference, with the goal of approaching, but not exceeding, the maximum weight, height and fit requirements for optimal safety.

Case

The index case is a 31-month-old, 15 kg, 91 cm, and previously healthy girl who was involved in a motor vehicle collision (MVC). She was a rear seat passenger in a forward-facing restraint system that supported rear-facing restraint up to 18 kg and 74 cm. Her vehicle was involved in a T-bone collision at highway speeds with another stationary vehicle. Due to the nature of the impact, she was placed in a cervical collar on site. She did not experience loss of consciousness, but on admission was notably lethargic. Physical examination revealed a large frontal scalp laceration and abrasions congruent with seatbelt injuries but overall, no neurological deficits or weakness. Computed tomography of the cervical spine showed a fracture of the body of C2 through the growth plate with subluxation of the dens onto the body of the C2 vertebra (Fig. 1).

Treatment of the odontoid fracture was by closed reduction and application of a pediatric halo-vest device intraoperatively, under general anesthesia (Fig. 2). Following her procedure, she remained stable and was able to mobilize, and was discharged from the hospital. One month post-operatively, because she recovered well and there was no radiographic evidence of residual translation or subluxation to the cervical spine, her halo device was removed. She was placed in a cervical collar following the procedure and remained in stable condition.

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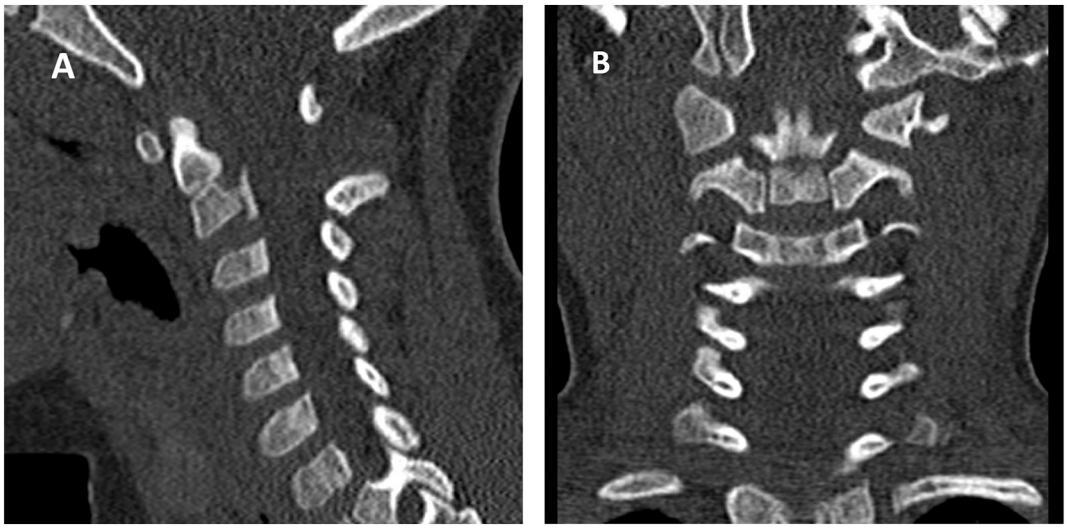

Fig. 1. Computed tomography images of the cervical spine. (A) Sagittal view showing the fracture extending through the neurocentral synchondrosis of C2 with subluxation of the dens onto the C2 body as well as the C2 body and dens fragments separating from the lateral masses. (B) Coronal view showing the C2 body and dens fragments displacing superiorly through the neurocentral synchondroses.

Fig. 2. Index case following closed reduction of the odontoid fracture and application of a pediatric halo-vest device.

Discussion

Unintentional injuries are the leading cause of death for Canadian children aged one to four. This age bracket benefits from the protective effect of infant and convertible child restraint systems (CRS), which reduce the risks of death and serious injury substantially [1]. Pediatric physician organizations have long understood that rear- and forward-facing CRS (RFCRS and FFCRS) reduce the risk of severe injury in MVCs, and have developed strong policy statements advocating for their proper use [1]. Provincial legislation varies however; Ontario requires a RFCRS from birth to 9 kg. Beyond this, parents may select an orientation that aligns with the limitations of the specific CRS available, but it is now accepted that extended rear-facing (until the RF maximums are met) is best practice.

