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Post-trauma scoliosis after conservative treatment of thoracolumbar spinal fracture in children and adolescents: results in 48 patients

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Abstract

Purpose Authors examined a case series of patients younger than 18 years old who had sustained a traumatic thoracolumbar spine fracture to evaluate radiological and clinical findings of coronal spinal balance, after conservative treatment.

Methods From 1996 to 2014, a tricentric cohort of 48 patients with an average age of 12 years was radiographically reviewed at 50 months. Cobb angle of fractured vertebra and regional Cobb angle were measured both at baseline and follow-up. Analyses were done according to initial Risser grade, number of fractures and level of injury.

Results There was a total of 11 scoliosis. In group with Risser grade 3 or above, with a single vertebral fracture and lumbar fracture, final regional Cobb angle was statistically higher than initial regional Cobb angle.

Conclusions The prevalence of scoliosis in our population is higher than those of idiopathic scoliosis; Risser grade 3 or above, lumbar fracture and a single fracture seem to account for more severe coronal deformation.

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Keywords Thoracolumbar fracture · Children and adolescents · Scoliosis · Conservative treatment · Vertebral growth

Introduction

Spine injuries in children are relatively rare and represent a small percentage of overall injuries to children (range 0.3–4 %) [1–4], they are less common than in adults because of the greater mobility and elasticity of the pediatric spine and the smaller mass of the child's body. The incidence of pediatric spine injuries has been reported to be 2–5 % of all spine injuries [1] and occurs in the thoracic or lumbar spine in 20–60 % of injuries [3]. Conservative treatment remains the most common treatment because children and adolescents have strong bones with excellent healing potential and usually reconstitute loss of vertebral height. Child spinal injuries are determined by the presence of growth plates. There are two groups of cartilage involved in vertebral growth: the cartilage of the vertebral endplate and the neurocentral cartilage. The cartilage of the vertebral endplate is responsible for the growth in height, like the growth plate of a long bone. In this way, a traumatic separation of the vertebral endplate can account for abnormal growth because of premature epiphyseal fusion, in the manner described by Salter and Harris in long bones. This is one hypothesis to explain coronal spinal deformity after vertebral fracture. Post-trauma scoliosis are well known [1, 5] but, to our knowledge, there is no report which focuses on the coronal plane analysis after vertebral fracture. The aim of the present study was to evaluate radiological and clinical findings of coronal spinal balance, after conservative treatment of spinal fracture.

Materials and methods

A tricentric (two hospitals, three departments of surgery) retrospective study was performed between 1996 and 2014. A computer search was initiated to find all patients under 18 years old who were hospitalized because of lumbar and/or thoracic vertebra fracture. Patients who underwent surgery during the first year after the accident, patients with neurological deficiency and patients with pre-existing scoliosis or spinal malformation were excluded. Fractures were classified according to Magerl fracture classification. All patients' demographic data are summarized in Table 1.

Radiological measurements

All angular measurements were calculated by the method of Cobb with Surgimap software and were done by a single person to decrease measurement bias. On anteroposterior (AP) radiographs, local and regional Cobb angles (Fig. 1) were measured to quantify the deformity of each fractured vertebra and the deformity between vertebrae at the upper and lower limits of the curve, respectively. The difference between final and initial local Cobb angles was called local deformity (LD); and the same difference regarding regional Cobb angles was called regional deformity (RD). All measurements were done at the moment of the accident, authors using full spine radiograph with brace or cast and at last follow-up with another full spine radiograph without contention; all radiographs were done in standing position. Scoliosis was defined according to the Scoliosis Research Society (SRS) by a Cobb angle above 10° and, vertebra rotation was asserted by Nash and Moe method.

Analysis

Several analyses were done according to the initial Risser grade, the number of vertebrae fractured (single fracture and several fractures) and the level of injury (thoracic and lumbar). The first analysis was made in each group to characterize LD and RD. The second analysis was made to compare subgroups between them. The third analysis was to search for a correlation between sagittal and coronal deformity.

