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Pediatric seatbelt injuries: diagnosis and treatment of lumbar flexion-distraction injuries

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Motor vehicle accidents are the major cause of flexion-distraction injuries of the thoracolumbar spine. In a retrospective review, we present the results of operative treatment for six pediatric patients who sustained such injuries while wearing seatbelts. There were three purely ligamentous injuries, two bony injuries (Chance fractures), and one combination injury. There were also concomitant neurological and intra-abdominal injuries. Of note is that two patients had either their spinal or abdominal injury missed on initial evaluation. All patients were treated surgically with open reduction and internal fixation. At average follow up of 2 years, all patients had a full range of motion with no back pain. Five had returned to their preinjury activity levels, while the sixth patient was paraplegic from his injury but was able to ambulate at home with crutches and knee–ankle–foot orthoses. We recommend operative reduction and two-level fusion of these injuries when (1) instability is apparent in either a purely ligamentous injury or an overtly unstable fracture-pattern, (2) significant kyphosis is present which cannot be reduced or maintained in a cast, or (3) there is associated neurological or intra-abdominal injury.

Keywords: pediatric seatbelt injuries; lumbar flexion-distraction injuries; thoracolumbar spine.

Introduction

Although morbidity and mortality from motor vehicle accidents (MVAs) have been reduced because of increased seatbelt use,[1–8] MVAs are the major cause of over 75% of flexion-distraction injuries of the thoracolumbar spine.[9,10] These seatbelt injuries are a result of hyperflexion of the spine about a fixed point anterior to the vertebral body axis.[11–22]

To date, however, no reports have detailed the clinical outcome of pediatric patients who underwent operative treatment for these injuries. We present six cases in which such flexion-distraction injuries of the lumbar spine were treated by surgery, and make recommendations regarding evaluation and treatment.

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Materials and methods

We reviewed the medical records and radiographs of children who had sustained spinal trauma and were treated at the University of Wisconsin Hospital over a 5-year period (1985–90), and identified six children who underwent operative treatment for flexion-distraction injuries of the lumbar spine sustained while wearing seatbelts during MVAs.

Patients and their parents were interviewed to record vehicles involved and type of accident, patient's position in the car and type of seatbelt worn. Type of injury and degree of kyphosis were determined from preoperative radiographs and computed tomography (CT). Other injuries, in particular concomitant intra-abdominal trauma, were noted. Method of reduction, instrumentation used, and type of fusion performed were obtained from the operative reports. Quality of fusion and degree of

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lordosis were determined from post-operative radiographs, including flexion-extension lateral views.

Patient follow up included a complete orthopedic history and physical examination. A neurological examination was also conducted when appropriate.

Results

Patients

There were four male and two female patients. Average age at time of injury was 8 years and 1 month. All were involved in a high speed (> 50 MPH) MVA in which the vehicle struck another vehicle head-on (three), broadside (two), or struck a utility pole (one). Four patients were restrained in the back seat by a lap belt only. Two patients were seated in the front passenger seat wearing a three-point restraint. One, however, was wearing the restraint with the shoulder strap tucked behind his torso, thereby effectively acting as a lap belt only. Pertinent clinical information is summarized in Table I.

Orthopedic injuries

Three patients had purely ligamentous injuries which were considered unstable (Figs 1a, b). Two patients had bony injuries (Chance fracture) (Figs 2a, b). One patient had a two-level injury with a bony Chance fracture at one level and a purely ligamentous injury at the level below. The level of injury was L1–2 in one patient, L2–3 in two patients, and L3–4 in two patients. The two-level injury involved levels L2–3 and L3–4. All patients had CTs of the spine and only one showed a facet fracture. There were no burst injuries of the vertebral body. Preoperative kyphosis ranged from 5° to 28°, with an average of 18°.

Neurological injuries

Two patients had associated neurological injuries. The patient with the two-level injury sustained a severe injury to his cauda equina with resultant paraplegia at L3 level. At the time of surgery, severance of multiple nerve roots was found at the site of the L3–4 bilateral facet dislocation and the

Table I Clinical summary of patients sustaining flexion-distraction injuries

Case	Sex	Age (yr. + mo.)	Type of injury[a]	Level of injury	Neurologic injury	Abdominal injury
1	F	6 + 10	Ligamentous	L2–3	None	None
2	M	11 + 9	Type II Chance fracture	L2–3	L2 nerve root injury	Jejunal rupture
3	F	14 + 10	Type I Chance fracture	L3–4	None	None
4	M	3 + 10	Type II Chance fracture Ligamentous	L2–3 L3–4	L3 paraplegia	Traumatic jejunal stricture[b]
5	M	5 + 7	Ligamentous	L1–2	None	Complete ileal transection with serosal tears of colon
6	M	5 + 11	Ligamentous	L3–4	None	None

[a]Classification of bony injury according to Gumley.
[b]Diagnosed 7 days after accident.

