LIGAMENTOTAXIS WITH AN INTERNAL SPINAL FIXATOR FOR THORACOLUMBAR FRACTURES

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We assessed narrowing of the spinal canal in 39 burst fractures and fracture-dislocations of thoracolumbar vertebrae treated by the AO Internal Spinal Fixator, using CT preoperatively and at various stages postoperatively. Computer-aided planimetry was used to measure the narrowing, and its restoration shortly after instrumentation, or at 15 months.

The mean initial reduction of canal area was to 63.7% ± 18.8% of normal; this was restored to a mean of 95.4% ± 21.2% of normal when measured either soon after surgery or at 15 months ($p < 0.001$ for both groups). There was more improvement in cases assessed later. For fractures from D12 to L3, the mean canal area was restored to 99.4% of normal; but at L4 or L5 the mean restitution was to only 60.9% ($p < 0.05$). We found no correlation between preoperative loss of area and amount of restoration, or severity of neurological deficit. Nor was there any correlation between the delay before surgery and the improvement achieved.

The mechanism of fracture reduction appears to be a combination of distraction ligamentotaxis and forced hyperextension.

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Ligamentotaxis is a method of indirect reduction of fracture by the application of a strong distraction force (Vidal, Buscayret and Connes 1979), which is transmitted through intact ligaments and capsules and helps to restore skeletal anatomy. This method has been successfully used for fractures such as those of the tibial pilon and the distal radius. We have studied the use of similar principles for spinal fractures with retropulsed fragments.

The reduction of spinal fractures has been measured by correction of kyphotic deformity (Gertzbein, Macmichael and Tile 1982; Esses 1989), the sagittal index of narrowing (Blauth, Tscherne and Haas 1987), and by the restoration of vertebral body height (Aebi et al 1987). Myelography (Aebi et al 1988) and the measurement of anteroposterior canal diameter by CT (Esses, Botsford and Kostuik 1990) have been used to provide limited information on the results of canal decompression.

We have evaluated the efficacy of ligamentotaxis applied by the AO Internal Spinal Fixator for thoracolumbar fractures. We used computer-aided planimetry to assess the restoration of canal area, a method not previously reported.

PATIENTS AND METHODS

The AO Internal Spinal Fixator has been used since 1985 in the University Department of Traumatology, Freiburg, to stabilise over 100 thoracolumbar fractures of various types. These included severe compression and burst fractures with no canal narrowing, burst fractures and fracture-dislocations with canal narrowing, fractures with and without neurological deficit, and a few pathological fractures. For the purposes of this study we included only patients with evidence of canal narrowing from burst fractures or fracture-dislocations treated by ligamentotaxis. A total of 38 patients (39 fractures) had a minimum follow-up of two years with both preoperative and postoperative CT available. These patients were studied in detail.

There were 20 men and 18 women with a mean age of 32 years (15 to 57); one patient had fractures at both L2 and L4. Nineteen patients had no other injury; 19 had multiple injuries. The mechanism of injury was a fall from a height (17), a vehicle accident (14), sports injury (5) or direct injury (2). The levels of the fractured vertebrae were D12 (9), L1 (14), L2 (8), L3 (4), L4 (2), and L5 (2). Using Denis'(1983) classification, there were 34 burst fractures and 5 fracture-dislocations.

Narrowing of the spinal canal was graded on the preoperative scans into three groups (Wolter 1985): group 1 had narrowing to less than one-third of the normal (17); group 2 had narrowing to between one-third and two-thirds (21); and group 3 had less narrowing, leaving over two-thirds of normal (1). The preoperative neurological status was Frankel grade E in 14 patients, grade D in 23, and grade C in one.

