Flexion-distraction Injuries in Children and Adolescents

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educational objectives

As a result of reading this article, physicians should be able to:

1. Understand the spectrum of injuries associated with pediatric flexion-distraction injuries.
2. Distinguish the different patterns of pediatric flexion-distraction injuries.
3. Understand the treatment options and recommendations for pediatric flexion-distraction injuries.
4. Review the associations between restraints and flexion-distraction injuries in children.

ABSTRACT

Flexion-distraction injuries represent an uncommon pattern of injury in the pediatric population. Although this is a well-studied topic in adults, the literature on such injuries in children and adolescents is relatively sparse, with only low levels of evidence available to guide treatment. These injuries carry a high rate of concomitant injuries and a high morbidity and mortality in this population. Proper understanding of these complex injuries is important to ensure proper management and avoid complications.

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Flexion-distraction injuries of the spine in children and adolescents are relatively uncommon injuries, representing only 4% of pediatric spine fractures. These are high-energy injuries that occur during high-speed motor vehicle collisions, typically in children wearing only 2-point restraints. Flexion-distraction injuries are often a component of the seatbelt syndrome, which represents the association between spine trauma, intra-abdominal injuries, and abdominal wall ecchymosis. Although these injuries have been well studied in the adult population, relatively little is published on these injuries in the pediatric population. The available literature can often be challenging to interpret because many studies include flexion-distraction injuries only as a part of a more heterogeneous group of all seatbelt-associated spinal injuries. The purpose of this study was to evaluate and summarize the current literature on flexion-distraction injuries in the pediatric population.

Materials and Methods

The authors performed a systematic review of the current literature using PubMed, Ovid, Cochrane, and Google Scholar. The search terms used included chance, flexion-distraction, seatbelt syndrome, lapbelt injuries, and pediatric spine trauma. Only studies published in the peer-reviewed English-language literature between 1990 and 2010 were included. Patients younger than 18 years were considered pediatric. Chance fracture variants such as reverse Chance fractures or lateral distraction injuries were not included in the analysis. Published abstracts without available manuscripts were not included. The reference lists of relevant studies and the content lists of relevant spine and trauma journals were also searched to ensure that all relevant articles were included. Available studies were evaluated for the following measures: demographic data, mechanism of injury, type of restraints used, level of injury, associated injuries, associated neurologic deficits, treatment, and outcomes.

Results

Study Characteristics

A total 25 retrospective studies, case series, or case reports were identified, representing 131 patients with flexion-distraction injuries. No prospective studies were identified in the literature. Of these studies, 1 had a sample size greater than 20 patients, four had between 10 and 20 patients, five had between 4 and 9 patients, and 15 were case series or case reports with 3 or fewer patients.

Demographic Data. Patient age was available for 115 patients in these studies and ranged from 2 to 17 years. None of the studies identified a predilection among different age groups. Sex was specified in 115 patients (48 boys and 67 girls). No clear sex predilection was found in any study.

Mechanism of Injury. Twenty-four studies provided information on the mechanism of injury. Injuries were almost exclusively a result of motor vehicle collisions, which was identified as the mechanism of injury in 122 of 124 patients. The remaining 2 injuries were caused by motorcycle crashes. No data were available for 7 patients.

Restraints. Of those injured in motor vehicle collisions, information on the use of restraints was available for 121 patients. Eighty-three (69%) patients were restrained with 2-point restraints. Flexion-distraction injuries were less commonly seen in children wearing 3-point restraints (n=12; 10%) and those who were unrestrained (n=2; 2%). The remaining 33 patients were documented as restrained without specification of the type of restraint.

Location of Injury. Injury levels ranged from T12 to L5. The majority of injuries were located between L1 and L3 (95 of 116 levels), with the L2 and L3 vertebral body being most frequently described site of injury.

Injury Pattern

One study used an existing classification system to characterize the patients’ in-
Juries,\textsuperscript{11} and 2 studies created a classification based on their patient series.\textsuperscript{4,8} In their series of 6 children, Greenwald and Mann\textsuperscript{11} classified flexion-distraction injuries using Gumley classification.\textsuperscript{28} Purely ligamentous injuries were the most common and were seen in 3 of 6 patients. Of the injuries with a bony component, 1 entered through the lamina (type II) and 2 entered through the spinous process (type I).\textsuperscript{28}