Table II Abdominal and orthopedic management

Case	Abdominal management	Tme until surgery	Orthopedic management	Bone graft[a]	Kyphosis[c]
1	Negative abdominal CT	2 days	2 sublaminar wires at L2–3	Local	20 °K/9 °L/8 °L
2	Jejunal resection	26 days[b]	1 Harrington compression rod at L2–3 with nerve root decompression	Left ICBG	20 °K/4 °L/2 °L
3	Negative physical examination	3 days	Bilateral Harrington compression rods at L3–4	Left ICBG	18 °K/10 °L/6 °L
4	Jejunostomy	1 day	Interspinous processes suturing L2–S1	None	19 °K/3 °L/3 °L
5	Ileal resection and transverse colon resection	9 days	Halifax clamps with spinous process wiring at L1–2	Allo	28 °K/4 °L/4 °L
6	Negative abdominal CT	3 days	1 sublaminar wire at L3–4	Local	5 °K/4 °L/3 °L

[a]Bonegraft
Local—using spinous processes
ICBG—autologous iliac crest
Allo—banked cancellous graft.
[b]Spinal injury initially not diagnosed.
[c]Preoperative/postoperative/follow up
K = Kyphosis
L = Lordosis.

Table III Follow up results

Case	Clinical results[a]	Total follow up (months)
1	Excellent	21
2	Excellent	12
3	Excellent	63
4	NA[b]	12
5	Excellent	16
6	Excellent	32

[a]Excellent = no pain, full range of movement (ROM), and full activity.
[b]Patient with paraplegia resulting from MVA.

patient had complete loss of sensation and motor function below this level. The second patient presented with right anterior thigh pain and numbness, and 4+/5+ hip flexor weakness secondary to L2 nerve root injury. The remaining patients had normal neurological examinations. No patient sustained a major head injury.

Abdominal injuries (Table II)
All of the patients had abdominal bruising and abrasions consistent with a 'seatbelt sign' (Fig 3), and five complained of abdominal pain upon admission. Three of these patients had major intra-abdominal injuries, requiring exploratory laparotomy with some form of bowel resection and re-anastamosis.

One patient's original abdominal CT was interpreted as negative and, as a result, his abdominal injury was not diagnosed until 7 days after his original trauma. Another patient, who was initially treated at another hospital for his abdominal injury, did not have his spinal injury diagnosed until 3 weeks after his accident.

Orthopedic management (Table II)
All patients were treated surgically with open reduction and internal fixation. Five underwent surgery within an average of 3 days of their injury. The sixth patient, whose spinal injury was initially missed, had surgery 26 days after his accident. There were no major operative complications.

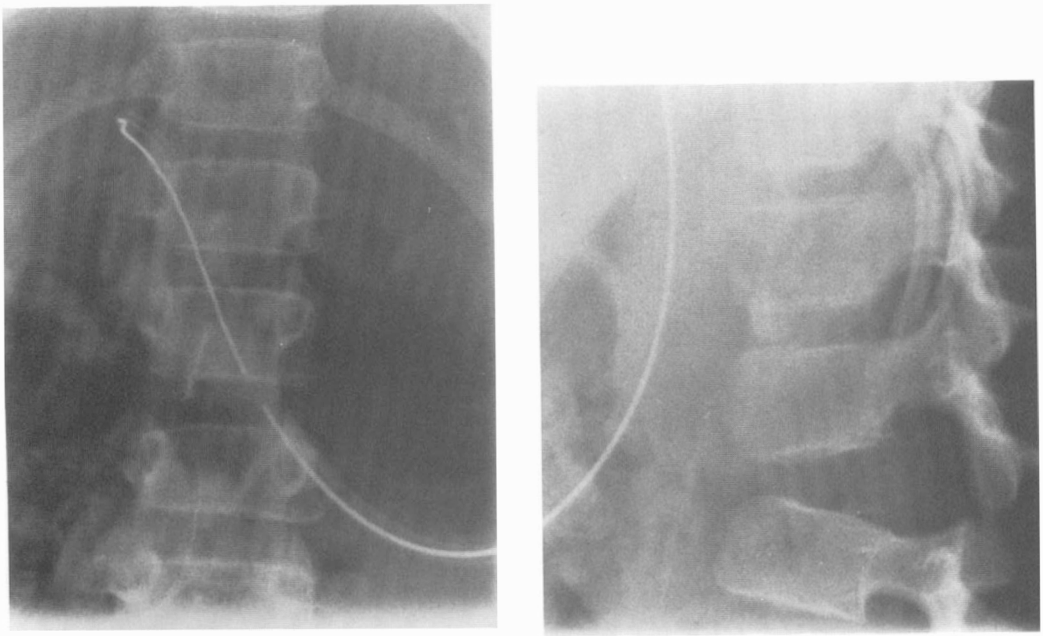
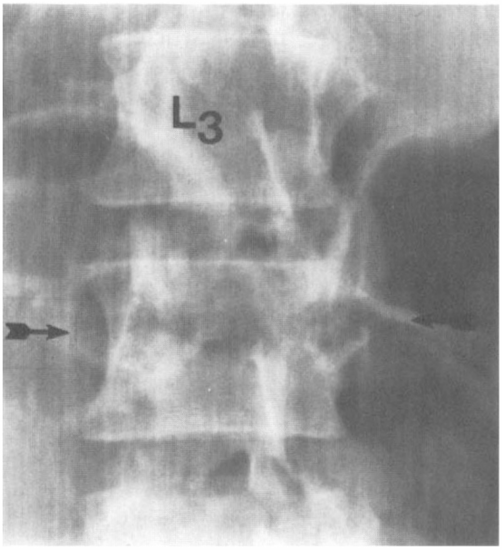


