ORIGINAL ARTICLE

Results of fusion and instrumentation of thoracic and lumbar vertebral fractures in children: a prospective ten-year study

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Abstract

Background   Researches on the results of surgical treatment of thoracolumbar spine fractures are infrequent. The aim of this study was to determine midterm outcomes of surgical treatment of these fractures in a prospective survey.

Methods   A case series study on pediatric patients with the diagnosis of thoracic and/or lumbar vertebral fractures was conducted over a ten-year period. Surgically treated patients were evaluated in the follow-up period, based on back pain, independent function, neurological status, and radiographic indices.

Results   There were 102 pediatric individuals, 61 boys and 41 girls, aged 3–17 years (mean 12 years of age) with thoracic and/or lumbar spinal fractures. Motor vehicle accident was the most common mechanism of injury (45.0 %). L1 was the most frequent level of fractured vertebra (24.4 %), and pelvic fracture was the most common associated orthopedic injury (21.5 %). Totally, 20 patients underwent surgery, but only fifteen (14 boys and one girl) participated in follow-up (mean 49 months; range 12–81 months). Posterior spinal fusion and instrumentation was accomplished in 12 cases. Three patients were operated by anterior approach and fusion followed by posterior fusion and instrumentation because of delay in diagnosis.

There were no major perioperative complications. Two cauda equina syndromes and two incomplete spinal cord injuries improved back to normal. Five cases (33.3 %) reported occasional back pain, and all patients were functionally independent. Radiographic indices improved significantly.

Conclusions   Spinal fusion and instrumentation in pediatric patients with unstable thoracolumbar vertebral fractures with or without spinal cord injuries have favorable radiographic and functional outcomes.

Keywords   Spine · Children · Vertebra · Fracture

Introduction

Vertebral fractures in children are relatively uncommon and represent 1–3.6 % of all pediatric skeletal injuries [24, 33]. Most of these injuries in children with less than 8 years of age involve cervical spine, while the thoracic and lumbar areas are affected most often in older children and adolescents [1, 9, 16, 28]. Spinal injury in children is a separate entity from adult fractures due to the differences in anatomical and biomechanical features, such as ligamentous laxity, incomplete ossification, the head size relative to the body, and intrinsic elasticity of the spine [24]. These injuries have a substantial potential for recovery in pediatric population [9]. Among all orthopedic injuries in children, the mortality rate is highest in patients with thoracolumbar fractures [19], largely because of high rate of associated brain, thoracic, and abdominal injuries [2, 8, 24] and the usual delay in diagnosis that is reported in up to 50 % of cases [30].

Despite many articles on the frequency and pattern of pediatric vertebral fractures in the literature, limited

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Table 1 Dennis pain scale

P1	No pain
P2	Occasional minimal pain; no need of medication
P3	Moderate pain; occasionally medication, no interruption of work or activities of daily living
P4	Moderate to severe pain; occasionally absent from work, significant changes in activities of daily living
P5	Constant, severe pain; chronic pain medication

Table 2 Modified Frankel classification of neurologic assessment

	Definition
A	Complete; complete motor and sensory loss
B	Incomplete; sensory but not motor function is preserved below the neurological level and extends through the sacral segment S4–S5
C	Incomplete; motor function is preserved below the neurological level, and the majority of key muscles below the neurological level have a muscle grade less than 3
D1	Preserved motor at midfunctional grade (power 3) and/or bowel or bladder paralysis
D2	Preserved motor at high functional grade (power 4–5) and/or neurologic bowel or bladder dysfunction
D3	Preserved motor at high functional grade (power 4–5) and normal voluntary bowel and bladder function
E	Normal; motor and sensory functions are normal

investigations have focused on surgical results of these injuries. We carried out a prospective study during 10 years with emphasis on midterm outcomes of surgical treatment of thoracolumbar spine fractures in children.