Pediatric cervical spine injuries are rare, however these injuries are most frequently sustained in MVCs [2]. The predilection for high cervical injuries is related to young children's comparatively large head:body mass ratio, increased spinal ligament laxity and incomplete ossification of vertebral bones [2,3]. The majority of pediatric cervical spine fractures are to the dens of C2, and most dens

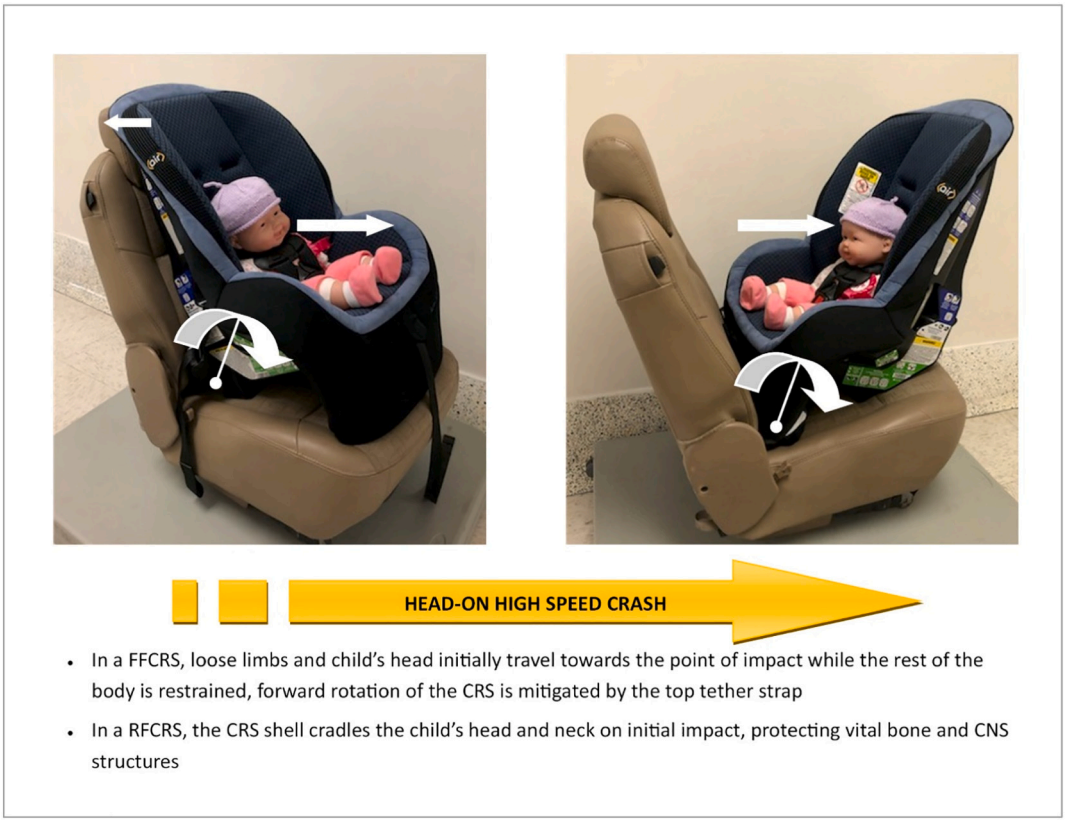

Fig. 3. Basic schematic of head-on crash mechanics pertaining to convertible CRS for forward-facing and rear-facing systems.

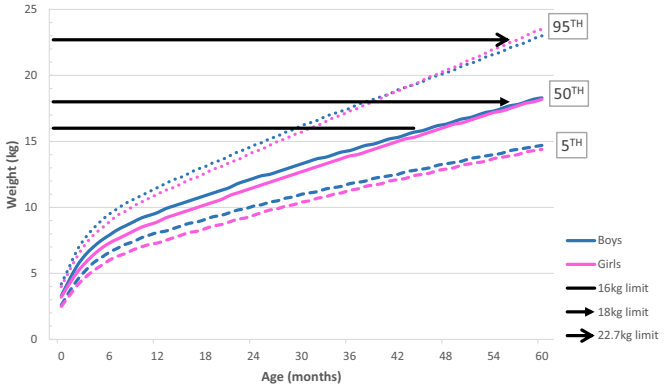

Fig. 4. Weight versus age for 5th, 50th and 95th percentile boys and girls ages 0–5, WHO (2020) Growth Data; black lines indicate RFCRS weight maximums for standard available restraints.

fractures occur at the base of the process (type II) [3,4]. Although fractures compose a small proportion of vertebral injuries in young children, late fusion of the dens with the body of C2, between 3 and 7 years of age, may predispose it to synchondrosis fractures with high-force, flexion injury mechanisms [2,3]. Biomechanical analysis suggests that head-on decelerations by more than 40 km/h (Fig. 3) produce enough force (~600 N) to horizontally shear the odontoid process from the C2 body in a forward-facing child [3]. The crash in the index case was of sufficient velocity to cause this injury.