Telephone interview

The authors attempted to contact each patient included in the study. Patients were asked about their pain, their professional and sport activities, and their painkillers' consumption.

Statistical analysis

Data were presented as mean and range. A Student t test was performed to compare series. A difference of $p < 0.05$ was regarded as a statistical significant difference.

Results

The computer search found 320 patients in center 1 (2 departments of surgery) and 41 in center 2. After application of exclusion criteria and verification of patients' files, 48 patients were included, 23 males and 25 females (Fig. 2), with a total of 84 vertebrae. There were 43 thoracic fractures (T4–T12) and 41 lumbar fractures (L1–L5) (Table 2); 89.6 % are A1 fracture according to Magerl classification. All fractures were treated conservatively, 85.4 % had a brace and 14.6 % underwent reduction of the fracture and a cast. The mean age at the inclusion was 12.3 years old (range 2.6–17.1). Mean follow-up was 49 months (range 12–210) and 62 % of cases had a Risser grade 4 or 5 at the end of the follow-up.

Coronal deformity

Evolution of local deformity

Mean initial local Cobb angle (ILCA) was 3.05° (range 0–19) and mean final local Cobb angle (FLCA) was 2.6° (range 0–10). LD decreased by −0.3° but without any statistical difference between FLCA and ILCA.

Evolution of regional deformity

Mean initial regional Cobb angle (IRCA) was 5.9° (range 1–14) and mean regional final Cobb angle (FRCA) was 8.4° (range 1–34). RD increased by +2.5° with a statistical ($p = 0.01$) difference between FRCA and IRCA.

Final scoliosis

At the end of the follow-up, 11 patients (23 %) had a scoliosis with a Cobb angle above 10° and associated rotation (Fig. 3); according to Nash and Moe method, rotation was characterized as + in five patients and as ++ in six. Ten individuals had a Cobb angle at 20° or less and one had a Cobb angle above 20°. None of these 11 patients presented an IRCA above 10° on the initial AP radiograph.

Table 1 Demographic data

Patient number	Age (month)	Gender	Injury date	Risser's grade	Y-cartilage	Mechanism of injury	Level of injury	Fracture	Osteoarticular associated lesions	Visceral associated lesion	Total follow-up (month)	Risser's grade at follow-up
1	146.4	F	26/02/2012	1	Closed	MVA	L2	B1	No	Jejunum wound	24	4
2	213.6	M	24/01/1996	4	Closed	Fall	T12	A1	Head injury	No	12	5
3	171.6	M	25/03/2011	0	Open	Fall	T12	A1	No	No	18	0
4	135.6	F	02/03/2011	0	Open	SA	T11	A1	No	No	36	5
5	175.2	F	02/02/2011	4	Closed	Fall	L1 L2	A1 A1	Ankle sprain		36	5
6	177.6	M	21/07/2010	0	Open	SA	T5	A1	No	No	42	4
7	124.8	F	29/06/2010	0	Open	Fall	T9	A1	No	No	48	5
8	165.6	M	23/11/2010	0	Closed	SA	T4	A1	No	No	54	4
9	166.8	F	20/11/2010	4	Closed	Fall	T10 T11	B1 A1	Transverses apophysis fractures T7-12, ankle sprain	Right pneumothorax, left pulmonary contusion	36	5
10	136.8	M	28/03/2012	0	Open	Fall	T12	A1	No	No	24	1
11	148.8	F	27/02/2010	0	Open	MVA	L2	B1	No	Liver and pulmonary wound	48	4
12	198	M	01/03/2009	4	Closed	MVA	T6 T7 T8 T9	A1	No	Cervical and forearm wound	60	5
13	201.6	M	21/05/2004	4	Closed	SA	L1	A1	Facial traumatism, rib, pelvis and tibial fractures	No	120	5
14	198	F	21/07/2003	5	Closed	Fall	L2	A1			48	5
15	164.4	F	16/04/2008	4	Closed	Fall	L1 L2 L3 L4 L5	A1	Right foot dislocation, open fracture of right leg, left wrist fracture		72	5
16	140.9	F	14/01/2007	0	Open	SA	T10	A1	No	No	36	4
17	142.8	F	13/12/2008	0	Open	SA	T6 T7 T8	A1 A1 A1	No	No	12	1
18	130.2	M	30/10/1998	0	Open	Fall	T11	A1	Head injury	No	24	0

