Anders Moller
Ralph Hasserius
Jack Besjakov
Acke Ohlin
Magnus Karlsson

Vertebral fractures in late adolescence: a 27 to 47-year follow-up

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A. Moller (✉) · R. Hasserius
A. Ohlin · M. Karlsson
Department of Orthopaedics, Malmo
University Hospital, Malmo, Sweden
E-mail: ta.moller@spray.se
Tel.: +46-40-331000
Fax: +46-40-336200

J. Besjakov
Department of Radiology, Malmo
University Hospital, Malmo, Sweden

Abstract The long-term outcome of thoracic and lumbar fractures in late adolescence is sparsely described and it is unclear whether a fractured vertebral body in these years, as in young children, can be resituated in height. The purpose of this study was to in late adolescence determine the incidence, the long-term outcome and the modelling capacity in fractures of the thoracic and lumbar region. The incidence of vertebral fractures 1950–1971 in individuals aged 16–18 years was through the radiological archives evaluated in a city cohort of 228,878 citizens, of whom 13,893 were aged 16–18. A follow-up, 27–47 years after the injury, including subjective, objective and radiological evaluation was conducted in 18 boys and 5 girls. Twenty-nine boys and 11 girls were registered with a thoracic or lumbar vertebral fracture during the study period conferring an annual incidence of 0.14‰. Of the 23 individuals that attended the follow-up, 14

had one-column compression fractures, one a Denis type A, six a Denis type B, one a Denis type D and one a Chance fracture. At injury, one had a partial paresis in one leg and one developed a transient paraparesis during the first week. All were treated non-operatively. At follow-up, 18 individuals had no complaints while 5 had occasional back pain, 20 were classified as Frankel E and 3 as Frankel D. The radiographic ratio of anterior height to posterior height of the fractured vertebral body was unchanged during the study period. Thoracic and lumbar vertebral fractures in late adolescence with no or minor neurological deficits have a predominantly favourable long-term outcome, even if no modelling capacity of the fractured vertebral body remains in late adolescence.

Keywords Adolescence · Epidemiology · Vertebra · Fracture · Long-term outcome · Radiological

Introduction

The literature infers that vertebral fractures in young children are rare with an increasing incidence found in late adolescence, so that spine fractures account for 2–3% of all childhood fractures [4, 20, 24]. The fractures in children are more evenly distributed in the spine [21], contrary to in adults, where fractures usually occur in the thoracolumbar region [11, 31]. In addition, cases without

neurological deficits are usually described with a favourable long-term outcome [13, 14, 18, 20–22, 24, 26]. This could perhaps, at least partly, be explained by the modelling capacity in young children, reducing the deformity and restoring the height of the fractured vertebral body by growth [21], a capacity not found in adults [25, 31]. To our knowledge, no long-term studies exist which report both clinical and radiographic outcome decades after a thoracic or lumbar fracture sustained in

late adolescence, at the end of vertebral growth [1], and if there exist a modelling capacity of a fractured vertebral body in these ages. By including individuals aged 16–18 years, we could specifically evaluate the hypothesis forwarded in a previous paper [21], that a fractured vertebral body could only be modelled in height in young children with a large remaining growth potential.

Against this background we hypothesised that thoracic and lumbar fractures in late adolescence (1) are more common than during childhood, (2) have a fracture distribution resembling the distribution in adults, (3) have predominantly a favourable, long-term outcome and (4) have no modelling potential to reduce the deformity of a vertebral body.

Material and methods

We aimed to re-evaluate all radiographs in individuals aged 16–18 years, with a diagnosed thoracic or lumbar vertebral fracture during the period 1950–1969, by help of a radiologist. As the radiographs of vertebral fractures sustained during 1954 and 1956 were missing, 2 years were added (1970 and 1971) to achieve 20 years of fracture epidemiology. The study was performed in a city of 228,878 inhabitants of whom 13,893 were between the age of 16 and 18 years in November 1960. In November 1970 there were 264,937 inhabitants, of whom 13,959 were between the age of 16 and 18 years, that is, a city with a virtually stable population over this period. The mean population aged 16–18 years during the study period was estimated to be 13,893.

