Allografts with titanium cage in the treatment of tuberculous spondylitis: at least 3-year follow-up study

YanJun Wang

graduate school of Tianjin Medical University

Hong Zhang (✉ wangyj1973@126.com)

PLA Army General Hospital

Research

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Abstract

Background Anterior radical debridement and spinal fusion with instrumentation have been advocated in treating the spinal tuberculosis patients. But there are few long-term studies on the efficacy of fresh-frozen allografts with titanium cage in reconstruction of the anterior spinal column after debridement and decompression for tuberculosis. The purpose of this study was to evaluate the efficacy of anterior allografts with titanium cage which were stabilized with anterior or posterior instrumentation at least 3-year follow-up study.

Methods A retrospective analysis of 133 patients were treated between January 2002 and December 2012. There were 71 men and 62 women. Those patients were evaluated according to clinical and radiographical record for a minimum of 3 year, including deformity correction, pain and neurologic status. The kyphosis deformity was measured on lateral radiographs according the angle between the superior endplate of the first upper uninvolved vertebra and the first lower uninvolved vertebra. In the lumbosacral region, the kyphosis angle was measured by two lines along the posterior border of the first normal vertebra above the level of the lesion and posterior margin of sacrum on lateral radiographs. Clinical evaluation of back pain was evaluated and documented according to VAS pain score. Patients with neural deficits were graded according to the ASIA scale.

Results The preoperative kyphosis deformity improved in all patients postoperatively from a mean of 20.8° (range, 12°-35°) to 3.9° (range, 2°-7°), with the average deformity correction of 16.1° ($t = 38.59$, $p < 0.0001$). The earliest radiologic evidence of allograft incorporation was identified between 18 and 24 months after surgery, and bony fusion was seen in all patients at final follow-up. We put forward our criteria to classify allograft incorporation at the last follow-up. Grade 1 49 patients; Grade 2 73 patients; Grade 3 11 patients; Grade 4 no patient. The average VAS pain score was 7.7 (range, 6–9) preoperatively, and decreased to 1.4 (range, 1–3) 3 months after surgery ($t = 97.88$, $p < 0.0001$ vs. initial). Of the 44 patients who developed neural deficits before their operations, 41 patients improved according to the ASIA AIS. 3 patients did not have substantial improvement and remained Grade AIS B.

Conclusions Radical debridement followed by allograft with titanium cage in reconstruction of the anterior spinal column offers very satisfactory results in patients with tuberculous spondylitis. It provides immediate stability, offers lasting kyphosis correction, bypasses the donor site morbidity and difficulties involved in obtaining structural autograft.

Background

Musculoskeletal tuberculosis accounts for approximately 10% of all extrapulmonary tuberculosis cases [1] and spinal tuberculosis comprises up to 50% of musculoskeletal tuberculosis [2]. Approximately 98% of spinal tuberculosis affects the anterior column of spine [3]. These patients often develop collapse of vertebrae because of tuberculous destruction, resulting in varying degrees of kyphosis, and 10%~47% develop neurologic deficits [4]. Antituberculous chemotherapy and immobilization lead to a favorable outcome in most of the patients by preventing abscess formation and neurologic deterioration [5]. Surgical intervention with radical debridement and stabilization is sometimes considered for the patients with severe pain from abscess, neurologic impairment from spinal cord compression, significant bone destruction, progressive kyphotic deformity or instability and antituberculous-resistant or recurrence [2, 6]. Eradication of infection is the primary aim of surgical treatment in spinal tuberculosis, with the prevention or correction of spinal deformity and recovery from neurological deficits [7]. Anterior radical debridement and spinal fusion with instrumentation have been advocated in treating the patients with spinal tuberculosis [8, 9]. Radical debridement of the compromised anterior column that has lost its structural integrity requires reconstruction for prevention or correction of spinal deformity [10–12]. There are few long-term studies on the efficacy of fresh-frozen allografts with titanium cage in reconstruction of the anterior spinal column after debridement and decompression for tuberculosis [12–14]. In the current study, the efficacy of anterior allografts with titanium cage, which were stabilized with anterior or posterior instrumentation, were evaluated 3 to 8 years after anterior radical debridement and spinal fusion for spinal tuberculosis.