Table 1 continued

Patient number	Age (month)	Gender	Injury date	Risser's grade	Y-cartilage	Mechanism of injury	Level of injury	Fracture	Osteoarticular associated lesions	Visceral associated lesion	Total follow-up (month)	Risser's grade at follow-up
19	31.7	M	15/03/2010	0	Open	Fall	T12	A1	No	No	48	0
20	132.4	F	12/10/2011	0	Open	SA	L1	A1	No	No	12	0
21	123.7	M	23/03/2003	0	Open	SA	T4 T5 T6	A1 A1 A1	No	No	24	0
22	186	F	15/12/2006	4	Closed	SA	L3 L4	A1 A1			101	5
23	156.7	F	12/07/1997	0	Closed	MVA	L1	A1	Pelvis fractures, head injury	No	36	5
24	189.6	M	12/06/2008	4	Closed	MVA	T6 T7 T8	A1 A1 A1	Head injury	Abdominal injury	66	5
25	120.9	F	27/02/2007	0	Open	SA	L2	A1	No	No	36	1
26	93.6	F	14/04/2007	1	Open	SA	L1	A1			84	4
27	202.8	F	14/12/2008	4	Closed	Fall	A1 A1	A1 A 1	Fractures of transverse apophysis T4-6, rib fractures	Pulmonary contusion	48	5
28	85.2	F	16/07/2008	0	Open	SA	T6 T7 T8 L1	A1 A1 A1 A1	No	No	66	5
29	200.4	M	10/12/2008	4	Closed	MVA	L5	A1	Left forearm, right femur and radius fractures, head injury	No	72	5
30	124.8	F	13/07/2005	0	Open	SA	T4 T5 T6	A1 A1 A1	No	No	24	3
31	105.6	M	19/02/2004	0	Open	MVA	L1	B1	No	Duodenal contusion	120	5
32	153.6	F	26/05/2005	3	Closed	SA	L1 L2 L3	A1 A1 A1				
33	108	M	10/12/2012	0	Open	SA	T8 T9	A1	No	No	24	0
34	134.4	M	08/07/2005	0	Open	Fall	T9	A1	No	No		
35	128.4	F	08/01/2009	0	Open	SA	T6 T7 T8	A1	No	No	24	0
36	140	F	25/06/2001	1	Closed	Fall	L1	A1	No	No	24	4
37	183.6	M	07/04/2001	3	Closed	MVA	L1 L2 L3 L4	A1 A1 A1 A1	Right foot dislocation, sacrum fracture	Liver fracture	12	4

Table 1 continued

Patient number	Age (month)	Gender	Injury date	Risser's grade	Y-cartilage	Mechanism of injury	Level of injury	Fracture	Osteoarticular associated lesions	Visceral associated lesion	Total follow-up (month)	Risser's grade at follow-up
38	106.3	F	30/03/1993	0	Open	SA	T7 T8	A1 A1	No	No	72	
39	150	F	15/07/2003	1	Open	MVA	T9	A1	Head injury	No	132	5
40	97.2	M	07/08/2010	0	ouvert	SA	L1 L2	B1	No	No	42	0
41	161.9	M	27/07/2003	0	Open	MVA	T8 T9	A1 A1	Head injury	No	12	0
42	106.8	F	13/07/2006	0	Open	SA	T7	A1	No	No	96	5
43	148.8	M	24/04/2008	0	Open	SA	L3	A1	No	No	18	3
44	205.2	F	14/01/2010	5	Closed	SA	L2	A1			48	5
45	180	M	13/12/1996	4	Closed	MVA	L1 L2	A1 A1	Face fracture	No	210	4
46	158.5	M	20/06/1998	0	Open	SA	L2	A1	Left foot and hand fractures	No	12	
47	160.7	M	30/01/1998	0	Open	SA	L1	A1	No	No	12	
48	195.6	F	26/02/2000	4	Closed	MVA	L1 L2	A1	Rib fractures	Left pneumothorax	12	5