Virtually all fracture patients attend the trauma unit at the city hospital, as this is the only emergency hospital

in the city. Fractures sustained within the population, but out of the city, are referred to the Orthopaedic Department for clinical follow-up, a visit at which the fractures are classified to ensure complete ascertainment. Fewer than 3% of all fracture patients in the city are estimated to attend a private medical facility for treatment, usually for more insignificant fractures with minor need for treatment. These fractures will not be classified in the hospital archives [15]. Additionally, all radiographs, journals, referrals and reports have been saved in the archives of the city hospital for the past century, leaving the opportunity to identify and reclassify old fractures and evaluate primary treatment and outcome.

Primary treatment and outcome were retrospectively evaluated through old medical referrals, reports and radiographs. The fractures were classified according to the Denis classification, with the knowledge that this classification is based on fractures in adults [7]. The heights of the discs and the inter-pedicular width were determined at the fractured level and the closest normal cranial and caudal levels. The sagittal diameter of the spinal canal was measured at the shortest midline perpendicular distance from the posterior surface of the vertebral body to the inner surface of the neural arch with the knowledge that this method was primarily described for assessing the width in the lumbar spine [12]. The ratio anterior height/posterior height of the fractured vertebral body was used to calculate whether the degree of compression of the fractured vertebra changed during the study period (Fig. 1). Local kyphosis was estimated as the angle between the lines drawn through the posterior corners of the cranial and caudal vertebral bodies adjacent to the fractured vertebra [10] (Fig. 2). Degree of scoliosis was classified by the Cobb angle and

Fig. 1 Method of measuring the degree of vertebral body compression of the fractured vertebra by calculating the ratio anterior height/posterior height on a lateral radiograph

Fig. 2 Method of measuring the degree of local kyphosis of the injured segment on a lateral radiograph

any lateral, anterior or posterior displacement of the fractured vertebral body was measured by a ruler.

A clinical and radiological follow-up was performed at a mean of 34 years (range 27–47) after the injury. At follow-up 10 subjects were unable to locate, 23 participated in the evaluation while 7 denied full participation, even if they accepted to answer a back pain and disability score. The subjective outcome was evaluated by the Oswestry Score [8] together with a question regarding work capacity. The objective outcome was evaluated by the Frankel classification [9]. The radiographic outcome included anteroposterior (AP) and lateral radiographs of the thoracic and lumbar spine (Fig. 3), evaluated in the same manner as the primary radiographs. The investigators were uninvolved in the treatment of the patients.

Statistics

Data are presented as mean $\pm$ SD or mean and range. Student's *t* test between pairs was used in the compari-

son of baseline and follow-up data. The Chi square test was used in the comparison of the incidence of individuals with fractures during the first and second decade of the study. A difference of $P < 0.05$ was regarded as a statistically significant difference. The study was approved by the Ethics Committee of Lund University and the Radiographic Committee at Malmö University Hospital, Malmö, Sweden.

Results

Epidemiology

In total we found 40 individuals, 29 boys and 11 girls aged 16–18 years with a thoracic or lumbar vertebral fracture during the defined period, conferring an annual incidence of 1.44/10,000 individuals (0.14‰). The index fracture was in 20 cases (50%) found in the thoracic region (one in Th3, Th4, two in Th5, Th6, Th7, one in Th8, Th9, two in Th10, Th11 and six in Th12), and in 20 cases in the lumbar region (12 in L1, three in L2, two in L3, one in L4 and two in L5). Twenty-one fractures (52%) were classified as one-column compression fractures, one as a burst fracture Denis A (location L5), 16 as burst fractures Denis B (location Th5, Th7, Th10, Th11, three in Th12, six in L1, two in L3 and one in L5), one as a burst fracture Denis D (location Th6) and one as a Chance fracture (location L2). Nine individuals had additional, minimal compression fractures in one adjacent vertebra, four in two vertebrae, three in three vertebrae and two in four vertebrae. Eighteen individuals sustained the fracture during the first decade and 22 during the second decade of the study (NS).