Materials And Methods

A retrospective analysis of 133 patients with tuberculous spondylitis of the thoracic and lumbar spine treated by anterior radical debridement and spinal fusion using allografts with titanium cage was performed to evaluate the incorporation of allografts. Approval to conduct this study was obtained from our institutional review board, and informed consent was obtained from each patient. These patients were treated between January 2002 and December 2012 in the Department of Spine Surgery, The Second Hospital of Tangshan, China. The main indication for surgery was severe pain from abscess, neurologic impairment from spinal cord compression, significant bone destruction, progressive kyphotic deformity or instability and antituberculous-resistant or recurrence.

There were 71 men and 62 women. Mean ($\pm$ Standard Deviation) age of this series was 46.9 ± 12.3 years (range, 20–69 years). Patients were evaluated according to clinical and radiographical record for a minimum of 3 year, including deformity correction, pain, and neurologic status.

The mean follow-up period was 46.7 months (range, 36–57 months). The demographic and diagnostic characteristics of patients were listed in the Table 1.

Table 1
Summary of clinical date in the serials

Case No.	Age(Y) /Sex	Level	Duration of disease(mo)	Surgical procedure	Kyphotic angle			VAS pain score			Neurologic status(ASIA)		Fusion grade	Follow-up (months)
					Pre-op	Post-op	FFU	Pre-op	Post-op	FFU	Pre-op	FFU		
1	52/F	L3□ L4	14	CAPP	27	3	3	7	1	0	E	E	2	56
2	61/M	L2□ L3	11	AP	21	5	6	7	1	0	E	E	2	57
3	39/M	L4□ L5	4	CAPP	19	3	4	7	1	0	E	E	2	52
4	44/F	L4□ L5	9	CAPP	19	3	3	6	1	0	E	E	3	36
5	25/F	L4 ~ S1	12	CAPP	28	5	6	9	3	2	E	E	3	46
6	39/F	L5	4	CAPP	23	2	2	9	3	2	E	E	1	41
7	52/M	L5□ S1	4	CAPP	22	2	2	8	1	1	E	E	2	52
8	46/M	L3□ L4	4	CAPP	24	3	4	8	2	1	E	E	2	44
9	59/F	L5□ S1	9	CAPP	23	2	2	8	3	2	E	E	3	57
10	52/F	L4□ L5	6	CAPP	16	2	2	7	1	0	E	E	2	41
11	38/F	L1□ L2	5	AP	18	3	4	7	1	0	E	E	1	49
12	51/F	L3□ L4	15	CAPP	20	5	6	8	2	0	E	E	2	44
13	59/F	L5	11	CAPP	21	5	7	7	1	0	E	E	2	47
14	48/M	L3□ L4	4	CAPP	22	3	3	7	1	0	E	E	1	51
15	43/F	L4	10	CAPP	23	3	4	7	1	0	E	E	1	42
16	49/M	T12□ L1	11	AP	18	6	6	7	1	0	D	E	2	43
17	42/F	L1□ L2	15	AP	20	5	6	7	1	0	E	E	2	39
18	27/M	T12 ~ L2	8	CAPP	31	6	6	9	1	1	E	E	2	42
19	34/F	L1□ L2	12	AP	19	6	7	8	1	0	E	E	1	56
20	62/M	L2□ L3	6	AP	14	2	4	7	1	0	E	E	2	46
21	61/M	L2□ L3	15	AP	20	6	6	8	2	1	E	E	2	43
22	56/M	T6 ~ T9	15	CAPP	29	6	7	7	1	0	D	E	2	45
23	68/F	L1□ L2	14	AP	13	2	3	9	3	2	D	E	3	38
24	42/F	T12□ L1	3	AP	12	2	5	7	2	1	D	E	1	55

FFU = final follow-up; AP = anterior procedure; CAPP = combined anterior and posterior procedure

