Thoracolumbar spinal fractures
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Document Version
Publisher's PDF, also known as Version of record

Publication date: 2002

Link to publication in University of Groningen/UMCG research database

Citation for published version (APA):
Burst fractures of the thoracolumbar spine: changes of the spinal canal during operative treatment and follow-up


Accepted European Spine Journal October 2002

Introduction

One of the goals of operative treatment of spinal fractures is restoration of the anatomy of the spinal chain, including the spinal canal. Since 1988 we have been using instrumental decompression of the spinal canal at the thoracolumbar junction in an indirect way, what is said to be by ligamentotaxis through distraction applied via pedicle screws of an internal fixator [1;9-11;16;23-25].

In a dorsal approach all fractures were treated by instrumental angular reduction, distraction, and stabilisation with Dick’s internal fixator [8;9;11]. Since 1995 we have used the Universal Spine System® Synthes. The procedure was combined with unilateral (1988-1989) or bilateral (1989-1996) transpedicular cancellous bone grafts, as described by Daniaux [5]. Posterior spondylodesis was performed only at the level of the disturbed cranial or caudal end plate [26;27].

Several authors have described spontaneous remodelling of the spinal canal during the course of treatment, with or without instrumentation. This finding has been used as an argument against all operative treatment or against direct (open) manipulation of the bony fragment [3;4;17;21;24;34]. One of the parameters that correlate with spinal canal encroachment is the posterior vertebral height (PVH)
Another important factor concerning the reduction is the antikyphosed position of the disk and its bony fixation as well as the rigid fixation [1;7]. To quantify the process of reduction during operation and spontaneous remodelling during the period of reconvalescence, we studied this process in patients with burst fractures of the thoracolumbar junction who were treated by indirect fracture reduction and internal fixation. There were three questions to answer:

- Are there any changes of the posterior segmental height PSH (the sum of posterior vertebral height and posterior intervertebral height) in plain lateral radiographs during operation and in the course of further treatment?
- Does bony narrowing of the spinal canal, as identified in plain lateral radiographs disappear in the course of treatment, and if so, how many of these patients have developed a normal width of the spinal canal two years after the initial treatment?
- Are there changes of the midsagittal diameter of the spinal canal in selected cases with considerable preoperative spinal canal narrowing, as measured in CT-slices.

Presumably the effect of the so-called ligamentotaxis can be measured as changes of the above mentioned parameters in the perioperative period. The PSH reflects the length of the segmental part of the posterior longitudinal ligament that is involved in the ligamentotaxis. The effect of spontaneous remodelling is reflected in changes of the studied parameters after the operation.

Materials and methods

Between March 1988 and August 1996 183 consecutive patients with thoracolumbar fractures (T9-L5) were treated operatively at the Traumatology Department of the University Hospital Groningen. Of these patients 95 had A3-fractions of the thoracolumbar junction (T9-L2) that were treated with indirect operative reduction and fixation with Dick’s internal fixator, combined with transpedicular cancellous bone grafting and posterior spondylodesis (Table 1). In these patients the preoperative plain lateral radiographs (t=0) were studied, as well as the postoperative radiographs (t=1), the radiographs after 9 months (before implant removal, t=9), and at 24 months (t=24).

The sub-classification, according to the comprehensive classification, of the fractures and the percentage of patients with neurological deficit are shown in table 2 [29].
Table 1 Level of spinal fractures (n=95)

<table>
<thead>
<tr>
<th>Level</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T9</td>
<td>1 (1.1)</td>
</tr>
<tr>
<td>T10</td>
<td>1 (1.1)</td>
</tr>
<tr>
<td>T11</td>
<td>1 (1.1)</td>
</tr>
<tr>
<td>T12</td>
<td>24 (25.3)</td>
</tr>
<tr>
<td>L1</td>
<td>51 (53.7)</td>
</tr>
<tr>
<td>L2</td>
<td>17 (17.9)</td>
</tr>
<tr>
<td>Total</td>
<td>95 (100)</td>
</tr>
</tbody>
</table>

Table 2 Comprehensive classification in 95 patients with A3-fractures and the number and percentage of neurological deficit