Baseline data

In the cohort of 23 cases that accepted to participate in the follow-up examination, 18 were boys with a mean age of 17.3 years (range 16–18) and 5 girls with a mean age of 17.5 years (range 16–18) at the time of the injury. Five individuals (3 boys and 2 girls) had suffered a low-energy trauma, defined as a fall in the same plane, or had sustained a kick, and 17 individuals (15 boys and 2 girls) were exposed to a high-energy trauma, defined as a fall of more than 2 m or being involved in a motor-vehicle accident. The type of trauma was unknown in one patient. All cases attended the emergency care unit with back pain. Additionally, one had a partial paresis in the left leg, retrospectively classified as Frankel D and one developed during the first week after injury a transient paraparesis, retrospectively classified as Frankel D. However, after 8 weeks this patient was fully recovered according to the medical report. All others were classified as Frankel E. All were treated non-operatively.

Fig. 3 Lateral radiograph of boy aged 18 showing fracture of vertebra Th12 and L1 **a** at the time of the fracture event **b** after 30 years

Three were treated with mobilisation with a truncal plaster for a mean of 8 weeks (range 3–16), four with immobilisation in bed for a mean of 6 weeks (range 4–12), one of whom also had a truncal brace. The reason for the bed immobilisation was in one case a femoral fracture, in one bilateral ankle fractures while the reason for the bed immobilisation was unknown in two cases. Mobilisation as soon as the pain allowed, with no brace or external support, was advocated for 17 patients. The mean period of absence from school or work was 2.3 months (range 0–6) (Table 1).

The index fracture was in 11 cases (48%) found in the thoracic region (one in Th3, Th4, Th5, Th6, Th7, Th8, Th10, respectively, and four in Th12), and in 12 in the lumbar region (six in L1, three in L2 and one in L3, L4 and L5, respectively).

Fourteen fractures (61%) were classified as one-column compression fractures, one as a burst fracture Denis A (location L5), six as burst fractures Denis B (location Th7, two Th12, two L1 and one L3), one as a burst fracture Denis D (location Th6) and one as a Chance fracture (location L2). Six individuals had additional, minimal compression fractures in one adjacent vertebra, three in two vertebrae, two in three vertebrae and one in four vertebrae.

At baseline, the inter-pedicular distance at the fracture level was larger than at the level above but not different than the level below (Table 1). There were no lower disc height or smaller sagittal spinal canal width at

fracture level compared to adjacent levels (Table 1). The ratio anterior/posterior height of the fractured vertebra was lower than the ratio of both the vertebra above and below (Table 1). One patient had a 8 mm lateral and a posterior displacement of 12 mm compared to the adjacent vertebrae. Two patients had a 2 and 8 mm posterior displacement of the fractured vertebrae compared to the vertebrae above, respectively.

Changes during the follow-up period

The inter-pedicular distance, the sagittal spinal canal width and the kyphosis increased in absolute values from baseline to follow-up at all levels while the disc heights, the degree of scoliosis, the degree of anterior, posterior and lateral displacements were unchanged (Table 1). The ratio fractured level/level above and the ratio fractured level/level below of the interpedicular distance, the disc height and the sagittal canal width did not change during the follow-up period (Table 1).

Endpoint data

At follow-up, 18 of the 23 evaluated patients reported excellent results with no back pain or disability. Five cases (two with a compression fracture at L1 and L2, respectively, two with a fracture Denis type B of Th7

Table 1 Age, absence from school, study length, subjective, objective and radiographic outcome in individuals aged 16–18 years at injury. Data presented as mean $\pm$ SD

