Posterior instrumentation with transpedicular calcium sulphate graft for thoracolumbar burst fracture

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Abstract From October 2005 to September 2006, 20 patients with an acute thoracolumbar burst fracture underwent posterior instrumentation with transpedicular intracorporeal calcium sulphate grafting. The mean age of the patients at surgery was 41.8 years; 14 were men and six were women. The mean follow-up period was 28.5 months. Pre-operative computed tomography showed that the mean canal compromise was 53.5%. The Cobb angle was improved from 21.70 to 2.40°, and the final loss of correction was 4.60°. The anterior body height was corrected from 50.3% to 86.6%, and the average loss of anterior body height was 7.7% at final follow-up. All six patients with partial neurological deficit initially had improvement. According to the Denis criteria, the average pain score was 1.8, and the final mean work score was 2.5. Only one case had implant failure. Analysis of the results indicated that this technique can restore and maintain sagittal alignment and anterior body height, providing satisfactory short-term clinical results.

Résumé D'octobre 2005 à septembre 2006, 20 patients ayant présenté une fracture thoraco lombaire ont bénéficié d'une instrumentation postérieure avec greffe transpédiculaire intercorporelle. Les patients étaient âgés de 41,8 ans au moment de l'intervention, 14 étaient de sexe masculin et 6 de sexe féminin. Le suivi moyen a été de 28,5 mois. L'angle de Cobb s'est amélioré de 20,80° à 2,40° et la perte de correction n'a été, au suivi final, que de 4,60°. La hauteur du mur vertébral antérieur s'est corrigé de 50,3% à

86,6%, la perte de hauteur n'a été de que 7,7% au dernier suivi. Les six patients ayant présenté un déficit neurologique partiel initial ont été améliorés. Selon les critères de Denis, la valeur moyenne du score était de 1,8 et le score travail de 2,5 au suivi final. Un seul cas présentait un débricolage des implants. L'analyse de ces résultats permet de penser que cette technique peut restaurer un bon alignement sagittal et la hauteur des corps vertébraux avec des résultats satisfaisants à court terme.

Introduction

Thoracolumbar burst fractures are often induced by axial loading causing failure of both anterior and middle columns. Whether the optimal treatment for managing thoracolumbar burst fracture should be non-operative or operative is debatable [24]. Biomechanical and clinical studies, however, indicate that a loss of anterior vertebral body height exceeding 50%, angulation exceeding 20° or canal compromise exceeding 50% can destabilise the thoracolumbar spine and should be surgically treated [4].

Posterior short-segment pedicle fixation and fusion is now widely used for treating unstable thoracolumbar burst fracture. The posterior instrumentation enables indirect reduction of canal encroachment and early correction of kyphosis. Despite these advantages, loss of correction and a high failure rate of posterior instrumentation due to failed anterior spinal column support have been reported [4, 19]. Intracorporeal cancellous bone grafting to the fractured body was developed to solve these problems [8]. However, if the cancellous bone graft is autogenous, donor site complications are a major concern. Possible complications include persistent donor site pain, infection, haematoma formation and meralgia paraesthetica [3, 12].

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Calcium sulphate pellets plus local lamina bone chips are safe in spine surgery and can achieve a similar fusion rate as autogenous iliac bone graft used in one- or two-segment instrumented posterolateral lumbar fusion [7]. An earlier biomechanical study evaluated injectable calcium sulphate cement for kyphoplasty in a simulated cadaveric vertebral compression fracture model. The experimental results showed that calcium sulphate cement for kyphoplasty achieves vertebral body strength and stiffness comparable to that of polymethylmethacrylate (PMMA). These results suggest that calcium sulphate cement can provide adequate structure support immediately after surgery [23]. Given these encouraging reports and the increasing experience of this medical team in using injectable calcium sulphate cement to treat metaphysis fractures of long bones (distal radial fracture or proximal tibia fracture), we hypothesised that calcium sulphate grafting to a fractured vertebral body following short-segment posterior instrumentation could provide initial strength to support the anterior spinal column and improve healing of the fractured body by enhancing osteoconductive ability. Beginning in October 2005, patients with an acute thoracolumbar burst fracture were treated with posterior short-segment instrumentation followed by anterior fractured body augmentation with injectable calcium sulphate graft. This study evaluated clinical and radiographic outcomes of acute thoracolumbar burst fractures treated with this method.