<table>
<thead>
<tr>
<th>Classification</th>
<th>n</th>
<th>Neurological deficit (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A3.1</td>
<td>55</td>
<td>9 (16.4)</td>
</tr>
<tr>
<td>A3.2</td>
<td>25</td>
<td>3 (12.0)</td>
</tr>
<tr>
<td>A3.3</td>
<td>15</td>
<td>3 (20.0)</td>
</tr>
<tr>
<td>A3 total</td>
<td>95</td>
<td>15 (15.8)</td>
</tr>
</tbody>
</table>

*Posterior segmental height*

The changes of the posterior segmental height PSH in the course of treatment and follow-up were analysed (Fig.1). Technical differences in radiographic technique were corrected using the proportion of the measured and unchanged height of the adjacent vertebral bodies. Correction of the imaging amplification factor in lateral radiographs (15-20%) was not done, because this would not influence the statistical tests. Most measurements were performed in the center of the photograph. In case of distortion of the radiograph by non centered beam the projected area of the disc was determined from the oval outlines of the rims of the vertebral endplates (Fig.1). Guidelines as described by Frobin were followed, resulting in a relative measurement error of approximately 3%, consisting of a relative error of the posterior vertebral height of 2.2% (0.7mm) and of the disk height of 4.2% (0.5mm) [15].
Fig. 1 Measurement of posterior segmental height (PSH=PIH+PVH).
See text for explanation

**Bony narrowing**
In all 95 patients the plain lateral radiographs were studied and recognisable bony narrowing of the spinal canal (with or without recognition of a fracture part) were registered (Fig. 2). After an initial period in which conventional tomographies were used in the preoperative workup, all patients had preoperative CT-scans. In all preoperative CT-scans the midsagittal diameter was measured and patients were classified in 4 groups: no narrowing, less than one third canal narrowing, more than one third, but less than two third narrowing and more than two third canal narrowing [28].

![Fig. 2 Recognizable bony narrowing in plain lateral radiographs in patient with A3.1 fracture, preoperative t=0, postoperative t=1 (horizontal arrows pointing at fragment), at 9 months t=9, and at 24 months t=24 (vertical arrow pointing at completely reduced posterior wall)](image-url)
Midsagittal diameter
In 66 patients preoperative CT-scans were available to measure the midsagittal
diameter. In 13 patients with a preoperative narrowing of the spinal canal of more
than one third we compared the preoperative midsagittal diameter of the spinal
canal with the diameter at two years after operation by CT-scanning. In
computerized tomographies of the spinal canal preoperatively and after two years
the minimum midsagittal diameter of the spinal canal was compared to the mean of
the minimum diameter of the spinal canal one level cranial and one level caudal.
These percentages represent the remaining space in the spinal canal and changes in
diameter represent the summed effect of reduction and remodelling. The CT data of
these patients were compared to the data of the plain lateral radiographs.
Statistical analysis was performed with the paired samples t-test, a parametric test.

Results

Posterior segmental height
The mean PSH in preoperative radiographs measured 40.5 mm, after operation
43.2 mm, before implant removal 41.0 mm and at 24 months it measured 38.7 mm
(Table 3). Analysis of the (calculated) changing of the PSH in paired
measurements in the perioperative period, the period until implant removal and the
period until 24 months after the initial operation show an increase of the PSH
during operation of 2.7 mm (p<0.001). After the operation a decrease of 2.2 and
2.3 mm respectively occurs (p<0.005) (Table 4).

Table 3 Posterior segmental height (summed posterior vertebral height and posterior
intervertebral height) and percentages of patients with
recognisable bony canal narrowing in the plain lateral radiographs
during the course of treatment (n=95). SD Standard deviation

<table>
<thead>
<tr>
<th>Period</th>
<th>PSH (mm)</th>
<th>SD (mm)</th>
<th>Bony narrowing (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative</td>
<td>40.5</td>
<td>5.7</td>
<td>76.5</td>
</tr>
<tr>
<td>Postoperative</td>
<td>43.2</td>
<td>4.1</td>
<td>18.4</td>
</tr>
<tr>
<td>At 9 months</td>
<td>41.0</td>
<td>3.9</td>
<td>8.2</td>
</tr>
<tr>
<td>At 2 years</td>
<td>38.7</td>
<td>3.8</td>
<td>2.4</td>
</tr>
</tbody>
</table>
**Table 4** Paired samples t-test comparing the calculated differences of the length of the ligament along PVH and PIVS to the test value zero.