Materials and methods

All patients with thoracolumbar spine fracture aged 17 years and younger who referred to senior authors between April 1999 and April 2009 were included in this study. Complete demographic features of patients, such as age, sex, time of injury, and mechanism of injury, were obtained. Plain anteroposterior and lateral radiographs and CT scan of the spine were taken. Magnetic resonance imaging (MRI) was obtained in patients who were treated by surgery. We evaluated the level and configuration of spinal injury, pattern and frequency of neurological compromise, associated injuries, and radiographic indices, including Denis classification of spinal fractures, kyphosis angle, collapse percentage, and canal compromise of all patients.

Of the 102 patients with thoracolumbar fractures, twenty underwent surgery. Indications for surgery included unstable three-column fractures, fracture dislocations, fractures with more than 20° kyphosis, canal compromise of more than 50 %, or neurological injuries. All patients were operated through posterior approach with posterior instrumentation to reduce the fracture with ligamentotaxis [22] except three cases with a delay in diagnosis that were operated through anterior approach followed by posterior instrumentation and fusion. Operation time, blood loss, perioperative complications, and construct configuration were recorded for these patients. Patients used thoracolumbosacral full-time orthosis for about three months after surgery.

Postoperatively, the patients had follow-up visits at 2, 12 weeks, 6, 12 months, and then annually. The collected data included back pain, level of function, neurologic status, sphincter control, and radiographic features. The pain was recorded using Dennis pain scale shown in Table 1 [10]. Level of function was evaluated using the 7-level functional independence measure (FIM) score designed to

Table 3 Mechanism of injury in different age-groups

Mechanism of injury	0–9 years of age	10–17 years of age	0–17 years of age
Motor vehicle accident	1 (1.0 %)	45 (44.1 %)	46 (45.0 %)
Fall from height	4 (3.9 %)	41 (40.2 %)	45 (44.1 %)
Assault trauma	0 (0 %)	6 (5.9 %)	6 (5.9 %)
Bicycle accident	1 (1.0 %)	2 (2.0 %)	3 (3.0 %)
Others	0 (0 %)	2 (2.0 %)	2 (2.0 %)
Total	6 (5.9 %)	96 (94.1 %)	102 (100 %)

evaluate the level of assistance required by a person with the disability to perform basic life activities, with 1 indicating dependence and 7 indicating independence [13]. Neurological deficits and sphincter control were assessed according to the Frankel grade modified by Bradford and McBride as shown in Table 2 [4]. Sphincter evaluations were based on assessments such as voluntary voiding, rectal contraction, any catheterization to drain the bladder, and digital stimulation to trigger a bowel movement.

Results

Patients with thoracic and lumbar spinal injuries

Totally, there were 102 individuals, 61 boys and 41 girls, aged 3–17 years (mean age 12 years) with thoracic and/or lumbar vertebral fractures during the defined period of 10 years. The most common mechanism of injury was motor vehicle accident followed by fall from a height, assault trauma, bicycle accidents, and others including a patient crashed by collapsing wall and a case crashed after entrapment between tractor shank and its wheel (Table 3).

Table 4 Frequency of level of injured vertebra

Vertebra	L1	L2	L3	T12	L4	T7	T10	T5	T6	T11	L5	T8	T9	T4
Number	31	19	18	16	10	5	5	4	4	4	4	3	3	1

Table 5 Associated fractured bone in 28 patients with thoracic or lumbar spine

Associated fractured bone	Number
Pelvis	6
Ankle	4
Calcaneus	4
Distal radius	3
Humerus	2
Midfoot and forefoot	2
Mandible	1
Radius and ulna	1
Femur	1
Patella	1
AC joint dislocation	1

Among 127 fractures in 102 patients, L1 vertebra was the most common fractured level (Table 4). Most patients had only single fractured vertebra (83; 81.5 %). Among 19 cases with multilevel spinal injuries, eighteen had contiguous and one had noncontiguous spinal fracture pattern.

Twenty-eight cases (27.5 %) had associated injuries. Pelvic fracture was the most common associated fractured bone (21.5 %) followed by ankle and calcaneus (Table 5). Two cases had intra-abdominal hemorrhage due to spleen rupture and liver laceration.

Patients with thoracic and lumbar spinal surgeries:

A cohort of 15 (14 boys and one girl—mean age 14 years; range 10–17 years) cases out of 20 accepted to participate in the follow-up examinations (mean 49 months; range 12–81 months) (Table 6). Motor vehicle accident (reported in 10 cases) was the most common mechanism of injury.