MVA motor vehicle accident, *SA* sports accident

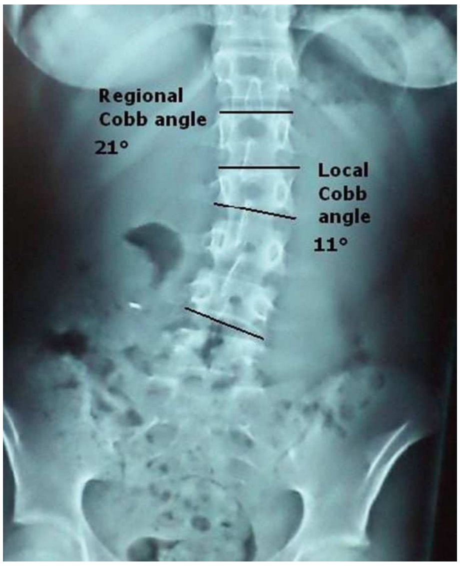

Fig. 1 Local and regional Cobb angles

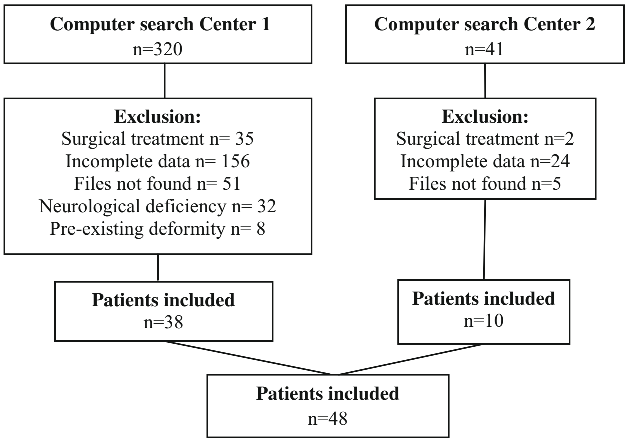

Fig. 2 Flow chart

Predictive factors of coronal deformity

The following statistical analyses were performed making subgroups to try to find predictive factors of coronal deformity.

Subgroup results: skeletal maturity, initial Risser grade

Patients were divided into two groups, group 1 with patients who had a Risser grade of 0, 1 or 2 and group 2 who had a Risser grade of 3, 4 or 5. Initially, both groups were comparable regarding the following data: age, gender, mechanism of injury, follow-up. In group 2, FRCA (mean = 9.9°, range 1–19) was statistically higher than the IRCA (mean = 5.8°, range 1–13) ($p = 0.03$). On the contrary, there was no statistical difference between IRCA and FRCA in group 1. There was also no statistical difference between ILCA and FLCA in each group.

Subgroup results: single fracture versus several staged fractures

Two groups were made regarding the number of fractures, group U, with a single vertebra fracture and group S, with several staged fractures. Initially, both groups were comparable regarding the following data: age, gender, initial Risser grade, mechanism of injury and follow-up. In group U, FRCA (mean = 9.0°, range 1–34) was statistically higher than IRCA (mean = 5.4°, range 1–14) ($p = 0.02$). There was no statistical difference regarding IRCA and FRCA in group S. There was also no statistical difference between ILCA and FLCA in each group.