Patients and methods

Between October 2005 and September 2006, 21 patients with single thoracolumbar burst fractures underwent calcium sulphate augmentation following indirect reduction and fixation with posterior short-segment instrumentation at this medical facility. All 21 patients were surgically treated for neurological deficit or thoracolumbar spine instability (sagittal kyphosis $>20^\circ$, or anterior body height collapse $>50\%$ or spinal canal compromise $>50\%$). Of these, one was a foreign labourer who left the country one month after surgery, and the remaining 20 patients were prospectively followed up. This cohort comprised 14 men and six women with a mean age of 41.8 years (range: 24–63 years). The most common cause of injury was a fall from a height (12/20). Fourteen patients had intact neurological status, and the other six had partial neurological deficits before surgery. Nine patients had associated injuries.

The 20 patients were followed up for at least two years. The mean follow-up period was 28.5 months (range: 24–35 months). Patients returned for clinical evaluation at one, three, six and 12 months and annually thereafter. Plain anteroposterior and lateral thoracolumbar

radiographs before surgery, after surgery and during each return visit were obtained for radiographic analysis. Pre-operative computed tomography (CT) scan of the spine was performed to evaluate canal compromise by fractured fragments. Sagittal plane kyphosis was measured from the superior end plate of the cephalic intact vertebra to the inferior end plate of the caudal intact vertebra. Percentage of anterior body height collapse and percentage of canal compromise were calculated using the formulas of Mumford et al. [20].

Pre-operative and final neurological impairments were assessed by the American Spinal Injury Association (ASIA) impairment scale. The clinical results, including pain scale and work scale, were evaluated at the one-year follow-up. Both pain and work status were recorded on a 5-point scale: P1, no pain; P2, occasional pain not requiring medication; P3, moderate pain requiring occasional medication; P4, moderate to severe pain requiring frequent medication; P5, constant incapacitating pain requiring chronic medication. Work status was recorded as follows: W1, returned to previous employment; W2, capable but did not return to previous employment; W3, unable to return to previous employment and currently employed in a different full-time job; W4, unable to return to previous employment and currently working part-time or frequently absent from work because of pain; W5, completely disabled and unable to work [10]. Other clinical data including duration of admission, injury-surgery interval, operation time, estimated blood loss and associated injuries were also recorded.

Surgical technique

Patients were placed in the prone position on four bolsters with the abdomen freely suspended. Using a standard posterior midline approach, pedicle screws were inserted into a vertebral body one level above and below the injured vertebra. The manual lordotic manoeuvre was first performed to correct kyphosis. After connecting rods and pedicle screws, distraction force was applied using spreader forceps. After indirect reduction and fixation, a trocar in a cannula was inserted into the fractured vertebra (Fig. 1a). An assistant prepared the injectable calcium sulphate graft (MIIG) (Wright Medical Technology, Arlington, TN, USA) when the cannula reached the optimal position. After removing the trocar, calcium sulphate graft was injected into the defect of the fractured body through the cannula under continuous fluoroscopic monitoring (Fig. 1b). No posterior or posterolateral fusions with bone graft were performed.

After surgery, patients were encouraged to sit on the second post-operative day and begin rehabilitation programmes. All patients were protected by a Taylor brace for three months.