Rumball and Jarvis\textsuperscript{4} identified 4 distinct injury patterns based on plain radiographs in their series of 10 patients. Type A represented a posterior bony injury extending into the middle column; type B represented a posterior avulsion with injury extending into the facets joints or vertebral apophysis; type C represented a posterior ligamentous injury associated with a fracture adjacent to the pars interarticularis extending through the middle column; and type D represented a posterior ligamentous injury associated with a bony injury through the lamina and into the adjacent vertebral body apophysis. In their series, type B injuries were the most common patterns (5/10) and type D the least common (1/10) (Figure 1).\textsuperscript{4}

A separate classification was created by deGauzy et al\textsuperscript{8} based on magnetic resonance imaging in their series of 18 patients. They classified injury patterns according to their relationship with the pedicle. Type I injuries represented an injury above the level of the pedicle with injury to the superior growth plate; type II injuries extended from the spinous process through the lamina, pedicle, and vertebral body; and type III injuries extended below the pedicle and injuring the inferior growth plate.\textsuperscript{8} In their series, type I injuries were the most common (8/18), followed by type II (6/18) and type III (4/18) (Figure 2).\textsuperscript{8}

Figures 3A and B show an example of a typical flexion-distraction injury sustained in a 13-year-old adolescent. Lateral imaging demonstrates a deGauzy type II or Rumball type A injury. Figure 3C shows the postoperative radiograph after reduction and short-segment fixation.

**Concomitant Injuries**

Flexion-distraction injuries were frequently associated with multiple concomitant injuries, including those to the abdominal viscera, thoracic cavity, vascular structures, brain, and musculoskeletal system. Rumball and Jarvis\textsuperscript{4} found an average Injury Severity Score of 16 at presentation (range, 10-26). Patients with flexion-distraction injuries and associated abdominal injuries have prolonged hospitalizations, with an average hospital stay of 31 days (range, 9-103 days).\textsuperscript{18}

Because of the retrospective nature of these studies, injuries in patients who died were not identified. As a result, mortality data could not be determined.

**Abdominal.** The majority of concomitant injuries were within the abdominal cavity, most often involving the hollow viscera. Such injuries ranged from lacerations and hematomas to complete transections at any level of the gastrointestinal tract. Associated solid organ injuries included the spleen, liver, common bile duct, kidneys, ureter, and pancreas. Although abdominal injuries were common in children with flexion-distraction injuries, they occurred at the same rate in children with other thoracolumbar spine fractures. The severity of abdominal pathology is highlighted by a laparotomy rate between 40% and 100% in patients with flexion-distraction injuries and associated abdominal injuries.\textsuperscript{4,10} Late development of enterocolic\textsuperscript{4} and duodenal\textsuperscript{9} fistulae have also been described.

Of note, Rumball and Jarvis\textsuperscript{4} found a delay in diagnosis of abdominal injuries of more than 24 hours in 2 of 10 patients. In addition, Mulpuri et al\textsuperscript{10} demonstrated that concomitant abdominal injuries were less common in patients wearing 3-point restraints compared with those wearing lapbelts only, with rates of 62% and 92%, respectively.

**Vascular.** Numerous studies reported associated injuries to the major abdominal vessels in children with flexion-distraction injuries of the spine.\textsuperscript{7,10,15,16,24,25} Injuries to the aorta ranged from intimal flaps to aortic dissection, as well as rupture of the abdominal aorta.\textsuperscript{7,10,16,25} Additional injuries included complete obstruction of the iliac arteries and avulsion of the ileal and sigmoid mesenteric arteries.\textsuperscript{7,24} Sequelae of these vascular injuries include lower-extremity ischemia and severe hemorrhages requiring transfusion, laparotomy, and vascular repair.\textsuperscript{10,16}
Neurologic Injuries. Rates of neurologic injury varied widely across the literature, with some reporting a 0% rate of neurologic injury \(^8,9,13-17,19,21,25-27\) and others reporting paraplegia rates as high as 30%.\(^4\) The largest series available reported spinal cord injury resulting in paraplegia in 2 (7.7%) of 28 patients and nerve root injuries in 4 (14.3%) patients.\(^7\)

Treatment
The treatment for these injuries varied across the literature, which corresponds with the change in available instrumentation during the study period. The majority of patients were treated with extension casting. Patients managed surgically were treated with instrumented posterior spinal fusions using a variety of implants, including pedicle screws, Harrington rods,\(^11,12\) Cotrel-DeBousset instrumentation,\(^20\) lamina plates and cables,\(^14\) spinous process wiring,\(^11,15\) sublaminar wires,\(^11\) and sublaminar fixation using polyethylene tape.\(^26\)

Only 1 study attempted to provide guidelines for injury treatment.\(^9\) In this series of 12 patients, 4 of 7 patients initially treated with bracing required surgical intervention due to progressive kyphosis. All 4 patients had initial kyphosis greater than 20°. Because of this study, this degree of initial deformity was proposed to be an indication for surgical fixation.\(^9\) No further studies have validated this recommendation, nor have any subsequent studies attempted to provide further treatment recommendations. In addition, no treatment recommendations exist for guidance of surgical level selection.

