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Thoracolumbar spinal fractures: segmental range of motion after dorsal spondylodesis in 82 patients: a prospective study

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Abstract In order to study the effect of dorsal spondylodesis on intervertebral movement in patients treated for thoracolumbar fractures, we measured the sagittal range of motion (ROM) in the segments above and below the fractured vertebral body 2 years after operation. Between 1991 and 1996, 82 consecutive patients with a fracture of the thoracolumbar spine (T12, L1, L2 and L3) were treated operatively with open reduction and stabilisation using an internal fixator, combined with transpedicular cancellous bone graft and dorsal spondylodesis. Eighteen T12, 42 L1, 17 L2 and 5 L3 fractures were included. The range of motion of two segments above and two segments below fracture level was measured. This was done on plain flexion and extension radiographs. The data were compared to normal values and to the zero distribution with the

Kolmogorov-Smirnov test. At all fracture levels the ROM of the segment adjacent to the disturbed endplate of the fractured body was zero (K-S test). All other evaluated segments showed significant loss of ROM ($P < 0.05$) compared to normal values, except segment L1-L2 in L3 fractures ($P = 0.058$). Dorsal spondylodesis at the level of the disturbed endplate in thoracolumbar spinal fractures leads to immobility in this segment, measured on flexion-extension radiographs 2 years after primary operative treatment. More than 50% loss of motion in the two adjacent levels is equivalent to complete loss of ROM in a second segment.

Keywords Spinal fractures · Spinal fusion · Range of motion, articular · Internal fixators · Segmental mobility

Introduction

Prevention of arthritic pain resulting from movement in subluxated or degenerated thoracolumbar facet joints is one of the main goals of spondylodesis of fractured vertebrae. Little is known about the effect of dorsal spondylodesis after trauma in terms of movement of the adjacent facet joints [5, 6]. In vitro stabilisation of calf lumbosacral spine specimens has shown increased mobility of the remaining adjacent segments after dorsal internal fixation [26]. In the canine model, the adjacent segments have shown increased mobility while walking on a treadmill, 12 weeks post fusion.

In patients with a fracture, we performed a fusion at the level of the disrupted (upper) endplate, in order to reduce the movements in the facet joints at this level [13].

In order to study the effect of dorsal spondylodesis on intervertebral movement, we measured the sagittal range of motion (ROM) in the vertebral segments above and below the fractured vertebral body to answer the following questions:

1. Does dorsal spondylodesis of one segment also cause loss of ROM at other segments, or does it result in increased ROM at the surrounding segments?
2. Does dorsal spondylodesis result in ankylosis of the affected intervertebral disc space?

Materials and methods

Between February 1991 and May 1996, 93 consecutive patients with a fracture of the thoracolumbar spine were treated operatively at the traumatology department of the University Hospital Groningen. Clinical records, operative records, follow-up records and radiographs were analysed. Because of small numbers of patients with T9-T11 and L4-L5 fracture levels, only the data of the T12, L1, L2 and L3 fractures were analysed ($n=82$). According to Magerl's comprehensive classification, 67 type A fractures, 8 type B fractures and 6 type C fractures were treated; one fracture could not be classified because of missing data (Table 1) [15]. Several related and unrelated traumatic diagnoses were made. Cone/caudal or root lesions were identified in 14.6% of the patients (Table 2).

Fracture reduction and fixation was performed by means of dorsal instrumentation with the Dick internal fixator or Universal Spine System (Synthes), combined with two-sided transpedicular cancellous bone graft and dorsal spondylodesis following the methods of Dick, Daniaux and Blauth [2, 3, 5, 6].

Table 1 Comprehensive classification in 82 patients

Level	<i>n</i>	Type A	Type B	Type C	Unknown
T12	18	16	0	1	1
L1	42	36	4	2	0
L2	17	11	3	3	0
L3	5	4	1	0	0

Table 2 Accompanying traumatic lesions in 82 patients

	<i>n</i>	%
No other lesions	46	56.0
Neurologic deficit	9	11.0
Unrelated other lesions	24	29.3
Unrelated other lesions as well as neurologic deficit	3	3.7

Fig. 1 Intervertebral angles at different segments

Table 3 Normal range of motion (ROM, in degrees), with standard deviation values (SD) in spinal segments