Follow-up results

Mean values of radiographic indices of patients undergoing surgery are shown in Table 7. There was a 26.7 % incidence of neurological deficit (4 cases) in these patients. One was a 16-year-old boy with burst fracture of L3 and 80 % canal compromise leading to cauda equina syndrome. He had no sensation, motor function, and sphincter control below the injury level (Frankel grade A). Bladder function recovered 6 weeks after operation. Sensory and motor functions partially improved after 8 months. Another patient was a 12-year-old boy with severe paraplegia without sensory loss following T6–T7 burst fracture with 60 % canal compromise. He recovered 4 months after surgery with normal muscle power. Two other patients were graded as Frankel D1 and Frankel D2. Normal function returned after about 2 and 4 weeks, respectively.

Of 15 cases underwent surgery, ten patients (66.6 %) had no back pain in the follow-up visits as evaluated by Dennis pain scale. Three cases had occasional minimal back pain without any analgesic use (P2). Two patients with moderate back pain (P3) used analgesic occasionally. It was notable that all cases (100 %) were totally independent according to FIM score.

There was no perioperative complication except a wound infection treated by intravenous antibiotics. Also, there were no late complications such as pseudoarthrosis or broken device.

Three patients with delayed diagnosis should be reported separately as follows:

Case 1

A 15-year-old boy was referred with low back pain about 2 months after bicycle–car accident. On examination, kyphotic deformity was obvious without any neurologic deficit. Spinal injury had been missed on initial evaluation (Fig. 1a). Severe flexion–distraction injury of T10–T11 was obvious on X-rays (Fig. 1b, c) and MRI (Fig. 1d) taken on arrival to our hospital. The patient was treated by anterior spinal release and fusion followed by posterior spinal fusion and instrumentation. Solid fusion without any complication was seen about 3 years after surgery (Fig. 1e, f).

Case 2

A 12-year-old boy, entrapped between tractor wheel and its shank, referred 6 months after injury with nonsurgically treated pelvic fracture and palpable deformity at thoracolumbar junction. Neurological examination was normal. Radiographs showed flexion–distraction injury of T11–T12 (Fig. 2a, b). Surgery was planned in two stages due to rigidity of the deformity. T12 partial corpectomy, T11–T12, T12–L1, L1–L2 discectomy, and rib strut grafting were performed through anterior approach (Fig. 2c) followed by posterior spinal fusion and instrumentation 1 week later. After 5-year follow-up, the patient had normal neurological examination and solid spinal fusion without any complication (Fig. 2d, e).

Table 6 Demographic features and operation data of patients underwent surgery due to thoracic or lumbar spine fractures

Age	Gender	Mechanism of injury	Associated injury	Level of fracture	Dennis type	Indication for surgery	Time between injury and surgery	Operation duration (h)	Blood loss during surgery	Type of surgery
15	M	Bicycle–car accident	–	T_{10}–T_{11}	Flexion–distraction	Old flexion–distraction	2 months	4, 7:15	1,200^{cc}, 1,250^{cc}	ASF + PSF
12	M	Crashing by tractor	Pelvic Fx	T_{11}–T_{12}	Flexion–distraction	Old flexion–distraction	6 months	5, 8	1,100^{cc}, 900^{cc}	ASF + PSF
10	M	MVA	Femur Fx	T_{12}–L_1	Flexion–distraction	Old flexion–distraction	2 months	3, 5	750^{cc}, 400^{cc}	ASF + PSF
16	F	MVA	–	L_1	Flexion–distraction	Flexion–distraction	3 days	4	650^{cc}	PSF
16	M	Falling down	–	L_3	Burst	Cauda equina syndrome	4 days	2:30	450^{cc}	PSF
12	M	MVA	Distal radius Fx	T_6–T_7	Burst	Canal compromise: 60 %	3 days	4	700^{cc}	PSF
11	M	MVA	Spleen rupture, forearm Fx	T_6–T_7–T_8	Burst	Unstable Fx, kyphosis: 40°	20 days	8	300^{cc}	PSF
17	M	Falling down	–	T_7–T_8–T_9	Burst	Unstable Fx, kyphosis: 26°	10 days	4	700^{cc}	PSF
15	M	MVA	–	L_1–L_2	Burst	Canal compromise: 50 %	6 days	5	400^{cc}	PSF
14	M	MVA	Malleolus Fx	L_2–L_3	Burst	Unstable Fx	2 days	2	750^{cc}	PSF
16	M	MVA	Liver laceration	T_{12}	Burst	Canal compromise: 50 %	3 weeks	5	500^{cc}	PSF
15	M	Falling down	–	L_3	Burst	Kyphosis: 35°	9 days	3:15	300^{cc}	PSF
16	M	MVA	–	L_4	Burst	Canal compromise: 50 %	5 days	2:30	500^{cc}	PSF
17	M	MVA	–	L_4	Burst	Cauda equina syndrome	3 days	3:15	300^{cc}	PSF
15	M	MVA	–	L_4	Burst	Vertebral collapse: 50 %	4 days	2:45	300^{cc}	PSF