Case No.	Age(Y) /Sex	Level	Duration of disease(mo)	Surgical procedure	Kyphotic angle			VAS pain score			Neurologic status(ASIA)		Fusion grade	Follow-up (months)
					Pre-op	Post-op	FFU	Pre-op	Post-op	FFU	Pre-op	FFU		
25	32/F	T10 T11	7	AP	20	6	6	6	1	0	C	D	1	46
26	52/M	L4 L5	7	CAPP	23	2	2	9	2	1	E	E	2	45
27	47/M	L2 ~ L4	5	CAPP	23	5	6	8	1	0	E	E	2	53
28	28/F	L2 L3	4	AP	18	5	5	7	1	0	E	E	1	47
29	46/F	T10	5	AP	15	5	5	6	1	0	D	E	1	57
30	46/M	L2 ~ L5	13	CAPP	25	7	8	8	2	1	E	E	3	51
31	29/F	L2 L3	12	AP	12	2	4	8	1	1	E	E	2	36
32	53/M	L4 L5	8	CAPP	22	2	3	7	1	0	E	E	2	39
33	61/M	T12	8	AP	15	2	2	8	2	1	D	E	2	54
34	48/M	L1 L2	6	AP	18	5	5	9	2	1	E	E	2	42
35	32/M	L4 L5	9	CAPP	21	3	4	7	1	0	E	E	1	54
36	45/M	L4 L5	9	CAPP	19	4	4	8	1	0	E	E	1	36
37	59/F	L5 S1	11	CAPP	16	3	3	9	1	0	E	E	2	45
38	40/M	L2 L3	14	CAPP	27	4	6	9	3	2	E	E	2	41
39	21/F	T9 ~ L1	15	CAPP	33	3	4	8	1	1	E	E	3	36
40	50/F	L4 L5	4	CAPP	21	4	4	7	2	1	E	E	2	57
41	52/M	T7 ~ T9	4	CAPP	35	5	6	8	1	1	C	D	2	49
42	47/F	T8 ~ T10	6	CAPP	28	3	4	8	1	1	C	D	2	45
43	29/M	T9 ~ T12	8	CAPP	29	7	9	9	2	1	D	E	3	51
44	46/F	T9 T10	9	AP	12	3	5	7	1	0	D	E	2	44
45	39/F	L3 L4	9	CAPP	21	3	3	7	1	0	E	E	1	52
46	52/M	L4 L5	10	CAPP	13	4	4	7	1	0	E	E	2	47
47	42/M	L1 L2	10	AP	13	5	6	7	1	0	E	E	1	36
48	59/F	L2	9	AP	20	4	6	7	1	0	E	E	2	50

FFU = final follow-up; AP = anterior procedure; CAPP = combined anterior and posterior procedure

Case No.	Age(Y) /Sex	Level	Duration of disease(mo)	Surgical procedure	Kyphotic angle			VAS pain score			Neurologic status(ASIA)		Fusion grade	Follow-up (months)
					Pre-op	Post-op	FFU	Pre-op	Post-op	FFU	Pre-op	FFU		
49	68/F	L2□ L3	8	AP	14	5	5	7	1	0	E	E	3	41
50	57/F	L1□ L2	9	AP	19	2	4	8	1	1	C	E	2	41
51	49/M	L3□ L4	4	CAPP	24	5	5	8	1	1	E	E	1	46
52	67F	T11□ T12	3	AP	26	4	5	8	1	1	C	D	3	55
53	41/F	L3□ L4	4	CAPP	21	3	4	7	1	0	E	E	1	43
54	68/M	L2□ L3	11	AP	17	3	5	7	1	0	E	E	2	44
55	52/M	L2□ 3L	4	CAPP	24	6	6	7	1	0	E	E	2	54
56	41/M	L1□ L2	11	AP	13	6	7	7	1	0	C	D	1	56
57	35/M	L1 ~ L3	3	CAPP	33	7	8	7	1	0	D	E	2	37
58	59/M	T6□ T7	14	AP	24	4	4	8	1	0	D	E	2	48
59	40/M	T11□ T12	4	AP	18	4	6	8	2	1	D	E	2	41
60	53/M	L3□ L4	10	CAPP	24	2	3	7	1	0	E	E	1	37
61	29/F	T10□ T11	8	CAPP	25	5	5	8	1	1	E	E	1	44
62	45/M	T7 ~ T9	9	CAPP	30	3	6	9	2	1	D	E	2	51
63	48/M	L5□ S1	10	CAPP	15	2	2	8	2	1	E	E	2	38
64	28/M	L2□ L3	15	CAPP	20	6	7	9	2	1	D	E	1	40
65	49/M	L2	15	AP	15	3	3	9	2	1	E	E	1	49
66	43/F	L1□ L2	10	AP	13	3	4	7	1	0	E	E	2	50
67	49/M	T10	9	AP	16	6	6	7	1	0	D	E	1	50
68	51/F	L4□ L5	3	CAPP	19	5	5	7	1	0	E	E	2	57
69	34/F	L1□ L2	12	AP	15	6	6	9	1	1	E	E	1	39
70	21/F	L2□ L3	11	CAPP	26	3	4	7	1	0	E	E	1	50
71	59/M	L5□ S1	14	CAPP	19	5	6	7	2	1	E	E	2	42
72	42/F	T11□ T12	15	AP	15	5	5	8	2	1	D	E	1	48