Segment	ROM	SD
T10-T11	5.0	2 ^a
T11-T12	5.0	2 ^a
T12-L1	8.0 ^a	2.2 ^a
L1-L2	11.9	2.27
L2-L3	14.5	2.29
L3-L4	15.3	2.04
L4-L5	8.2	2.99

^a Presumed values

Fracture reduction (angular reduction and distraction) was obtained by indirect manipulation using pedicle screws. Cancellous bone was taken from the dorsal iliac bone near the sacro-iliac joint and was put in the reduced vertebral body transpedicularly [3]. The facet joints at the level of the traumatised disc were opened and the cartilage was removed. Cancellous bone was packed around the joints at the dorsolateral side [2]. No ventral operations, discectomies or laminectomies were performed.

Postoperatively, all patients were transferred to a rehabilitation centre, where they were allowed to walk after 10 days in a simple reclination corset, which was worn for 9 months. In the final 3 months, patients only wore the corset in the daytime. After 9 months the implants were removed. Three months later the patients were instructed to resume all former activities. Two years after the spondylodesis, flexion and extension radiographs were obtained, which were analysed in this study.

The intervertebral angles at the two segments cranial to the fractured vertebral body and at the two segments caudal to the fractured vertebral body were measured (Fig. 1).

Measurements were made on plain radiographs while patients were standing with a maximum voluntarily flexed and extended spine. The X-ray beam was directed at the fracture level. Patient data were statistically analysed using SPSS/PC in comparison to normal movements (Table 3) and with respect to the levels that were intentionally immobilised by dorsal spondylodesis [8]. Measured data were compared to normal values and zero-distributions by the Kolmogorov-Smirnov (K-S) one-sample test, a statistical so-called goodness-of-fit test, like the chi-square test. The K-S test determines whether a sample of observed scores can reasonably be thought to have come from a population of scores with a theoretical distribution; in this case observed scores of differences and the zero-distribution. The K-S test is preferred in small numbers of measurements of a continuous (at least ordinal) scale, as in our study, because, unlike the chi-square test, it does not need to combine categories, and thus avoids losing information. The exact K-S test is definitely more powerful than the asymptotic chi-square test in tests with small samples. The tests are equally powerful with (very) large samples [27].

Results

Mean patient age in the T12 fracture group was 41.7 years, and this turned out to be slightly higher than in the T11, L1 and L2 fracture groups (35.5, 37.8 and 37.7 years respectively; $P<0.05$, Wilcoxon test).

T12 fractures

The results of the measurements of the intervertebral angles at maximum flexion and maximum extension around

the T12 vertebral body 2 years after the initial operation are listed in Table 4. At segment T11-T12, no significant movement could be determined. The other segments (T10-T11, T12-L1 and L1-L2) showed a range of motion of 1.50°, 4.61° and 6.56° respectively ($P<0.05$, $P<0.05$, $P<0.001$ respectively, compared to the zero-distribution, K-S test).

L1 fractures

The ROM values of the intervertebral segments around the first lumbar vertebral body are listed in Table 5. In 42 L1 fractures the mean ROM at level T12-L1 was 0.14° ($\pm 1.30^\circ$), i.e. no significant movement, at a level where the normal ROM is between 5° and 12°. At the surrounding levels, T11-T12, L1-L2 and L2-L3, the ROM was 2.32°, 4.67° and 9.29° respectively ($P<0.001$, compared to the zero-distribution, K-S test).

L2 fractures

No significant ROM was shown at the L1-L2 level, but significant ROM was found at segments T12-L1, L2-L3 and L3-L4 ($P<0.001$, $P=0.005$, K-S test, Table 6).

L3 fractures

Results concerning the third lumbar vertebral body are shown in Table 7. In five patients no significant ROM could be determined in segment L1-L2 ($P=0.058$) and segment L2-L3 ($P=0.182$), whereas L3-L4 and L4-L5 were mobile ($P<0.005$, $P<0.05$; K-S test).