M male; *F* female; *MVA* motor vehicle accident; *Fx* fracture; *ASF* anterior spinal fusion; *PSF* posterior spinal fusion and instrumentation
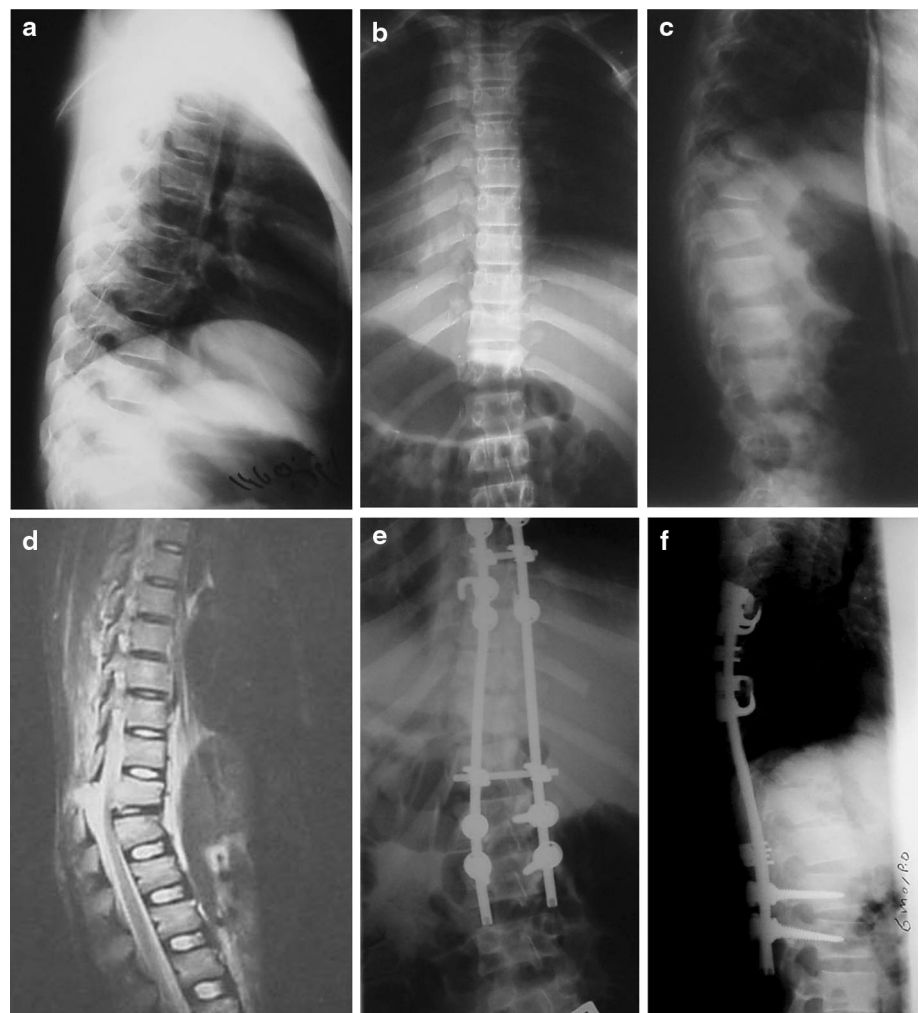
Table 7 Mean of radiographic indicates of cases underwent surgery