Subgroup results: level of injury, thoracic versus lumbar

Patients were divided into two groups regarding the level of injury, group T, thoracic vertebra fracture and group L, lumbar vertebra fracture. Initially, both groups were comparable regarding the following data: age, gender, mechanism of injury and follow-up. But, there was a statistical difference between the two groups regarding the initial Risser grade ($p = 0.003$); in group T, 83.3 % were Risser 0, 1 or 2, whereas in group L there were only 50 % of Risser 0, 1 or 2. In group L, FRCA (mean = 10.6°, range 1–34) was statistically higher than IRCA (mean = 5.9°, range 1–13) ($p = 0.007$). The same analysis in group T did not find any statistical difference. There was also no statistical difference between ILCA and FLCA in each group.

Analyses between subgroups (Table 3)

Correlation with sagittal deformity

Our analyses reported no statistical correlation between coronal and sagittal deformity at the last follow-up, or in thoracic ($r = -0.2$) or lumbar area ($r = 0.05$).

Table 2 Level injury

Fracture level	T4	T5	T6	T7	T8	T9	T10	T11	T12	L1	L2	L3	L4	L5
Number of fracture	3	3	7	7	8	6	2	3	4	17	14	5	3	2

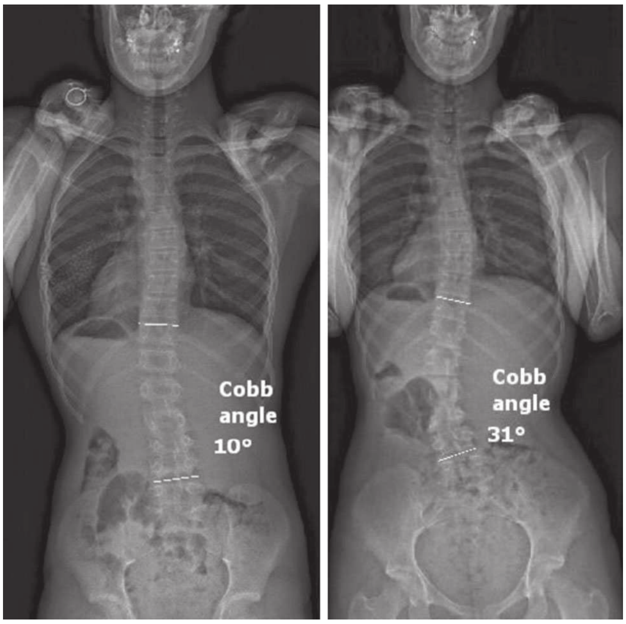

Fig. 3 Example of left lumbar scoliosis 4 years after L2 fracture

Others analyses

Clinical findings

Thirty-two patients were contacted by telephone, 81 % reported back pain; but 87.5 % revealed that back pain did not disturb their daily life and did not require any medication. Only one patient had stopped his professional activity, 31 of the 32 patients (97 %) continued their professional or student life as before.

Mechanism of injury

The mechanism of injury was sport accidents in 50 %, motor vehicle accidents (MVA) in 26 % and falls (accidents or suicide attempts) in the last 23 %.

Associated lesions

There were 42 % of associated injuries in our series. Associated skull and long bone fractures were present in 33 % of all cases, abdominal and/or thoracic injuries in 18.75 %.