The operation was carried out at a mean of 2.4 days after injury (from a few hours to 7 days) in the 34 patients who presented directly to us; 24 were treated in under 3 days

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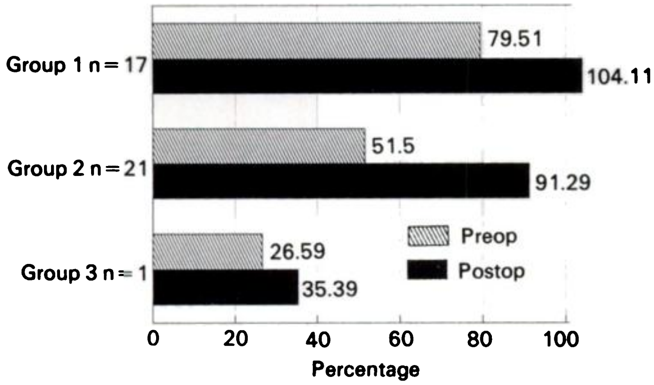

Fig. 1

Planimetry results showing the average preoperative and postoperative canal areas for the three groups: group 1 < 33%; group 2 33% to 67%; group 3 > 67%.

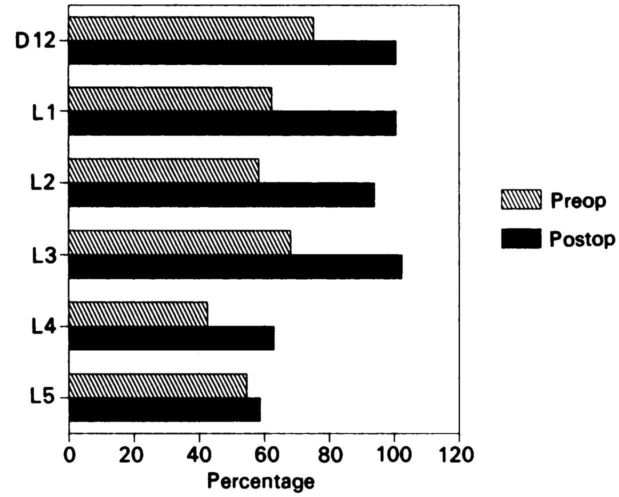

Fig. 2

Average preoperative and postoperative canal areas related to vertebral level.

and 10 from 4 to 7 days. Four patients were delayed referrals from other hospitals; they had operations from 12 to 18 days after injury. The Internal Spinal Fixator was used in all cases, with techniques and after-care which have been previously described (Dick 1984, 1987; Aebi et al 1987). We always use an image intensifier while inserting Schanz screws and perform transpedicular bone grafting in most cases.

The preoperative CT scans were assessed by planimetry, using the Sigma Scan/Jandel system to determine the canal area. The preinjury dimensions of the canal were estimated by averaging those of the adjacent vertebrae. Postoperative scans were made a few days after surgery in 14 patients and before implant removal, usually performed after 15 months, in the other 24. All measurements were made by one author (AK) who was not associated with the selection or treatment of the patients. The mean of three readings was used to obtain each value. We also determined the accuracy of placement of Schanz screws in the pedicles (Gertzbein and Robbins 1990).

RESULTS

Table I summarises the details of all the patients, and Figure 1 shows the results of planimetry. The estimated initial canal area had been reduced to 63.7% ± 18.8 (SD); it was restored to a mean of 95.4% ± 21.2 after surgery ($p < 0.001$, Wilcoxon test). We found no correlation between the degree of initial narrowing and the final dimension. As regards level, fractures from D12 to L3 gained nearly 100% restitution of their canal area (Fig. 2), while those below L3 were restored to a mean

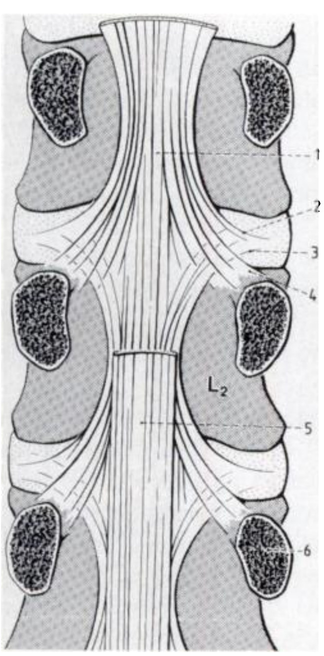

Fig. 3a

Fig. 3b

Diagram and specimen to show the posterior longitudinal ligament on the dorsal aspect of the upper lumbar vertebral bodies: 1, deep layer; 2 and 3, fibres to annulus fibrosus; 4, fibres to pedicle; 5, superficial layer; and 6, pedicle. (Specimen by permission of Prestar FJ and Putz R 1982).