	Kyphosis angle (°)	Collapse percentage (%)
Pre-op	26.5	50.5
Post-op	11.0	41.0
Final follow-up	12.5	45.5

Case 3

A 10-year-old boy referred 2 months after car pedestrian accident with low back pain. He also had associated femoral shaft fracture. On arrival, his neurological examination was normal. X-rays (Fig. 3a, b) revealed T12–L1 flexion–distraction injury. Anterior release, discectomy, and grafting were performed followed by posterior spinal fusion and instrumentation 1 week later. Follow-up radiographs (Fig. 3c, d) showed acceptable alignment and solid fusion 2 years after operation.

Discussion

Not only pediatric thoracolumbar spinal injuries are generally considered to be rare, but also they may be missed or diagnosis may be delayed. Thoracic and lumbar spine injuries become more common with age in children [3, 9, 23]. Likewise, about 96 % of cases in the current study had an age of more than 10 years. Motor vehicle accident was the leading cause of thoracolumbar spine fractures (45.0 %). It is similar to other studies [21, 25, 29]; however, some researchers have reported sports-related injuries [18] or falls from a height [20, 34] as the most frequent mechanism of injury.

Thoracolumbar junction is the most common injured site in pediatric population [12]. The most common fractured vertebra in our series was L1 (31 cases) with more than 50 % of fractures occurred between T12 and L2. We found that fractures of lumbar spine were more common than thoracic spine (82 vs. 45). Similar finding was reported by

Fig. 1 A missed case of T10–T11 flexion–distraction spinal injury. Initial radiograph (**a**). X-rays (**b**, **c**) and MRI (**d**) after 2 months showed flexion–distraction injury through the disk. Standing radiographs 3 years after surgery (**e**, **f**)