Differences compared to normal ROM values

Relative differences to the normal values of segments related to the fracture level are summarised in Table 8 and Fig. 2. At all fracture levels, the ROM of the segment ad-

Table 4 Mobility (in degrees) 2 years after operative treatment of T12 fracture in 18 patients (*SEM* standard error of the mean, *CID* confidence interval of the difference)

Segment	Paired differences			95% CID		<i>t</i>	<i>df</i>	Signif.
	Mean	SD	SEM	Lower	Upper			
T10-T11	1.50	2.16	0.54	0.35	2.65	2.777	15	0.014
T11-T12	0.33	1.33	0.31	-0.33	0.99	1.065	17	0.302
T12-L1	4.61	7.05	1.66	1.11	8.12	2.776	17	0.013
L1-L2	6.56	4.02	0.95	4.56	8.55	6.922	17	<0.001

Table 5 Mobility (in degrees) 2 years after operative treatment of L1 fracture in 42 patients

Segment	Paired differences			95% CID		<i>t</i>	<i>df</i>	Signif.
	Mean	SD	SEM	Lower	Upper			
T11-T12	2.32	3.69	0.61	1.09	3.55	3.832	36	<0.001
T12-L1	0.14	1.30	0.20	-0.26	0.55	0.713	41	0.480
L1-L2	4.67	0.92	0.61	3.44	5.89	7.707	41	<0.001
L2-L3	9.29	4.56	4.5	7.70	10.88	11.894	33	<0.001

Table 6 Mobility (in degrees) 2 years after operative treatment of L2 fracture in 17 patients

Segment	Paired differences			95% CID		<i>t</i>	<i>df</i>	Signif.
	Mean	SD	SEM	Lower	Upper			
T12-L1	3.62	3.10	0.86	1.74	5.49	4.209	12	0.001
L1-L2	0.00	1.77	0.43	-0.91	0.91	0.000	16	1.000
L2-L3	6.65	4.77	1.16	4.20	9.10	5.747	16	<0.001
L3-L4	6.50	7.11	1.90	2.39	10.61	3.420	13	0.005

Table 7 Mobility (in degrees) 2 years after operative treatment of L3 fracture in five patients

Segment	Paired differences			95% CID		<i>t</i>	<i>df</i>	Signif.
	Mean	SD	SEM	Lower	Upper			
L1-L2	4.8	4.1	1.83	-0.27	9.87	2.626	4	0.058
L2-L3	0.50	0.58	0.29	-0.42	1.42	1.732	3	0.182
L3-L4	10.4	3.6	0.60	5.96	14.84	6.500	4	0.003
L4-L5	12.3	5.1	2.56	4.10	20.40	4.782	3	0.017

Table 8 Mobility (in degrees) in segments above and below the fracture level (see Fig. 1 for segment numbering)

Segment	Fracture T12		Fracture L1		Fracture L2		Fracture L3		Lindsey total motion [13]
	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	
I	1.50*	0.54	2.32*	0.61	3.62*	0.86	4.8	1.83	3.22
II	0.33	0.31	0.14	0.20	0.00	0.43	0.50	0.29	1.34
III	4.61*	1.66	4.67*	0.61	6.65*	1.16	10.4*	0.60	3.08
IV	6.56*	0.95	9.29*	4.5	6.50*	1.90	12.3*	2.56	6.88

* Significant difference to the zero-distribution

Fig. 2 Mobility in adjacent segments 2 years postoperatively (see Fig. 1 for segment numbering)

adjacent to the upper endplate of the fractured body did not differ from zero (K-S test).

Discussion

Measurements

Radiological measurements in analysis of segmental ROM can best be done after implantation of small tantalum balls, for example during posterolateral fusion in patients suffering from spondylolysis, spondylolisthesis, lumbar disc disorders or facet joint arthritis [9, 25]. For the purpose of our study, i.e. merely depicting more or less ROM in single segments in relation to operative fracture therapy, reliable comparison of the intervertebral angles can be done without implantation of radiopaque material.

Non-radiological measurement, for example with a Myrin inclinometer, is unreliable in single segments [16]. Measurements of segmental ROM using skin markers, and calculating their relative position, have been found to correlate highly with the radiological position of the lumbar vertebrae [12]. New computer-aided instruments, like the Spinal Mouse, combine the data concerning the relative position of the spinal vertebrae with a database of segmental heights and age-specific characteristics. This method will need further research in clinical studies to prove the reliability of external measuring of the segmental angles [24].

Normal movement

Little is known about the ROM of the uninjured spine, or of the spine after trauma in general and after operative treatment for spinal fracture in particular. Normal ROM was studied in the 1970s by Louis, White and Panjabi, and resulted in the creation of lists of segmental ROM, as published by Louis (Table 3) [14]. These studies revealed the ROM of the total spine; however, the segment T12-L1 has never been studied or published. For practical and mathematical reasons, we assumed this level to have a segmental ROM of 8°, because the facets of T12-L1 have a lumbar orientation, and one would expect the ROM to fit in with the ROM of the other lumbar facet joints [8, 19].