Period 1= perioperative period, period 2= the period between initial operation and implant removal, period 3= period after implant removal until end of follow up at 24 months. CID= confidence interval of the difference, SEM= standard error of the mean, t= test value, df= degrees of freedom

<table>
<thead>
<tr>
<th>Period</th>
<th>n</th>
<th>Mean (mm)</th>
<th>SD  (mm)</th>
<th>SEM (mm)</th>
<th>95% CID Lower</th>
<th>95% CID Upper</th>
<th>t</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>83</td>
<td>2.72</td>
<td>5.72</td>
<td>0.63</td>
<td>1.47</td>
<td>3.97</td>
<td>4.34</td>
<td>82</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>2</td>
<td>82</td>
<td>-2.16</td>
<td>4.60</td>
<td>0.51</td>
<td>-3.17</td>
<td>-1.14</td>
<td>-4.25</td>
<td>81</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>3</td>
<td>83</td>
<td>-2.29</td>
<td>3.29</td>
<td>0.36</td>
<td>-3.01</td>
<td>-1.57</td>
<td>-6.34</td>
<td>82</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

**Fig.3** Percentage of patients with bony spinal canal narrowing in plain lateral radiographs in 95 patients with A-type fractures

**Table 5** Narrowing of the spinal canal measured in CT-scans of 66 patients with burst fractures and the number and percentage of neurological deficit

<table>
<thead>
<tr>
<th>Narrowing</th>
<th>n (%)</th>
<th>Neurological deficit (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>7 (10.6)</td>
<td>1 (14.3)</td>
</tr>
<tr>
<td>&gt;0-1/3</td>
<td>32 (48.5)</td>
<td>4 (12.5)</td>
</tr>
<tr>
<td>1/3-2/3</td>
<td>23 (34.8)</td>
<td>5 (21.7)</td>
</tr>
<tr>
<td>&gt;2/3</td>
<td>4 (6.1)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Total</td>
<td>66 (100)</td>
<td>10 (15.2)</td>
</tr>
</tbody>
</table>
**Bony narrowing**

In plain lateral radiographs recognizable bony encroachment of the vertebral canal was seen preoperatively in 76.5% of the patients, postoperatively in 18.4%, at nine months in 8.2% and at two years in 2.4% (Table 3 and Fig.3).

**Midsagittal diameter**

Preoperative CT-scans in 66 patients with A-fractures showed in 89.4% a measurable spinal canal narrowing. Less than one third canal narrowing was found in 48.5%, 34.8% had more than one third spinal canal narrowing, but less than two third. Only 6.1% of the patients had more than two third canal narrowing. Patients with spinal canal narrowing of 1/3 to 2/3 showed the highest percentage of neurological deficit (Table 5).

Traumatic narrowing of the spinal canal in the sagittal plane in the preoperative CT-scans left a mean residual midsagittal diameter of 52.3% (n=66). After two years the midsagittal diameter was 78.3% (n=13). Bony narrowing in the lateral radiographs in these patients was recognized in 92% and 15% respectively (Table 6).

| Table 6 | Residual percentage of midsagittal spinal canal diameter in CT-scan and number (percentage) with recognizable bony narrowing in lateral radiograph in 13 patients |
|-----------------|-----------------------------------------------------|------------------------------------------------------|
| | Canal narrowing in CT | Bony narrowing (%) |
| | Mean (%) | SD | |
| Preoperative | 47.7 | 21.6 | 12 (92) |
| Two year | 21.7 | 20.5 | 2 (15) |

The paired samples t-test showed that the changes between preoperatively and two years postoperatively accounted for 25.0% (2 tailed significance p<0.001) (n=14) (Table 7).