Table I. Details, results of planimetry, and neurological status of 38 patients (39 fractures) treated by ligamentotaxis for burst fractures

				Area of canal (cm^2)					Frankel grade	
Level/case	Age (yr)	Sex	Delay (days)	Estimated normal	Preop	Final	Decrease in canal area (*per cent*)	Final canal area (*% of normal*)	Preop	Postop
D12										
1	57	M	2	2.78	1.90	1.94	*31.81*	*69.59*	D	E
2	20	M	4	3.89	3.06	3.63	*21.29*	*93.17*	D	E
3	44	M	1	3.14	2.85	3.97	*9.32*	*126.25*	D	D
4	19	F	1	2.26	2.51	2.76	*- 10.87*	*122.01*	E	E
5	21	F	2	2.99	2.11	3.54	*29.37*	*118.65*	C	D
6	35	M	3	2.42	1.95	2.32	*19.38*	*95.71**	D	E
7	21	M	1	2.64	1.63	3.14	*38.19*	*119.00*	D	D
8	33	M	18	2.40	1.43	1.79	*40.40*	*74.55**	E	E
9	17	F	1	2.83	1.58	2.46	*44.09*	*86.73*	D	E
							(mean *24.78*, SD *17.39*)	(mean *100.63*, SD *21.48*)		
L1										
1	15	M	1	3.13	2.18	3.39	*30.35*	*108.41*	D	E
2	51	F	1	2.58	1.91	2.54	*26.14*	*98.57*	D	D
3	20	M	1	3.51	2.47	3.93	*29.55*	*111.78*	E	E
4	23	F	6	2.44	1.82	2.20	*25.62*	*89.97*	E	E
5	33	F	14	2.74	1.86	3.24	*32.03*	*118.17*	D	D
6	30	F	1	3.12	3.33	3.20	*- 6.69*	*102.63**	D	D
7	43	M	1	4.03	1.60	2.46	*60.26*	*60.95**	E	E
8	20	F	12	3.10	1.55	2.38	*50.08*	*76.88**	E	E
9	28	F	2	3.15	1.59	2.55	*49.43*	*81.18**	E	E
10	35	M	1	2.84	1.82	2.80	*35.68*	*98.84*	D	D
11	36	F	2	2.36	1.06	2.62	*55.23*	*111.18**	E	E
12	50	M	4	2.82	1.40	2.73	*50.23*	*96.95**	E	E
13	23	F	5	3.48	1.97	3.91	*43.27*	*112.39*	D	E
14	30	M	4	2.95	1.60	4.16	*45.79*	*141.38*	D	D
							(mean *37.64*, SD *17.02*)	(mean *100.66*, SD *19.72*)		
L2										
1	17	F	1	2.86	2.15	2.99	*24.88*	*104.65*	E	E
2	23	F	1	2.86	2.15	3.50	*24.96*	*122.02*	D	D
3	35	F	7	2.82	1.33	2.29	*52.98*	*81.13**	E	E
4	47	F	2	2.66	1.2	2.00	*54.82*	*75.19**	D	E
5	32	M	1	3.79	2.06	3.85	*45.74*	*101.58*	D	E
6	24	M	1	2.36	1.32	2.05	*44.12*	*87.10**	D	D
7	52	M	7	3.36	1.89	2.86	*43.66*	*85.01*	E	E
8†	25	F	5	3.34	1.94	3.18	*41.85*	*95.04*	D	D
							(mean *41.63*, SD *11.27*)	(mean *93.97*, SD *15.14*)		
L3										
1	30	M	6	2.93	2.28	3.19	*22.04*	*109.13*	D	D
2	23	M	1	2.43	2.50	2.77	*- 2.88*	*114.03**	D	D
3	29	F	2	2.62	1.09	2.51	*58.39*	*95.91*	D	E
4	20	F	1	2.14	1.08	1.94	*49.70*	*90.67*	D	D
							(mean *31.81*, SD *27.84*)	(mean *102.43*, SD *10.96*)		
L4										
1	29	M	1	3.65	1.56	1.96	*57.23*	*53.63**	E	E
2†	25	F	5	3.03	1.29	2.20	*57.72*	*72.48*	D	D
							(mean *57.47*, SD *0.21*)	(mean *63.05*, SD *13.32*)		
L5										
1	17	M	17	3.68	3.03	3.02	*17.48*	*82.22*	E	E
2	38	M	1	3.56	0.95	1.26	*73.42*	*35.39**	D	D
							(mean *45.45*, SD *39.55*)	(mean *58.81*, SD *33.11*)		