Variable	Baseline	Follow-up	Baseline versus follow-up	Injured versus normal at baseline	Injured versus normal at follow-up
Age (years)	17.4 $\pm$ 0.7	51.6 $\pm$ 6.0	–	–	–
Absence from school (months)	2.3 $\pm$ 2.2	–	–	–	–
Follow-up (years)	–	34.2 $\pm$ 5.8	–	–	–
Subjective outcome					
Oswestry score	–	2.5 $\pm$ 6.3	–	–	–
Objective outcome					
Frankel E (numbers)	21	20	–	–	–
Radiographic outcomes—anteroposterior view					
Pedicle width fracture vertebra (mm)	23.5 $\pm$ 4.3	25.4 $\pm$ 4.6	$P < 0.001$	–	–
Pedicle width vertebrae above (mm)	22.7 $\pm$ 4.1	24.2 $\pm$ 4.2	$P < 0.001$	$P < 0.05$	$P < 0.05$
Pedicle width vertebrae below (mm)	23.4 $\pm$ 4.3	25.8 $\pm$ 4.7	$P < 0.001$	NS	NS
Disc height above fracture vertebra (mm)	8.0 $\pm$ 4.3	9.7 $\pm$ 4.4	NS	NS	NS
Disc height below fracture vertebra (mm)	8.4 $\pm$ 3.4	9.4 $\pm$ 4.0	NS	NS	NS
Closest normal disc height (mm)	8.2 $\pm$ 2.7	9.2 $\pm$ 3.7	NS	–	–
Ratio: pedicle width fracture vertebra/pedicle width vertebra above	1.23 $\pm$ 0.89	1.06 $\pm$ 0.10	NS	–	–
Ratio: pedicle width fracture vertebra/pedicle width vertebra below	1.01 $\pm$ 0.06	0.99 $\pm$ 0.04	NS	–	–
Ratio: disc height above fracture vertebra/normal disc height	0.95 $\pm$ 0.36	1.06 $\pm$ 0.36	NS	–	–
Ratio: disc height below fracture vertebra/normal disc height	1.00 $\pm$ 0.27	1.04 $\pm$ 0.36	NS	–	–
Radiographic outcome—lateral view					
Fracture vertebra anterior height (mm)	24.5 $\pm$ 6.6	24.3 $\pm$ 6.7	NS	–	–
Fracture vertebra posterior height (mm)	32.6 $\pm$ 7.0	33.3 $\pm$ 7.3	NS	–	–
Vertebra above anterior height (mm)	27.5 $\pm$ 3.8	27.8 $\pm$ 3.9	NS	$P < 0.05$	$P < 0.05$
Vertebra above posterior height (mm)	32.1 $\pm$ 5.2	34.1 $\pm$ 4.6	$P < 0.05$	NS	NS
Vertebra below anterior height (mm)	30.5 $\pm$ 6.9	30.3 $\pm$ 7.8	NS	$P < 0.001$	$P < 0.001$
Vertebra below posterior height (mm)	33.5 $\pm$ 5.7	34.9 $\pm$ 5.7	$P < 0.05$	NS	NS
Fracture vertebra canal width (mm)	17.8 $\pm$ 4.2	20.0 $\pm$ 4.0	$P < 0.05$	–	–
Vertebra above canal width (mm)	18.4 $\pm$ 3.4	20.3 $\pm$ 4.6	$P < 0.05$	NS	NS
Vertebra below canal width (mm)	18.2 $\pm$ 3.1	20.5 $\pm$ 4.2	$P < 0.01$	NS	$P < 0.05$
Ratio: anterior height/posterior height fracture vertebra	0.74 $\pm$ 0.17	0.72 $\pm$ 0.20	NS	–	–
Ratio: anterior height/posterior height vertebra above	0.87 $\pm$ 0.10	0.82 $\pm$ 0.10	$P < 0.05$	$P < 0.01$	$P < 0.05$
Ratio: anterior height/posterior height vertebra below	0.91 $\pm$ 0.17	0.87 $\pm$ 0.25	NS	$P < 0.001$	$P < 0.001$
Ratio: canal width fracture vertebra/canal width vertebra above	0.98 $\pm$ 0.17	0.99 $\pm$ 0.09	NS	–	–
Ratio: canal width fracture vertebra/canal width vertebra below	0.97 $\pm$ 0.15	0.97 $\pm$ 0.06	NS	–	–
Kyphosis ($^{\circ}$)	8.8 $\pm$ 10.8	12.1 $\pm$ 12.9	$P < 0.05$	–	–
Scoliosis ($^{\circ}$)	3.4 $\pm$ 4.2	3.5 $\pm$ 4.2	NS	–	–
Lateral displacement (mm)	0.3 $\pm$ 1.7	0.4 $\pm$ 2.1	NS	–	–
Anteroposterior displacement (mm)	1.0 $\pm$ 2.9	1.2 $\pm$ 3.8	NS	–	–