Discussion

The present series of 84 vertebrae confirms that conservative treatment of wedge compression fractures without neurological lesion ensures stabilization with moderate residual deformity. It confirms that patients with the most skeletal immaturity (Risser grade 2 or less) have greater bone remodeling power. But, in 11 cases, restoration of height is inconclusive. Prevalence of scoliosis in our series is 23 % whereas prevalence of idiopathic scoliosis (IS) is 0.47–15.3 % [6–8], decreasing to 0.2–3 % for a Cobb angle superior to 30° [6, 9]. This result suggests that a fracture of the thoracolumbar spine is a risk factor of scoliosis. Other publications find scoliosis after conservative treatment of spinal fractures. Parisini [1], in a series of 29 patients, reports four (31 %) burst fractures (one T5, two L1 and one L3) treated conservatively with a mean final Cobb angle of 20°. Karlsson [4] has two individuals (8.3 %), in a series of 24 patients, who developed a scoliosis with 11° and 13° Cobb angles. Gnanenthiran et al. [10] find only one (2 %) scoliosis, in a series with 50 patients, with a Cobb angle of 14°. The authors note that, in our series and in literature, post-traumatic scoliosis has small Cobb angles. The hypothesis to explain the incapacity to reconstitute loss of vertebral height in immature patients is the post-traumatic epiphysiodesis, as it may be encountered in long bones [11].

An interesting result in the analysis of the whole series is the improvement of local deformity whereas regional deformity worsens. The phenomenon of epiphysiodesis does not explain this result while the Hueter and Volkmann principle could. They describe how increased pressure on the end plate of bone retards growth (Hueter) and conversely, reduced pressure accelerates growth (Volkmann). Indeed, we can imagine that initial LD takes time to heal and during this time an asymmetric growth occurs worsening the RD. Once the deformity reaches certain proportions, the effect of gravity on lever arm created continues to be a major deforming force. Using this principle, scoliotic curves have been reproduced on animal studies. Braun [12] creates an idiopathic type of deformity in goats by applying forces across the spine and finds wedging of the vertebrae similar to that seen in scoliosis in humans. Similarly, Mente [13, 14] and Stokes [15, 16] in separate studies on rat models not only create scoliosis but also succeed in correcting it reversing the forces. Another explanation is the involvement of the intervertebral disc in the curve increase. Schlosser [17] studies the contribution of VB and intervertebral discs to three-dimensional (3-D) spinal deformity in adolescent idiopathic scoliosis (AIS); he concludes that the discs contribute more to 3-D deformity than the bony structure, because of the decreased stiffness of intervertebral fibrocartilage as compared to bony vertebrae. Modi [18] in a series of 150 adolescent AIS concludes that wedging in disc and body increases with progression of the scoliosis and disc wedging is more profound in the lumbar area. This could explain why, in our series, lumbar fractures have a higher deformity rate than thoracic fractures. But, all of these studies are done on patients with

Table 3 Analyses between subgroups

	ILCA	p	FLCA	p	IRCA	p	FRCA	p	LD	p	RD	p
Group 1: Risser 0, 1, 2 $n = 51$	Mean = 3.2 Range 0 to 19	$p > 0.05$	Mean = 2.2 Range 0 to 10	$p > 0.05$	Mean = 6.7 Range 1 to 14	$p > 0.05$	Mean = 7.9 Range 0 to 34	$p > 0.05$	Mean = −1.0 Range −18 to 6	2 > 1 $p = 0.006$	Mean = 1.9 Range −12 to 28	$p > 0.05$
Group 2: Risser 3, 4, 5 $n = 33$	Mean = 2.9 Range 0 to 10		Mean = 3.2 Range 0 to 8		Mean = 5.8 Range 1 to 13		Mean = 9.9 Range 1 to 19		Mean = 0.9 range−4 to 5		Mean = 3.8 Range −4 to 12	
Thoracic (T) $n = 43$	Mean = 3.4 Range 0 to 19	$p > 0.05$	Mean = 2.2 Range 0 to 8	$p > 0.05$	Mean = 5.6 Range 1 to 14	$p > 0.05$	Mean = 6.2 Range 1 to 19	$L > T$ $p = 0.02$	Mean = −1.3 Range −18 to 5	L > T $p = 0.003$	Mean = 0.5 Range −12 to 9	$L > T$ $p = 0.02$
Lumbar (L) $n = 41$	Mean = 2.6 Range 0 to 8		Mean = 3.1 Range 0 to 10		Mean = 6 Range 1 to 13		Mean = 10.6 Range 1 to 34		Mean = 0.9 Range −4 to 6		Mean = 4.6 Range −4 to 28	
Single fracture (U) $n = 32$	Mean = 3.5 Range 1 to 19	$p > 0.05$	Mean = 3.1 Range 0 to 10	$p > 0.05$	Mean = 5.3 Range 1 to 14	$p > 0.05$	Mean = 9.0 Range 1 to 34	$p > 0.05$	Mean = 0.7 Range −5 to 6	$U > S$ $p = 0.03$	Mean = 3.6 Range −3 to 28	$p > 0.05$
Several fractures (S) $n = 52$	Mean = 2.4 Range 0 to 8		Mean = 1.9 Range 0 to 8		Mean = 6.5 Range 1 to 13		Range 0 to 19 Mean = 7.4		Mean = −1.1 Range −18 to 5		Mean = 0.9 Range −12 to 12	