* measured soon after operation: the others were measured at implant removal (about 15 months)
† this patient had 2 fractures: at L2 and L4

60.9%. The difference between these two groups is significant ($p < 0.05$, Wilcoxon test).

The neurological status changed from Frankel grade C to D in one case, remained at grade D in 14 patients (15 fractures) and changed from grade D to grade E in nine. All 14 patients with grade E remained unchanged; none became worse. We found no correlation between the degree of canal narrowing and the severity of neurological damage (Wilcoxon test), or between the time interval from injury to operation and the success of restitution of the canal.

The 14 patients who had their postoperative CT soon after surgery had an average initial narrowing to 51.5% of normal, with restoration to 79.9% of normal. The 24 who were scanned after a mean of 15 months had an initial narrowing to 31.4% of normal; at 15 months the canal was restored to 99.8%. In both groups the improvement obtained was highly significant ($p < 0.001$, Wilcoxon test).

The CT also allowed verification of the accuracy of screw placement in 147 of the 168 screws inserted. Of these, 124 (84.5%) were correctly located in the pedicle, 16 (10.8%)

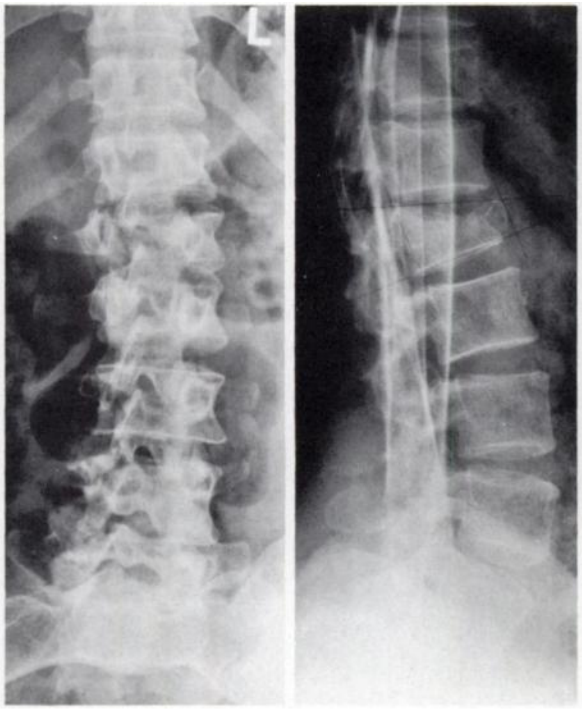

Fig. 4a

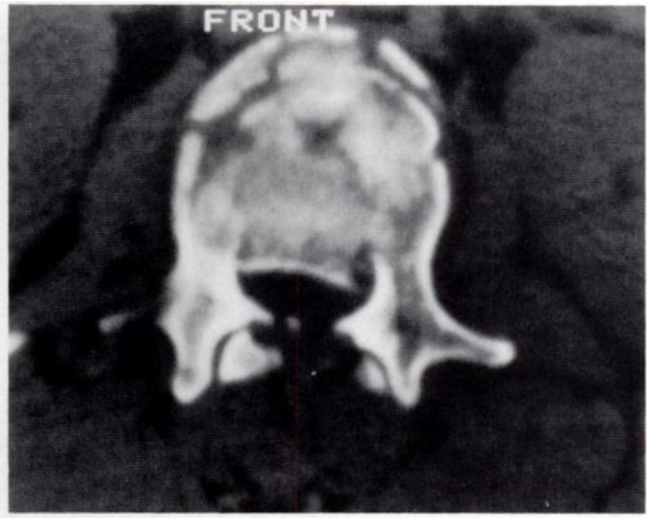

Fig. 4b

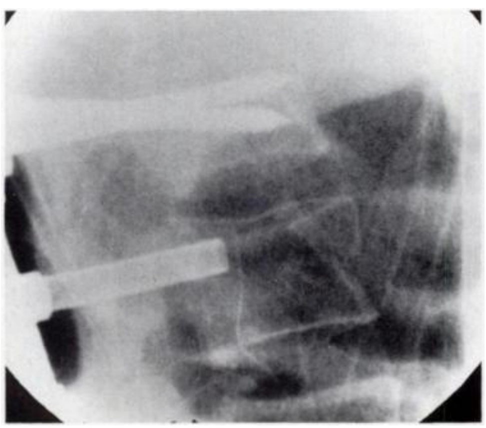

Fig. 4c

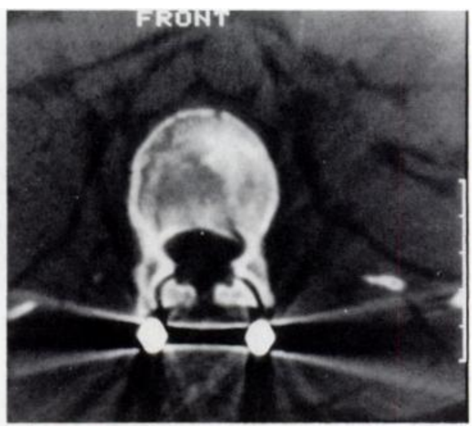

Fig. 4d

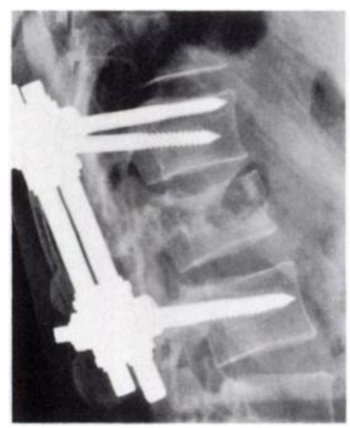

Fig. 4e

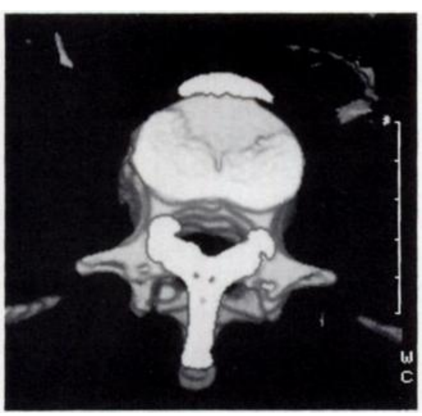

Fig. 4f

Radiographs and CT scans of a 36-year-old woman with a burst fracture of L1 and no neurological deficit. Figure 4a – Preoperative radiographs. Figure 4b – Preoperative CT scan showing narrowing to 55%. Figure 4c – Transpedicular bone grafting under image-intensifier control. Figure 4d – Early postoperative CT scan showing complete restoration of spinal canal. Figure 4e – Radiograph at one year before implant removal. Figure 4f – Three-dimensional CT reconstruction after implant removal.

were slightly medial, and 7 (4.7%) were slightly lateral. None was extrapedicular.