and L3, respectively, and one with a fracture Denis type A at L5) reported occasional back pain not necessitating analgesics with an Oswestry Score of 6, 8, 8, 8 and 28, respectively. Four of them were in full-time work and one in early retirement due to back pain and radicular leg pain that had developed years after the fracture event as a result of a slipped disc and failed back surgery. Twenty individuals were classified as Frankel E and three as Frankel D. The first patient with impaired

neurology achieved this at the fracture event. The second developed neurological deficits more than a decade after the fracture due to a traffic accident. The third developed weakness in the left leg two decades after the trauma due to a myelopathy in the cervical region, whereas the fracture had occurred in L1.

Radiologically, the inter-pedicular distance at the fracture level was at follow-up larger in absolute values than at the level above but not different than the level

below, the spinal canal width was narrower at the fractured level compared to the segment below but no different compared to the level above whereas the disc heights above or below the fractured vertebra were no different compared to adjacent discs (Table 1).

The patient with an at-baseline combined lateral and posterior displacement of 8 and 12 mm had now a displacement of 10 and 17 mm. The patient with an at-baseline displacement of 8 mm had now a displacement of 7 mm. The patient with an at-baseline posterior displacement of 2 mm had now no displacement. One patient with at-baseline no displacement had now a posterior displacement of 4 mm compared to the vertebrae below.

Dropout analyses

Among those 17 individuals who did not participate in the follow-up examination, 11 were boys with a mean age of 17.4 years (range 16–18) and 6 girls with a mean age of 17.7 years (range 17–18) at injury. Eleven patients were exposed to a high-energy trauma while the type of trauma was unknown in six. One patient was at admission paraplegic. Anterior wedge compression fractures were found in seven patients and burst fractures Denis type B in ten (location Th5, Th10, Th11, Th12, four L1, one L3 and one L5). Nine fractures (53%) were sustained in the thoracic region (Th5, Th6, Th7, Th9, Th10 in one case, Th11 in two and Th12 in two) while eight (47%) were found in the lumbar region (L1 in six, L3 in one and L5 in one). Three individuals had additional, minimal compression fractures in one adjacent vertebra, one in two vertebrae, one in three vertebrae and one in four vertebrae. The Oswestry Score was in those seven individuals who answered the questionnaire mean 10 (range 0–36).

Discussion

This study reports an annual incidence of thoracic or lumbar vertebral fractures during late adolescence of 0.14‰, with a distribution of fractures more resembling that in adults. The subjective, long-term outcome after a non-operatively treated fracture without or with only minor neurological deficits is predominantly favourable up to half a century after the fracture. The deformity of the fractured vertebral body did not, as is in young children, decrease with age [21], no increase in disc height was seen and the prevalence of back pain up to 47 years after a vertebral fracture was no higher than the expected prevalence of back pain [27].

This study supports the notion that the incidence of thoracic and lumbar vertebral fractures is higher in older than in younger children [4, 20, 24]. The annual incidence of vertebral fractures in children younger than

16 years of age in the same city has previously been reported to be 0.07‰ [21], half compared with the incidence in individuals aged 16–18 years. The annual incidence in the same city in men aged 50–54 years has previously been reported to be 1.4‰ and in women 1.2‰, with an increasing incidence found with advancing age, so that the incidence in men aged 85–89 years is 11.1‰ and in women 12.6‰ [16]. In Edinburgh, the incidence of vertebral fractures in children aged 15–19 years is reported to be 0.1‰ [30], in Great Britain in boys aged 16–17 years 0.15‰ and in girls 0.13‰ [5] while in Rochester community in Minnesota, the incidence of vertebral fractures in individuals aged ≤ 35 years is reported to be 2.0‰ [23]. However, it is difficult to estimate the true incidence of spine fractures, as some individuals may never seek medical care and as radiographic examination after a minor trauma in the past was rare (personal communication). Therefore, if anything, the epidemiological data presented in the current report probably underestimate the “true” incidence of vertebral fractures in childhood [18, 20].