AIS, not with post-trauma spinal deformity. Moreover, literature has varying results regarding disc lesion after VB fracture. Karlsson [4] reports no decrease in disc height at the fracture level but just a modification of nucleus pulposus intensity on the T2-weighted MRI, whereas Kertulla [23] finds 57 % of disc degeneration with a strong association between endplate damage and adjacent intervertebral disc degeneration. The hypothesis of intervertebral disc involvement in post-trauma spinal deformity has to be studied further to know its role in final spinal deformity.

The analysis regarding the level of injury shows that lumbar fractures are more responsible for coronal deformity than thoracic fractures; this could be explained by the greater mobility of lumbar vertebrae in comparison with thoracic vertebrae which are attached to the rib, making a rigid assembly less sensitive to deformity. Parisini [1] reports the same tendency as our series.

The difference in group with a single fracture where FRCA is higher than IRCA is not found in the group with several fractures. Local deformity is higher in group with a single fracture than in group with several fractures. Authors make the hypothesis that when there is just one fracture, the deformity is more important whereas when several vertebrae are involved the energy of the trauma is absorbed in a greater area, making the deformity smaller. Indeed, even if there is no statistical difference regarding ILCA between the two groups, ILCA is higher in group with unique fracture than in group with several fractures.

In our study, there is no correlation between coronal and sagittal deformity at the last follow-up; these results confirm that coronal analysis must be taken into account when the treatment of vertebral fracture is decided. Indeed, to be concerned only with sagittal plane does not seem sufficient and satisfactory.

The weakness in our study is the retrospective design responsible for a heavy loss of information and patients. The strength of this study is the follow-up and the radiographic evaluation by the same individual at both baseline and at follow-up.

Our series finds a high rate of back pain, but a functional satisfying result, because patients do not feel limited in their daily life and need no pain relief medication. We find varying values in literature; 12–57 % of back pain after conservative treatment [1, 4, 19, 20]. The rate of back pain in adolescents without back injury is high too: 7–70 % [21–23] depending on the definition of pain and study design; this makes the interpretation of our rate difficult because back pain is multifactorial and it is difficult to identify the precise origin. Initially, authors wanted to search a correlation between coronal deformity and back pain but, because of the high rate found, it was not possible to conclude.

Our series finds the same common mechanisms of injury as in literature [24]: sports accidents, MVA, pedestrian–

vehicle accidents, and falls with varying proportions according to publications.

Values concerning associated lesions are similar with those of literature: 42–65 % of patients have associated injuries with 5–50 % of skull or long bone fractures and 20–37 % of visceral (thoracic and/or abdominal) injuries [2, 24].

Conclusion

There is a higher prevalence of scoliosis in the population which sustains thoracolumbar spinal fractures. Risser grade 3 or above, lumbar fractures and single fractures seem to be responsible for more severe coronal deformation.

Conflict of interest None.

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