Figure 1 Ligamentous seatbelt injury in case 1. AP radiograph (a) reveals no apparent bony injury, with obvious widening between L2 and L3. Lateral view (b) demonstrates L2–3 flexion-distraction injury without apparent bony injury. Kyphosis was 20°.

a



b

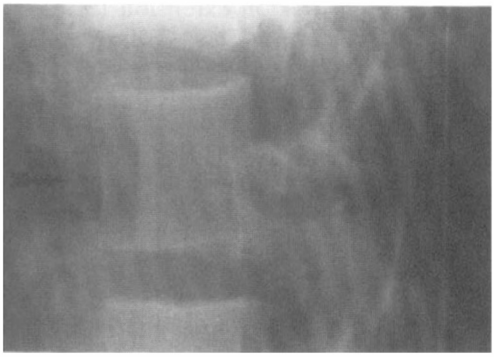


Figure 2 Seatbelt injury in case 3. AP radiograph (a) indicates fracture (arrows) through L4. Lateral view (b) (arrow) shows type I Chance fracture.

Figure 3 'Seatbelt sign'—abdominal bruising and abrasions at level where lap belt restrained passenger.

Two-level posterior spinal fusion with two-level instrumentation was performed in five patients. Sublaminar wires were used in two patients, Harrington compression rods in two, and Halifax clamps in one patient. Local bone graft was used in two patients, iliac crest bone graft in two, and allograft cancellous bone graft in one patient.

Decompression was performed at surgery on the patient with L2 nerve root injury. Stabilization for the patient with the two-level injury was accomplished by inter-spinous process fixation from L2 to S1 with heavy non-absorbable suture. Spinal fusion with bone graft was not performed in consideration of his young age (less than 4 years old) and the multiple levels involved.

Excluding the paraplegic patient, the average postoperative hospital stay was 6 days. All wore a TLSO for 10–12 weeks postoperatively. The paraplegic patient wore a thoraco-lumbar-sacral orthosis (TLSO) with his knee-ankle-foot othoses (KAFOs) attached for 3 months.

Operative outcome (Table III)

On follow-up radiographs, the five posterior spinal fusions appeared solid with intact hardware, and flexion/extension lateral radiographs showed no signs of instability. Flexion/extension radiographs at 1-year follow up on the paraplegic patient revealed maintenance of reduction and no demonstrable instability.

Kyphotic deformity was corrected an average of 22°, resulting in restoration of lumbar lordosis to an average of 4°. Lordosis remained an average of 3° at final follow up (an average of 2 years postoperatively).

At the time of final follow up, all patients, with the obvious exception of the paraplegic patient, had excellent outcomes. All had a functional range of motion of the spine with regard to flexion/extension and lateral bending and twisting. All spines were nontender and no patient complained of back pain. Five were able to function at their preinjury level. Four were able to participate in competitive athletics after their injuries.

At the 12-months follow up, there was no improvement in the neurological status of the paraplegic patient as he continued to have motor and sensory loss at the L3–4 level. However, he had no back pain and was able to ambulate in his house with crutches and KAFOs, using a swing-through gait.

The patient treated for the L2 nerve root injury had no demonstrable motor deficit 1 year after surgery and had recovered full strength of his hip flexors. He continued to have mildly decreased sensation in his right mid-anterior thigh (L2 paresthesia) but described it as only a mild nuisance.