DISCUSSION

The use of the Internal Spinal Fixator aims to restore the dimensions of the spinal canal by reducing retropulsed fragments. Our results indicate that this is achieved for fractures from D12 to L3, but fractures of L4 and L5 are less decompressed. Fracture reduction appears to be due to both ligamentotaxis and to forced hyperextension, which is known to be effective without operation (Böhler 1943) or with external (Magerl 1985) or internal fixation (Willen et al 1984; Aebi et al 1987; Dick 1987).

Ligamentotaxis reduces fragments by tensing the posterior longitudinal ligament (PLL) and to a less extent the anterior longitudinal ligament (ALL). The PLL has superficial and deep layers (Fig. 3; Prestar and Putz 1982). The superficial layer is 0.5 to 1 cm wide, and extends continuously from the foramen magnum to the L3/4 disc where most of its fibres terminate; some thin bundles do, however, reach the S1/2 disc. The deep layer is segmental; it is 1 cm wide in the midline of each vertebral body but spreads to blend with the annulus fibrosus and the periosteum of the upper margin and pedicles of each body. The ALL is wide and very strong (von Lanz and Wachsmuth 1982). Its superficial layer extends over 4 to 5 vertebrae in an overlapping fashion, and its deep layer connects adjacent vertebrae. It is attached to periosteum and thus to bone by Sharpey's fibres.

Ligamentotaxis can reduce only those retropulsed fragments that are still attached to a ligamentous structure. Where the PLL is intact, fragments near the midline are pulled back into place by the superficial fibres; fragments lying more laterally are reduced by their attachment to the deep layer. Continuity of the ALL ensures that overdistraction does not occur. The attachment of the annulus fibrosus to the endplates also probably contributes to the reduction by transferring distractive forces (Fredrickson et al 1992).

The relative failure of restoration of the spinal canal below the L3 level supports the view that ligamentotaxis is largely effective through the PLL: the thinner deep layer of the PLL below L3/4 cannot exert sufficient force. This may account for the poor reduction of our single case of a group 3 fracture involving L5. There is still considerable controversy concerning the indications for the open reduction of fractures with persistently retropulsed fragments.

In some of our cases (Table I) the canal was restored to an area greater than its estimated normal area. This is probably because there was considerable initial peripheral displacement of the posterior elements. Ligamentotaxis successfully restored the position of retropulsed fragments, but the ligaments have virtually no attachment to the posterior arch, and the posterior elements therefore remained displaced, leaving a larger than normal canal. Another factor is the delay in assessment in 24 of our cases. We found that the mean restoration of the spinal canal was to nearly 80% of normal soon after surgery, and to nearly 100% at 15 months. This difference supports, but does not prove, the opinion that fragments which remain displaced undergo resorption with time (Fidler 1988; Johnsson et al 1991). The role of remodelling requires further investigation.

There is still controversy concerning the indications for and timing of surgery for vertebral fractures, the relation between canal narrowing and neurological deficit, and the effect, if any, of decompression on neural recovery. Most previous studies have been based on plain radiographic and myelographic findings. These provide limited information on displaced fragments in terms of canal compromise; this may be responsible for the contrasting opinions. A few CT studies have been reported (McAfee et al 1983; Esses et al 1990); these give a better basis for classifying fractures and assessing canal dimensions. The addition of planimetry provides more complete information. The accurate delineation of canal size is essential if these questions are to be answered.

Use of the Internal Spinal Fixator provides good canal decompression in fractures with canal compromise and is a valuable addition to methods in which operation is considered necessary. Its use is increasing and an understanding of the mechanisms involved is therefore essential. For fractures from D12 to L3 it appears to achieve almost complete restoration of canal dimension and thus almost eliminates the need for open decompression (Fig. 4). It is less effective at L4 and L5 levels because of differences in ligamentous anatomy.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

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