Fig. 1 Illustration of the surgical procedure. **a** Intra-operative fluoroscopic image illustrating indirect reduction and fixation by pedicle screws; the cannula reached the optimal position in the fractured vertebra. **b** Defect filled with injectable calcium sulphate cement under fluoroscopic guidance

Results

In this series, the mean operation time was 161.7 min (range: 121–210 min), and the average estimated blood loss was 247.5 c.c. (range: 50–600 c.c.). The mean hospital stay was 13.7 days (range: 8–21 days), and the average injury-surgery interval was 4.8 days (range: 1–13 days). Twelve patients were injured by falling from a height, six were injured in motor vehicle accidents and two were injured by being struck by heavy objects. Posterior instrumentation used in this study included RF (Advanced Spinal Technology, Oakland, CA, USA) in eight patients and Prot (Merries International, Taipei, Taiwan) in 12 patients. Hardware failure occurred in only one patient (broken rod). Nine patients had other associated injuries: six with pelvic or acetabulum fractures, four with extremity long bone fractures, three with calcaneal fractures and two with rib or sternum fractures. Internal organ injuries included pneumothorax, lung contusion and urethral injury. No patients had wound infection due to spinal surgery. Table 1 shows the detailed clinical characteristics of the patients in this study.

Pre-operative CT showed that the average spinal canal encroachment was 53.5% (range: 26–72%). The average pre-operative kyphotic angle was 21.7° (range: 5–31°), which was corrected to 2.4° (range: –9 to 11°) immediately after surgery. The kyphosis correction achieved by the operation was 19.3°. The final mean local kyphosis was 7° (range: –8 to 16°). Loss of kyphosis correction was 4.6°. The average pre-operative anterior vertebral height collapse was 49.7% (range: 19–74%), which improved to 13.4% (range: 1–33%) in the immediate post-operative period. Anterior body height restored by the surgery was 36.3%. The final anterior body height collapse was 21.2% (range: 10–37%), and the average loss of body height correction was 7.8%. Calcium sulphate cement was invisible on radiographs in all patients at the three-month follow-up. Figure 2 shows a typical case. Table 2 displays radiographic data of the patients.

According to the ASIA neurological grading system, one patient had grade C, five had grade D and 14 had grade E before surgery. No neurological deterioration due to surgery was noted. Patients with pre-operative grade C neurological status improved to grade D by the final follow-up. All four patients with grade D neurological status pre-operatively eventually improved to grade E. The mean pain scale was 1.8 (1–4), and the mean work scale was 2.5 (1–5) at the final follow-up. Table 3 illustrates the neurological and functional results for all patients.

Discussion

Thoracolumbar burst fractures are usually associated with a fall from a height or motor vehicle accident. When treating thoracolumbar burst fractures, spinal stability and neurological status should be considered. The conventional posterior procedure clears the canal by forces of ligamentotaxis. This indirect method decompresses the spinal canal and may leave some degree of retropulsed fragments. Whether anterior surgery or a posterior procedure is superior for treating burst fractures with neurological deficits is still debatable. Although some studies have shown little correlation between spinal canal encroachment and neurological recovery [11, 17], some authors advise anterior surgery to remove retropulsed fragments [13, 16]. The protocol at this institution is to reserve anterior surgery for patients with moderate to severe neurological deficits (ASIA C, B, A). For this reason, most (19/20) patients in this series were neurologically intact or had minor neurological deficits (ASIA E, D). Only one patient with moderate neurological deficit had improved, although by only one grade, as of the most recent follow-up (ASIA C to ASIA D).

Posterior instrumentation to stabilize unstable thoracolumbar burst fractures has been used for decades. A Luque rod or Harrington rod is the initial posterior device for treating spinal fractures. One disadvantage of these devices