Discussion

Pathomechanism of Chance fracture

Howland *et al*[23] reported on a patient injured while wearing a lap belt, who sustained what they called a 'Chance fracture'. They explained the mechanism of injury as similar to breaking a stick across one's knee, as the lap belt acted as a fixed point around which the patient's spine hyperflexed. Smith & Kaufer further elucidated the principle pathomechanism of these injuries as a distraction of the posterior spinal elements during hyperflexion around a lap belt.[24]

Previous pediatric series

While there are many articles regarding seatbelt injuries, relatively few specifically address the issue of these injuries and pediatric patients. Those that deal with pediatric seatbelt injuries consist mainly of case reports[25–28] or small series with incomplete detailing of orthopedic treatment and follow up.[29,30]

Associated intra-abdominal injuries

The association of intra-abdominal injuries with flexion-distraction spinal injuries was first recognized by Garrett & Braunstein[31] when they described the 'seatbelt syndrome'. Up to 80% of patients with flexion-distraction injuries of the spine caused by seatbelts have been found to have concomitant major intra-abdominal injuries. Hollow viscus injuries are the most common, especially when passengers wear lap belts and are seated in the rear seat.[32]

Argan reported that the majority of abdominal injuries from lap belt use occurred in children between the ages of 4 and 9.[9] This is thought to be due to differences in pediatric anatomy, including an increased head-to-body ratio with a more cephalad center of gravity causing increased torque about the axis of rotation.

In addition, the relatively underdeveloped pelvis makes for an improper fit of the lap belt, which could allow the child to 'submarine' under the lap belt.[3,29] Rather than the deceleration force of the upper body being dissipated by rotation about the hip joint, the lap belt rides above the iliac crests and over the abdomen, concentrating most of the force at the level of the upper lumbar spine with intra-abdominal injuries involving a similar level.[10,29,33]

Missing concomitant injuries

Of note is that in two of our patients with concomitant intra-abdominal and spinal injuries, one of the injuries was initially missed. This is not an uncommon occurrence. Previous reports have described both delay in the diagnosis of abdominal pathology in patients with known spinal injuries, as well as failure to initially recognize spinal injuries in patients with known abdominal trauma.[34,35]

Treatment choices for flexion-distraction injuries

Treatment of flexion-distraction injuries of the lumbar spine depends most notably on the perceived stability of the injury. Many regard the Chance fracture as stable in extension and have, therefore, treated these injuries non-operatively (usually with casting in extension).[24–26,30,33,35–37]

Gumley *et al*[33] treated 13 out of 20 patients with bony injuries with bed rest and extension casting for 6–8 weeks. Ten patients had good results, whereas two had residual kyphosis of 5° and one had asymptomatic non-union of the posterior elements. Seven patients were considered to have unstable injuries (including those with significant neurological damage) and were treated with open reduction and posterior spinal fusion. A variety of methods was used and these patients generally did well, especially those that had Harrington compression instrumentation.

LeGay *et al*[35] recommended surgical treatment for ligamentous injuries which did not involve bone, especially when facet joints were disrupted and subluxated. Poor prognosticators for non-operative treatment were facet joint fracture involvement and initial kyphosis greater than 17°.

Yu & Siu[37] reported on 26 patients with injuries of the lumbar spine while wearing a seatbelt. Of the 22 patients with bony injuries, 16 patients were treated non-operatively with postural reduction and hyperextension casting. At follow up, six patients had significant angulation (three greater than 20° and three greater than 30°). The authors believed that even though most of the patients with significant angulation were asymptomatic, the loss of normal lumbar lordosis was undesirable as it could lead to significant mechanical low back pain in the future, and recommended open reduction and internal fixation if reduction could not be obtained with postural reduction or maintained with hyperextension casting.

The incidence of neurological injury reported in large series is 11%–44%.[24,29–31,33,35,37–40] Approximately half are minor injuries (usually nerve root lesions) and half are major injuries (usually paraplegia). As in our series, patients with minor neurological injuries usually improved. There has been no documented improvement of major neurological injuries after surgical treatment.

Conclusions

Although there have been some favorable results from non-operative treatment of flexion-distraction injuries,[25,26,30,33,37] we prefer operative treatment for most of these injuries. We advocate short segment compression rodding, utilizing a pediatric-size rod and hook construct. We would now avoid sublaminar wires.

When injury is limited mainly to the bony elements, there may be less need for surgical intervention. However, we agree with Gertzbein & Court-Brown[38,39] that operative treatment avoids the morbidity associated with prolonged bed rest and body casting, and helps to mobilize the patient at an earlier stage. This is especially beneficial for patients requiring surgery for intra-abdominal injuries.

We recommend operative treatment of seatbelt injuries when (1) instability is apparent, with either a purely ligamentous injury or an overtly unstable fracture-pattern, (2) significant kyphosis is present and adequate reduction cannot be obtained or maintained in a cast (as this loss of normal lumbar lordosis could lead to mechanical low back pain in the future), (3) there is an abdominal injury requiring surgery, and the patient may benefit from early mobilization and is not a suitable candidate for cast wear, or (4) there is a neurological injury (as often some recovery in function may be obtained and rehabilitation is facilitated).

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