| Table 7 | Paired t-test, comparing differences between preoperative residual ratio of the midsagittal diameter of the spinal canal and the residual spinal canal at two years |
|-----------------|-------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Mean | SD | SEM | 95% CID | t | df | p |
| Lower | Upper | |
| Difference | 0.25 | 0.18 | 0.049 | 0.14 | 0.36 | 5.06 | 12 | <0.001 |
Discussion

It is generally accepted that bony encroachment of the spinal canal in the thoracolumbar region by one third or more might jeopardize the spinal cord [18;28]. There is a correlation between the level of the spinal fracture and the probability of neurological deficit. More cranial levels of fracture have a higher probability of neurological deficit [12]. The percentage of spinal canal narrowing as measured in CT-scan has a positive correlation with the probability of neurological deficit as well [12;18]. In this regard one should realize that the measured residual diameter at the preoperative radiographs is larger than the diameter at the moment of trauma [30]. Another aspect of interest is that the midsagittal diameter overestimates the canal narrowing, compared to area surface measuring [13].

*Posterior segmental height*

Through intact spinal ligaments and discs a partial fracture reduction will be induced when the patient is put in a supine position during initial care and transport. Extension does not widen the spinal canal in an unfractured spinal column [20], but the combination of angular fracture reduction and distraction will widen the spinal canal by means of ligamentotaxis [14]. For anatomical reasons ligamentotaxis below L2 level is weak or even absent [24]. If the longitudinal ligaments—especially the posterior longitudinal ligament—are not (completely) disrupted, distraction and antikyphosis (ligamentotaxis) can achieve a reduction of bony fragments narrowing the spinal canal of the injured spine. The effect of the forces conducted via the attachment of the annulus to the endplates by instrumental and postural antikyphosing reduction will add to the restoration of the spinal canal wall.

*Bony canal narrowing*

It is the trabecular structure of the spinal body that causes the typical trapezoid fracture part in the posterior wall in burst fractures, which results in narrowing of the spinal canal. The trabeculae are found at the medial corner of the base of the pedicles and extend in a radial array throughout the vertebral body. A stress concentration near the base of the pedicles results in the typical fracture at the posterior wall of the vertebral body in severe compression [19]. In 1991 Johnsson reported about 17 thoracolumbar fractures and concluded that manipulative open reduction of spinal canal wall and bony fragments in the spinal canal is not necessary because spontaneous spinal canal remodelling occurs in operated and non-operated patients. In his study 14 operated and 3 non-operated
patients in a follow-up of 1-4 year were evaluated. One of the conclusions was that there were no differences between non-operated and operated cases concerning the restitution of the spinal canal. In his study the measurements were difficult to interpret because laminectomy in some cases or interference from Harrington rods in other cases influenced the quality of the radiographs and the measurements [21]. Scapinelli reported in 1995 about 5 adult patients with thoracolumbar spinal fractures with associated intracanalar displacement of a large bone fragment. Two of these patients had no neurological deficit and three patients had. Four patients underwent operative posterior stabilization by Harrington rods and bone autografts without surgical decompression. These treatments lead to neurological recovery in all but one case. Comparison of computer tomography scans in all patients after 1.5 to 5 years later showed remodelling of the spinal canal. Rhythmic respiratory oscillations in the cerebrospinal fluid pressure were suggested as a factor in the mechanism of bone resorption. It was concluded that removal of intraspinal fragments is not longer necessary [32].

The discussion about laminectomy as the procedure of choice for decompression in patients with neurological deficit will probably never end completely. We earlier reported about 183 patients (17% of them had neurological deficit) treated by dorsal instrumentation, in which we only used operative decompression by laminectomy in one case, because of progressive neurological deterioration after the initial dorsal operative procedure [27]. Boerger [2] showed that no reason for surgical decompression can be found in published research. In the present study we confirm a link between initial canal narrowing and its risk for traumatic neurological deficit. We could not confirm a higher incidence of neurological deficit in the subclassification of more severe A3 fractures, but low numbers of A3.3 type fractures and low numbers of severe (more than 2/3) traumatic canal narrowing make it impossible to draw any conclusion of this observation. One should realize that the midsagittal diameter reduction overestimates the traumatic reduction of the spinal canal compared to CT area measurements [13].