In adults most spine fractures occur in the thoracolumbar junction [11, 31], a biomechanical weak spot between the stiff thoracic cage and the more mobile lumbar spine. In children below age 16 years, the fractures are more evenly distributed in the spine [21]. Several studies support this when they imply that no more than one-third of the fractures in children are located in the thoracolumbar (Th12–L2) junction [13, 14]. This is to be compared with the current study, in which a majority of the fractures were found in this region, suggesting that the distribution of the fractures in late adolescence more resembles the distribution of fractures in adults.

Most of the former patients with impaired neurology and subjective symptoms at follow-up had a long period free of symptoms following the fracture. This implies that the impairment was not an obvious result of the fracture. Additionally, the prevalence of former fracture patients with back pain was no higher than the age-specific prevalence of back pain in a population-based cohort [27]. Thus, it seems that non-operative treatment in stable compression fractures without neurological deficits in late adolescence cannot be regarded as a risk factor for future back disability. However, as the number of burst fractures and Chance fractures in the current study were low, all conclusions should be drawn with caution. In addition, if other treatment strategies, such as surgery, lead to an even better long-term outcome must be evaluated in future studies.

The outcome in individuals with a thoracic or lumbar fracture in late adolescence seems also more favourable than the outcome following a non-operatively treated, stable vertebral fracture in adults. From studies in adults, back pain has been reported in 21% out of 24 patients followed for 3 years [3], 25% out of 73 patients

followed for 5 years [29], 51% out of 41 patients followed for 1 year [25], 70% out of 20 patients followed for 4 years [2] and 79% out of 38 patients followed for 4 years [28]. Kraemer et al. [19] also reported that a health-related score, was lower in 24 adult individuals with a thoracic or lumbar burst fracture more than 2 years after the injury, in comparison with individuals with low back pain.

In a previous report, including patients younger than age 16 years, there was no reduced disc heights, no increased scoliosis, kyphosis, lateral, anterior or posterior displacement of the fractured vertebra [21]. Younger children also have a modelling potential, restoring the height of the fractured vertebral body with growth [21]. This modelling capacity of a vertebral body must, however, be separated from the modelling capacity of the spinal canal. Whereas a modelling capacity of the vertebral body only has been reported in young children [15], also adults with an intra-spinal fracture fragment restore the spinal canal area in the post-fracture period [6, 17]. A favourable outcome after spine fractures in young children is further supported by Parisini et al. [26] when reporting that 20 children aged below 16 years with compression fractures or a two-column burst-fractures without neurological deficits did not develop a kyphosis or scoliosis exceeding 10° in an 18 years follow-up. The data in the present study also support the radiologically favourable long-term outcome after this kind of fractures, when reporting that there was no increased scoliosis, displacement or disc reduction in the fractured segment and an increased kyphosis of no

biological significance. However, there are also reports describing both the development of kyphosis, displacement and back pain after vertebral fractures in elderly children [22, 24, 26].

The strength of this study is (1) reliable epidemiological data with the existing fracture ascertainment system, (2) the so far longest follow-up period after a vertebral fracture sustained in late adolescence, providing the possibility to address the radiological outcome in regard to growth disturbances, degenerative changes and restoration of the formerly fractured vertebra and (3) additional radiographic evaluation both at baseline and follow-up. Its weakness is the retrospective design, the inclusion of most stable, one-column compression fractures, the inability to evaluate patients with also neurological deficits and the small sample size, especially as regards unstable fractures.

Conclusion

Thoracic and lumbar vertebral fractures in adolescence with no neurological deficits and treated non-operatively have a predominantly favourable outcome even if a modelling capacity, restoring the height of the fractured vertebral body, do not occur in these ages.

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