Table 1 Clinical characteristics of the patients

Patient No.	Age (years)	Gender	Mechanism of trauma	Level	Follow-up (months)	Operation time (min)	Estimated blood loss (cm ²)	Hospital stay (days)	Injury-surgery interval (days)	Associated injury
1	50	F	Fall	L1	35	150	100	13	6	Nil
2	45	F	MVA	L1	34	182	300	11	7	Nil
3	50	F	MVA	L1	34	121	50	10	3	Coccyx fracture
4	34	M	Fall	L1	33	130	150	19	4	Sternal fracture, sacral fracture
5	29	M	Fall	L3	32	150	250	15	3	Bilateral calcaneal fracture
6	43	M	Fall	L1	31	159	250	15	3	Nil
7	24	M	MVA	L1	30	210	100	10	3	Nil
8	37	M	Struck	L1	29	163	150	18	8	Rib fracture, lung contusion
9	50	F	Fall	L2	29	177	200	15	4	Nil
10	50	M	Fall	L2	28	168	100	9	1	Left calcaneal fracture
11	45	M	Fall	L2	28	208	300	13	6	Nil
12	33	M	Fall	L2	27	161	100	13	2	Nil
13	36	M	Struck	L2	27	127	100	15	2	Nil
14	24	M	MVA	L3	26	162	600	14	8	Left metacarpal fracture, right acetabular fracture
15	27	M	Fall	L1	26	156	400	14	13	Right radial fracture, right elbow dislocation, right calcaneal fracture, pelvic fracture
16	50	F	MVA	T12	25	100	250	8	1	Nil
17	53	M	Fall	L3	25	203	500	12	12	Right radial fracture, right metatarsal fracture, pelvic fracture, urethral injury
18	63	M	Fall	L1	25	153	250	14	1	Nil
19	45	F	Fall	L2	24	170	200	21	6	Pneumothorax, right humeral fracture, lung contusion, pelvic fracture
20	27	M	MVA	T12	24	183	600	14	3	Nil

MVA motor vehicle accident

Fig. 2 A 50-year-old female (case 3) sustained L1 burst fracture in a motor vehicle accident. **a** Pre-operative radiograph showed 29° local kyphosis and 66% anterior body collapse. **b** Post-operative radiograph revealed that surgery corrected the deformity to 2° local kyphosis and 18% anterior body height collapse. **c** Radiograph taken 2 years after surgery showing L1 body united with T12-L1 disc degeneration change. Local kyphosis deteriorated to 9° and anterior body height collapse had increased to 23%

is the long segments of immobilisation required due to length of instrumentation, which is often difficult when used in the middle or lower lumbar region [2]. Another disadvantage of this “long rod-short fusion” technique is the possibility of osteoarthritis at the immobilised but unfused facet joint. Persistent back pain or progressive kyphosis after implant removal is believed to originate from these instrumented unfused segments [6, 9]. The development of pedicle screws has led to the use of “short instrumentation-short fusion” for treating unstable burst fracture to prevent

immobilisation of uninjured segments. Although clinical results are generally satisfactory, failure rates of posterior short-segment pedicle screw instrumentation ranged from 20 to 36% [4, 5]. Failed anterior column support is the main cause of hardware failure. Posterior transpedicular cancellous bone graft to the fractured body is apparently an ideal method for increasing anterior column support to prevent loss of correction and implant failure. However, a 10% hardware failure rate and a 40% loss of correction >10° have been reported in early follow-up of this technique [1].

Table 2 Radiographic data of the patients

Patient No.	Pre-operative spinal canal encroachment (%)	Local kyphosis angle (°)			Anterior body height collapse (%)		
		Pre-operative	Post-operative	Final	Pre-operative	Post-operative	Final
1	49	26	3	6	48	7	16
2	26	20	3	8	30	14	25
3	53	29	2	9	66	18	23
4	46	25	6	7	61	17	23
5	72	16	-9	12	51	16	20
6	36	21	1	5	32	14	29
7	68	25	1	7	58	18	23
8	69	28	11	16	69	33	25
9	65	18	2	5	52	1	37
10	52	12	2	3	41	7	11
11	71	31	4	6	71	1	12
12	66	20	3	15	51	9	10
13	38	21	4	6	51	13	16
14	54	12	-5	-4	36	15	22
15	52	21	6	7	44	21	23
16	49	29	5	10	74	17	18
17	65	5	-9	-8	19	2	11
18	40	21	9	15	42	17	27
19	66	29	6	7	61	13	25
20	32	24	3	8	37	15	16

Table 3 Neurological status and functional results of the patients

Patient No.	Neurological status (ASIA)		Functional results	
	Pre-operative	Final	Pain scale	Work scale
1	E	E	1	2
2	E	E	1	1
3	E	E	3	3
4	D	E	1	1
5	C	D	4	5
6	E	E	1	1
7	E	E	2	2
8	D	E	1	3
9	D	E	1	2
10	E	E	4	5
11	E	E	1	1
12	E	E	3	3
13	E	E	1	1
14	E	E	2	5
15	E	E	1	1
16	E	E	2	2
17	D	E	2	5
18	E	E	1	2
19	E	E	1	1
20	D	E	2	3

Long-term outcome studies of additional intracorporeal bone graft revealed no improvement in correction loss [15].