The present study shows that fracture reduction by angular correction and distraction is accompanied with a marked increase of patients with a cleared spinal canal from 23.5% to 81.6%. This very large change is followed by a further increase of the number of patients with complete canal clearance to 91.8% at 9 months postop. At the end of follow up- at 24 months postop -only 2.4% of the patients have residual canal narrowing (Fig.3).

**Midsagittal diameter**

The caliber of the vertebral canal in the lumbar region shows a large variation. The anteroposterior diameter in normal individuals decreases from 17.3 mm (range
13-22 mm at level L1) to 15.9 mm (range 9-21 mm at level L4) [6;28]. At the thoracolumbar zone cross section of spinal canal shows the transition of an oval format (thoracic spine) to a triangular form with rounded angles (lumbar spine) [28]. The diameter of the spinal cord has a mean caliber of 10 mm, although it might be broader at the thoracolumbar region. Normally this results in considerable spare room around the spinal cord. In 1998 de Klerk et al. reported about a retrospective study of 42 trauma patients with initial spinal canal stenosis of more than 25% that were treated conservatively [22]. Computerized tomography in his study was performed at 12 months to 108 months after the injury. One of their conclusions was that conservative treatment is followed by a marked degree of spontaneous restitution of the deformed spinal canal. They showed that the higher the initial percentage of canal stenosis, the greater the spontaneous reduction. Age at the time of injury was inversely correlated with the reduction in the percentage of spinal canal stenosis. No correlation was found considering the spontaneous reduction of the spinal canal stenosis and the time gone by since the injury. This suggests that the changes have occurred within the first 12 months. In 1992 Gertzbein showed a reduction of the preoperative canal encroachment by distraction forces, delivered by an internal fixator, from 54% to 40% only, but a selection of patients operated within the first four days after their injury showed a reduction from 56% to 38% [16]. The importance of the sagittal alignment with respect to the forces that act on the fracture parts has to be stressed. The antikyphosing reduction is reflected in an increase of the postoperative intervertebral angle [27]. The rigid fixation of the annulus to the upper and lower fragment parts will certainly add to the reduction forces. Segmental stability by rigid fixation will add to the persistence of the reduction force. In our series the lateral radiographs show that in only 18.4% of the cases canal encroachment could be visualized postoperatively. It seems logical to measure the midsagittal diameter in the lateral plain radiographs, but in contrast to the dorsal part of the vertebral body the arch can not be distinguished enough in the lateral radiograph to gain reliable measurements. The incidence of spinal cord injury with spine fractures and dislocations is approximately 14% of the total as ascertained from a survey of these injuries in Northern California [31]. Injuries to the cervical spine most often produced neurological damage, the incidence of neurological deficit being 39% [31]. Patients sustaining fractures of the vertebral bodies and posterior elements with some degree of malalignment of the spine even had a 61% incidence of neurological deficit. In our series we found more than 20% neurological deficit in patients with 1/3 to 2/3 spinal canal narrowing, but we saw 4 patients with a high degree of traumatic canal narrowing (>2/3) without any neurological deficit (Table 3). This
is surprising, because canal narrowing influences the risk of neurological involvement. L1-fractures with more than 65% of canal narrowing have a high probability to be accompanied by neurological deficit [18;33].

Conclusions

In this study we showed that the initial restoration of the spinal canal by indirect manipulation and disco-ligamentotaxis is incomplete. The posterior segmental height increases in the perioperative period and clearance of the spinal canal is observed in about 75% of the patients with traumatic canal narrowing in the plain lateral radiographs. Later ligamentotaxis does not play a role anymore, because the PSH even diminishes. The clearance of the spinal canal as interpreted from lateral radiographs continues in the course of follow-up. At two years after operation about 97% of all patients with burst fractures have a completely free spinal canal in the lateral radiograph, but not all fractures and fracture parts can be identified in plain lateral radiographs. So plain lateral radiographs seems to overestimate the process of remodelling.

This study provides clinical data for the description of (partial) spontaneous remodelling. This phenomenon can be observed in plain lateral radiographs, but not as accurate as in CT-scans.

References