Outcomes
Few studies have documented long-term outcomes, and none were identified that used objective outcome measures. Greenwald and Mann\(^11\) documented good to excellent results in 5 patients without associated spinal cord injury who were treated surgically. All returned to preinjury activity levels, with 4 of 5 involved in competitive sport at final follow-up.\(^11\) In the series by Glassman et al,\(^9\) ten of 12 patients were pain free, with the remaining 2 reporting occasional pain after a minimum follow-up of 6 months.

Discussion
Flexion-distraction injuries of the thoracolumbar spine are uncommon injuries in the pediatric population, with incidence rates ranging from 2.31% to 7.3% of pediatric thoracolumbar injuries.\(^5,7,10-12,16\) Although these injuries are relatively infrequent, it has been suggested that children are at an increased risk of sustaining flexion-distraction spinal injuries compared with adults.\(^29\) Because of an increased head-to-body ratio, children have a higher center of gravity than do adults. This results in a larger moment arm acting on the spinal column and increased force distribution to the spine at the time of injury.

Children are also often improperly restrained, which puts them at additional risk. Flexion-distraction injuries were classically associated with the use of 2-point restraints, and the majority of cases in the literature occurred in children wearing those restraint types. Because of their smaller stature, the shoulder straps of adult seatbelts are often situated over children’s necks. Therefore, children often place the shoulder strap of the seatbelt behind their backs, converting the 3-point restraint to a 2-point restraint in the process. A recent study found that 68% of children aged 4 to 8 years are improperly restrained in motor vehicles.\(^30\)

An additional factor that places children at an increased risk of flexion-distraction injuries is the position of the lapbelt. Because of children’s anatomy, the lapbelt often lies over the abdomen rather than over the hips and pelvis. This raises the fulcrum of injury to the level of the lumbar spine, increasing the risk of vertebral and abdominal injury.\(^12\) The use of belt positioning devices, such as booster seats, allows for proper lapbelt and shoulder strap positioning and may play a significant role in the prevention of flexion-distraction injuries. Currently, no cases of flexion-distraction injuries have been documented in children who were using a booster seat. Although improper seatbelt use is an important factor in many flexion-distraction injuries, even when properly used, standard seatbelts provide less protection to children compared with adults, and flexion-distraction injuries may still occur even with proper use.\(^5,7,10-12,16\)

Flexion-distraction injuries are also commonly associated with additional injuries. In the current review, the authors identified injuries to the abdominal viscera as the most common associated injuries. Concomitant abdominal trauma can
occur from multiple mechanisms, including direct trauma from the lapbelt, deceleration injury, and injury from increased intra-abdominal pressure from acute hyperflexion.

Such injuries have been noted to be more common in children due to multiple factors. First, as mentioned previously, positioning the lapbelt over the abdomen puts the intra-abdominal organs at risk for injury. Children also have a less robust abdominal wall to provide protection from injury. The current authors identified a large number of patients in the literature with avulsion or complete rupture of the abdominal musculature caused by the lapbelt.

These injuries also carry a significant association with other severe injuries remote to the abdominal viscera. Head injuries, thoracic trauma, and abdominal aortic injuries were all found in association with pediatric flexion-distraction spinal injuries. The authors identified multiple reports of injuries to the abdominal vasculature, including transection, dissection, and complete occlusion. Although less common, these injuries have serious potential sequelae, which mandates clinical vigilance in patients who present with flexion-distraction injuries.

Among the studies available in the literature, a wide variety of operative and nonoperative treatments were used for the management of pediatric flexion-distraction spinal injuries. Within the cohorts of those treated operatively, a variety of instrumentation techniques were used to obtain fracture reduction and spinal fusion. This is representative of the advances in spinal instrumentation over the study period. Insufficient evidence was identified to guide treatment of these injuries. Results of treatment were generally favorable at long-term follow-up with a variety of treatment methods. No prospective studies were identified in the literature comparing treatment options, and a search of clinicaltrials.gov failed to identify any ongoing trials.

REFERENCES