Fig. 2 Flexion–distraction of T11–T12 6 months after injury in a 12-year-old boy. First X-rays (**a**, **b**). Radiograph after anterior surgery (**c**). Result of posterior fusion and instrumentation 5 years after surgery (**d**, **e**)
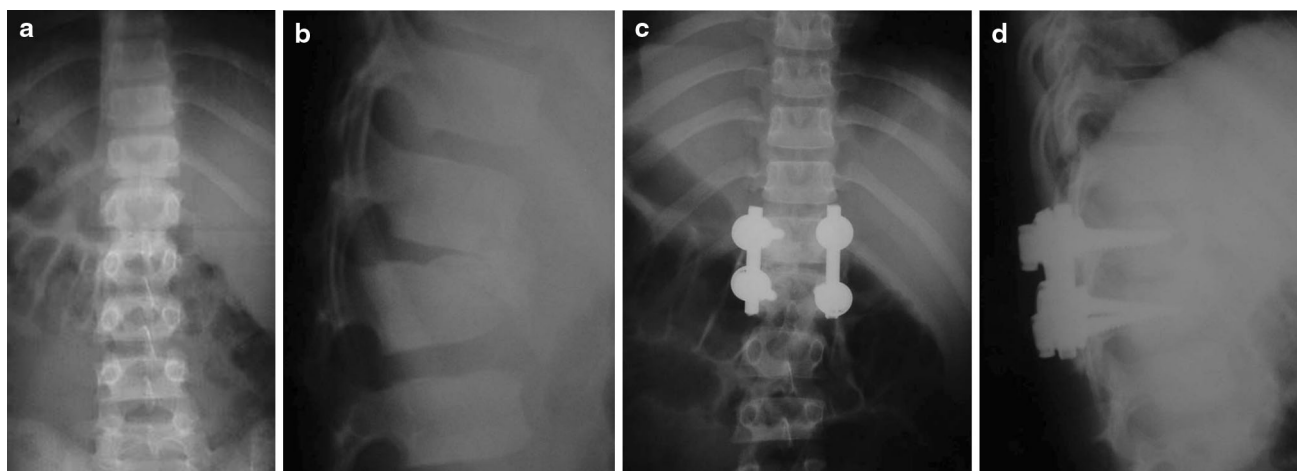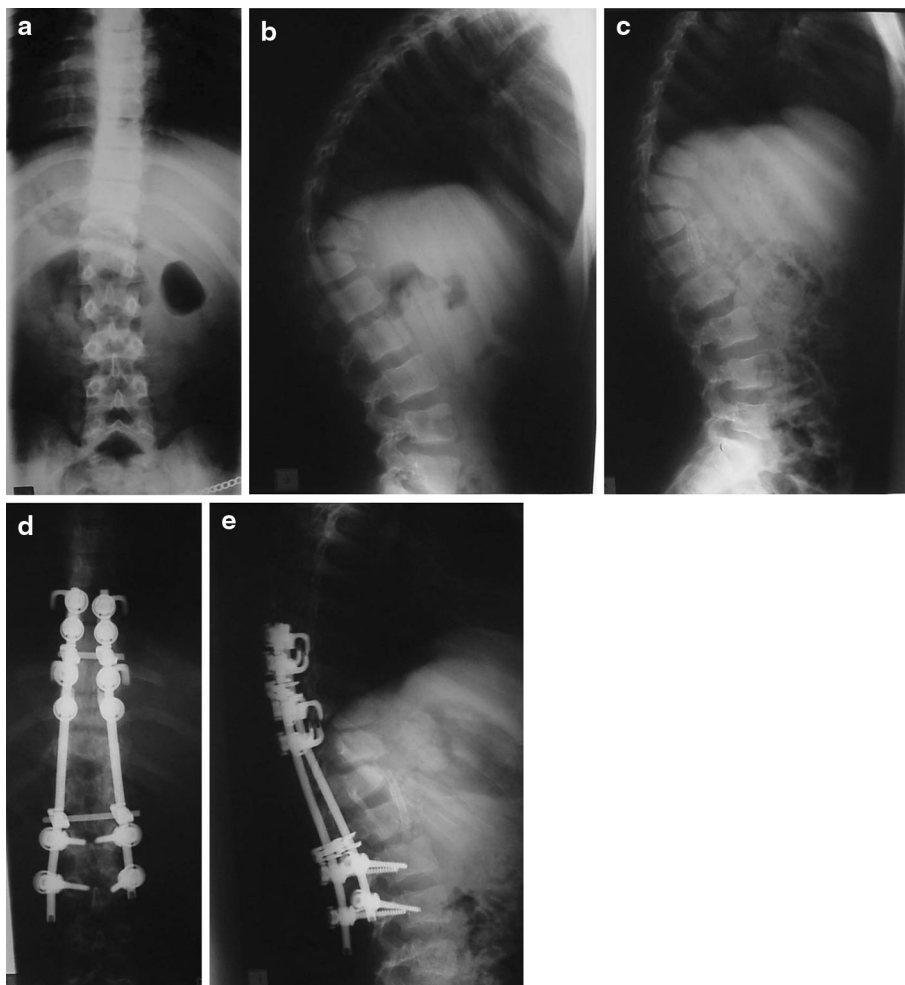

Fig. 3 Anteroposterior (**a**) and lateral (**b**) radiographs of a 10-year-old boy show T12–L1 flexion–distraction injury. Standing radiographs 2 years after surgery (**c**, **d**)

other authors such as Rumball and Jarvis [30], Turgut et al. [34], Cirak et al. [8], and Dogan et al. [9]. Nonetheless, some authors reported the opposite. Reddy et al. [29] described the thoracic region (T2–T10) as the most commonly injured area, accounting for 28.7 % of fractures, followed by the lumbar region (L2–L5). According to the

study of Parente et al. [25], T4–T8 (38.5 %) and T11–L2 (31.5 %) are the most frequent sites. Moreover, vertebral fractures in children most often appeared in the midthoracic region (47 %) in the study done by Kraus et al. [18].