Movement of the spinal column after fracture stabilisation

Segments with endplate disruption show less mobility than segments without endplate disruption, especially when a formal fusion is present [13]. Although in computer models an internal fixator reduces stress in the bridged discs, and only minimally influences the stresses in adjacent discs, one cannot expect that no changes at all will occur [22]. Recent magnetic resonance imaging (MRI) studies have given some insight into what might happen to the intervertebral disc in the follow-up of operatively and non-operatively treated thoracolumbar fractures. MRI showed that the disc may rupture or may sink through the fractured endplate into the vertebral body. An increase in kyphosis was suggested to be the effect of gradual creeping of the disc into the fractured endplate. Secondary degenerative aspects like desiccation of the nucleus pulposus were not visualised [18].

One should realise that segmental flexion and extension are merely the result of a sliding movement in the slightly curved facets. This rotational movement in a sagittal plane has a centre of motion just underneath the cranial endplate [20]. The movement changes when the form of the disc changes. Prevention of motion in the intervertebral facet joints will prevent movement in the intervertebral (disc) space, and will therefore prevent flexion and extension at this level. However, osseous healing of the dorsal fusion of the facet joints does not automatically imply “total stabilisation” of the segment [17]. Moreover, resection of the disc, combined with transpedicular interposition of can-

cellous bone graft in order to fuse the vertebral bodies results in failure of radiological fusion in 66% of the cases, and in some residual segmental movement [10]. The performance of disc resection is questionable anyhow, since MRI investigations have shown only minor structural damage to the nucleus pulposus and the fibrous disc structures [23].

ROM at adjacent segments

Accelerated degeneration of the facets of the segment adjacent to the fusion level, when performed for low back pain, has been described [11]. Hypertrophic degenerative arthritis, as well as severe disc degeneration (without herniation) [3] was found responsible for the recurrence of complaints after fusion. It is not certain whether this category of patients with degenerative disease can be compared to trauma patients [11].

All evaluated segments were less mobile than normal values. This observation was also recorded by Lindsey et al. [13]. It is therefore reasonable to conclude that compensational movement at adjacent segments does not occur, although increased mobility in adjacent segments was shown in the canine model 12 weeks post fusion [4]. The reason for this may be fibrosis by trauma or operative procedure, but it may also be an effect of prolonged partial immobilisation, pain or even psychosomatic mechanisms.

We advised 9 months of external immobilisation to protect the patient against implant failure. However, Rohlmann and co-workers recently showed that braces do not reduce the load on internal spinal fixators [21]. So it seems reasonable that shorter immobilisation should be considered in order to optimise the ROM of the unstabilised segments I and IV (Fig. 1).

No actual ROM values of spinal segments in comparable groups have been published in the literature. We compared our data to the ROM values supplied by White and Panjabi [14]. In a retrospective study about this subject, Lindsey compared the residual segmental mobility in 16 patients with fusion with that in 43 patients without fusion. At all levels, fused segments showed less mobility than unfused segments, and unfused levels were less mobile than normal segments. The mean ROM values of the different segments as found by Lindsey are listed in Table 8 [13]. In our data we observed that, besides the intended loss of motion in the upper disc segment caused by the spondylodesis, more than 50% of the ROM of both spared adjacent levels is lost as well in T10, L1 and L2 fractures. This loss accounts for 7°–13°, which is comparable to a complete loss of ROM of a second segment.

Paradox or inverse segmental movement was measured in the upper endplate segment in some patients. Instead of the movement observed normally, a small movement in the opposite direction was measured in these patients. We did not find an explanation for this phenomenon. A similar phenomenon has been described in the cervical spine as a physiologic condition. In the last part of the flexion motion, the C0-C1 segment does not flex further, but extends a little [1, 7, 20].

Conclusion

Dorsal spondylodesis at the level of the disturbed endplate in thoracolumbar spinal fractures leads to immobility in the affected segment, measured on flexion-extension radiographs 2 years after primary operative treatment. More than 50% loss of motion in the two adjacent levels is equivalent to complete loss of ROM in a second segment.

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