In traditional short-segment posterior instrumentation and fusion or intracorporeal bone graft, iliac bone graft must be harvested regardless of the technique used, and the possibility of donor site complications cannot be eliminated. Donor site morbidities include persistent donor site pain, infection, haematoma formation, iliac crest fracture and meralgia paraesthetica [3, 12]. To prevent these complications and to ensure adequate bone graft material, various synthetic bone graft substitutes had been developed and are now widely used by orthopaedic surgeons. Calcium sulphate was first used by Dreesman to fill bone defects caused by tuberculosis in 1892 and is still applied in orthopaedic treatments [25]. The material is radio-opaque on radiographs and provides a scaffold for repair of bone defects. The porous structure of calcium sulphate attracts capillaries and osteoprogenitor cell migration. Calcium sulphate is also resorbed at the same rate as new bone ingrowth [18]. The *in vivo* resorption time is 30–60 days [22]. The same phenomenon was also observed in this series: no patients revealed radiographic evidence of calcium sulphate three months after surgery. Surgical grade calcium sulphate is originally manufactured in pellet form but may not be optimal in some cases. Injectable calcium sulphate overcomes these problems. This product (MIIG) is calcium sulphate-based powder mixed with normal saline to form a paste-like material that can be injected into a defect

space. Injectable calcium sulphate had been successfully used in management of benign bone lesions in humans [14].

Radiographic parameters (vertebral body height, local kyphosis) revealed immediate improvement after surgery, but loss of correction was gradual. The mean loss of correction of kyphosis was 4.6°, and the average collapse in anterior body height was 7.8% in this series. A mean loss of kyphosis of 9–14° has been reported in other studies of intracorporeal cancellous grafting following posterior instrumentation [1, 8, 15]. Regardless of the method used for treating thoracolumbar burst fracture, the same phenomenon occurred. In thoracolumbar burst fractures, injuries were noted not only at the vertebral body but also at the end plate and disc. Instrumentation and grafting (bone or bone substitutes) can restore body height. However, maintaining body height requires a balance between bone healing and graft resorption. If graft absorption time is faster than new bone formation, the bony height collapses gradually. Further, disc degeneration with disc space narrowing may result from disc creep into the vertebral body through the injured end plate [21]. The disc contained in the vertebral body obliterated bone union and collapsed body height. Both body height collapse and disc space narrowing contribute to progressive kyphosis after surgery.

The average pain score in this study was 1.8, and no patients required chronic medication for incapacitating back pain. Only two patients had severe back pain requiring frequent medication, two had moderate pain, five had occasional pain not requiring medication and the remaining 11 had no complaint of back pain. Back pain was caused by local kyphosis, disc degeneration or facet joint degeneration. The average score on the work scale was 2.5 points. Of the 20 patients, 12 (60%) could resume their previous work. Although four patients were completely disabled, they all claimed that their disabilities were caused by associated injuries (calcaneal fracture, pelvic fracture or internal organ injury) not related to the spine injury.

Conclusions

This study demonstrated that short-segment posterior pedicle screw instrumentation and anterior body augmentation with injectable calcium sulphate cement is a simple and effective surgical treatment for patients with thoracolumbar burst fracture. This technique is effective for correcting deformity and maintaining adequate body height and alignment. Implant-related complications were low, and early clinical results were satisfactory. This method does not require fusion to the injured segment, thereby preserving joint motion. However, the number of patients in this study was small; it would be premature to advocate this technique. A long-term follow-up study of a larger patient

population may be needed to confirm the long-term effectiveness of this procedure.

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