Thoracolumbar injuries in children often present with multiple levels of fractures [1], particularly in smaller children [33]. Incidence of multilevel spinal injury ranges from 6 to 52 % [21, 24, 26, 33]. The result of our study was also in this range (18.5 %). Only one case in nineteen (5.26 %) had noncontiguous spinal injury. Noncontiguous injury is defined as spine injuries at more than one level separated by a region of normal spine [5]. Patients with noncontiguous multilevel spinal injuries are more likely to experience neurological injuries and are usually missed on initial examination [11]. Neurological injuries have been reported in 11.8–37.5 % of multilevel thoracolumbar fractures [11, 24].

Associated injures have been reported in over 65 % of children with spinal fractures [19] with traumatic brain injury being the most common associated injury [8, 24]. While we excluded major multiply injured patients from the survey, pelvic and acetabular fractures were the most frequent fractured bone associated with thoracolumbar spinal injuries in children. Two patients had intra-abdominal hemorrhage from liver and spleen lacerations.

About 7.5–30 % of patients with thoracolumbar fractures need operative treatment [9, 18, 21, 24, 28]. About 20 % of patients in the current study underwent surgery, whereas 82 cases received nonsurgical treatment. Although early surgical treatment is mandatory for unstable spinal injuries or fractures with myelopathy [26], we have treated three cases of delayed diagnosis with satisfactory follow-up results. Late diagnosis has been reported in up to 50 % of patients [30]. High index of suspicion is required for early diagnosis of spinal injuries in children. Furthermore, screening radiographs and MRI may be necessary in these patients because clinical examination alone identifies these injuries with a sensitively of 81–87 % and specificity of 68 % [17, 27, 31].

We also described some unusual cases of flexion–distraction injuries (type B in AO classification). The injury was posterior ligamentous disruption associated with transverse disruption through the disk. Flexion–distraction spinal injuries are among the most challenging topics to spine surgeons. Although these fractures have been linked to seat-belt injuries, it may occur in any deceleration injuries involving flexion force with the fulcrum anterior to middle column of the spine [32]. Bicycle crashes are the mechanism of injury in about 2 % of cases with these fractures [2]. The mechanism of injury in all three reported cases in our series was severe flexion of the spine after different types of accidents. MRI findings are the most relevant modality to differentiate between spinal pathologies not only in adults [7] but also in children with flexion–distraction injuries [12]. We recommend this modality for early diagnosis of flexion–distraction injuries particularly in patients with unusual mechanisms of injury.

Outcome of thoracolumbar spinal injuries in children depends predominantly on the severity of spinal cord injury and associated neurological deficits [14, 34]. Spinal cord injury has been reported in 15–45 % of cases [9, 14, 28, 33, 35]. Neurological deficit is related to the level of injury and the degree of canal compromise. Although patients with complete spinal cord injury have a poor prognosis for functional recovery, the children with cauda equine injury in our series had near-complete improvement after several months.

The safety and efficacy of spinal surgery in pediatric patients has been well established [15, 26]. There was no complication in 13 and 23 cases that underwent surgery by Santiago et al. [31] and Dogan et al. [9], respectively. We also had no major complication except a wound infection treated by intravenous antibiotics.

Kyphosis angle improved from 26.5° at presentation to 12.5° at final follow-up. This amount of correction is more than what explained by Vander Have et al. [35]. Even though all radiographic indices deteriorated during the follow-up period, it was small and generally insignificant.

While Moller et al. [23] reported occasional back pain in five out of 23 cases (21.7 %) during a long-term follow-up, we only had five cases (33.3 %) with some degrees of occasional back pain without any interruption of daily activities. Further investigation is necessary to clarify the incidence of chronic axial back pain in pediatric patients with spine fractures.

All patients were functionally independent with FIM score of 7, which is better than the report by Carreon et al. [6]. It seems that spinal fusion and instrumentation in pediatric spine fracture is highly successful in terms of functional outcome even in patients with spinal cord injury.

Conclusion

Although relatively rare, pediatric thoracolumbar spine fracture is an important diagnosis not to miss. Early diagnosis and treatment is critical, and a high index of clinical suspicion is essential in these patients. Spinal fusion and instrumentation of children with unstable thoracolumbar fractures with or without spinal cord injury has favorable radiographic and functional outcomes.

Conflict of interest None.

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