Literature suggests that the injury sustained by the index case was probably preventable, by instead using a RFCRS [3,5]. When a child is correctly restrained in an appropriate RFCRS, the shell of the restraint cradles the head and neck during abrupt decelerations (Fig. 3), preventing excessive cervical spine flexion and the consequent shearing forces. Epidemiological evidence shows a trend towards a significant injury risk reduction ($p = 0.052$) for RFCRS over FFCRS in children under 2 years of age, however analysis is complicated by exceptionally low event rates overall [6]. McMurry et al. reported only 3 spinal injuries and 47 AIS 2+ injuries (at least

moderate in severity) to any body region, in a data set that included 1107 children involved in car crashes who met inclusion criteria [6].

MVCs are a common mechanism to be reported in association with this specific injury [3–5], and pediatric cervical spine injuries in general [2]. Historically the appropriate time to transition children from RFCRS to FFCRS has been debated. Old recommendations focused on early reorientation to a forward facing position at approximately 1 year, or at 9–10 kg [7,8]. Current Ontario law states that children can legally be restrained in a FFCRS when they weigh more than 9 kg [7]. Caregivers and even physicians may understandably interpret this 9 kg requirement as a safety recommendation, and Canadian survey data suggests that most parents begin to restrain their children in a forward-facing orientation between the ages of 7 months and 2 years [8,9]. Snowdon et al. describes observations of 9772 children riding in motor vehicles and estimates that 72–81% of children aged 1–3 were riding in FFCRS [9]. These observations contrast best practice recommendations that highlight the importance of extended rear-facing [8]. However, there is a need for updated and more comprehensive data on the subject. The American Academy of Pediatrics policy statement recommends that children remain rear facing until the child outgrows the maximum specifications for rear-facing seating, or as long as possible [1]. Furthermore, experts have seemingly been calling for parents to consider extended (beyond 1–2 years of age) rear-facing for decades [3–5]. This disparity between the legal minimums for forward-facing restraint in Canada and our best practice motor vehicle safety recommendations is an important opportunity for educational intervention [1,8,9].

When compared with individual child restraint limits, World Health Organization (WHO) weight-for-age growth charts illustrate the dissonance in Canadian child passenger safety practices [10]. Biometric limits vary by make and model, including height and fit. Nearly all convertible RFCRS can safely restrain 50th percentile males and females up to 3.5 years of age (Fig. 4). Many commonly available convertible seats will rear-face up to ~18 kg, therefore 50th percentile males and females can typically be safely restrained up to 4.5 years of age (Fig. 4), provided they do not surpass a height or fit requirement. The index case was correctly restrained facing forward based on the CRS parameters, however best practice would have been to explore options to extend rear-facing for as long as possible, as many RFCRS sold in Canada support children taller than 100 cm. In fact, some of the most robust RFCRS available (22.7 kg rear-facing limit) can safely restrain 95th percentile children up to 4.5 years of age (Fig. 4).

Many case reports and studies highlight the intolerance of the pediatric cervical spine to large decelerating forces experienced in frontal crashes at high speed [3–5] and biomechanical analysis supports the notion that forward orientations (Fig. 3) expose the developing neck to excessive force in these events [3]. Experts now advocate for extended rear-facing restraint [1], though this may not be reflected in practice [7–9]. It is our recommendation that parents and caregivers should be counselled on the efficacy of rear-facing for their children with the aim to approach, but not exceed, maximum CRS requirements to optimize safety. Parents and caregivers should be advised to refer to their manual to understand limitations of their CRS and to explore options to extend rear-facing for as long as possible, including considering a CRS with higher biometric parameters. Ideally, older children should ride in booster seats until they are at least 145 cm tall, 8 years old, or 36 kg, and they have outgrown their booster seat.

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Declaration of competing interest

The authors declare no conflicts of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tcr.2021.100500.

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