FFU = final follow-up; AP = anterior procedure; CAPP = combined anterior and posterior procedure

Case No.	Age(Y) /Sex	Level	Duration of disease(mo)	Surgical procedure	Kyphotic angle			VAS pain score			Neurologic status(ASIA)		Fusion grade	Follow-up (months)
					Pre-op	Post-op	FFU	Pre-op	Post-op	FFU	Pre-op	FFU		
73	49/M	L4 ~ S1	8	CAPP	21	2	5	8	1	1	E	E	2	57
74	41/M	L3□ L4	10	CAPP	25	5	5	7	1	0	E	E	1	53
75	61/F	L1□ L2	11	AP	16	4	6	7	1	0	E	E	2	54
76	56/F	L3□ L4	8	CAPP	22	4	4	7	1	0	E	E	1	44
77	34/M	L4□ L5	4	CAPP	16	4	5	9	1	1	E	E	1	38
78	54/F	L2□ L3	13	CAPP	27	5	6	9	2	1	E	E	2	41
79	21/F	L3	15	AP	14	4	4	7	1	0	E	E	1	39
80	39/M	T11□ T12	5	AP	13	3	3	9	2	1	D	E	2	36
81	47/F	L1□ L2	6	AP	22	2	4	7	1	0	E	E	1	46
82	53/M	L4□ L5	5	CAPP	30	5	5	7	2	1	E	E	2	48
83	45/F	L5	7	CAPP	24	3	3	8	3	1	E	E	1	53
84	23/F	L4	6	AP	17	3	4	9	3	2	E	E	1	52
85	39/M	L1□ L2	15	AP	15	5	5	8	1	0	E	E	1	48
86	32/M	L3□ L4	12	CAPP	27	6	7	9	1	0	E	E	1	37
87	54/M	L4□ L5	14	CAPP	22	2	3	7	1	0	E	E	2	39
88	61/F	T3□ T4	10	CAPP	27	4	4	9	3	1	B	B	2	53
89	56/F	T11□ T12	15	CAPP	23	6	6	9	2	1	C	D	2	55
90	21/F	L5	11	CAPP	19	3	4	7	1	0	E	E	1	54
91	46/M	T3 ~ T5	5	CAPP	30	2	4	9	1	0	D	E	2	40
92	66/F	T9□ T10	15	AP	20	5	5	7	1	0	D	E	2	52
93	56/M	L4□ 5L	4	CAPP	17	3	3	8	1	1	E	E	2	47
94	36/M	L1□ 2L	15	AP	18	2	4	7	2	0	E	E	1	44
95	58/F	T1□ T2	6	AP	21	6	6	8	1	0	B	B	2	44
96	53F	T8□ T9	3	AP	22	4	4	9	1	1	D	E	1	44
97	63/M	T7□ T8	3	AP	12	2	3	9	1	1	D	E	2	54

FFU = final follow-up; AP = anterior procedure; CAPP = combined anterior and posterior procedure

Case No.	Age(Y) /Sex	Level	Duration of disease(mo)	Surgical procedure	Kyphotic angle			VAS pain score			Neurologic status(ASIA)		Fusion grade	Follow-up (months)
					Pre-op	Post-op	FFU	Pre-op	Post-op	FFU	Pre-op	FFU		
98	41/M	T2 ~ T4	9	CAPP	23	5	5	8	1	1	B	C	2	54
99	53/F	T12□ L1	9	CAPP	26	3	4	9	2	1	D	E	2	55
100	29/M	L5□ S1	14	CAPP	19	3	4	8	2	1	E	E	1	37
101	43/M	L4□ L5	4	CAPP	23	5	5	7	1	0	E	E	1	50
102	56/M	L3□ L4	4	CAPP	19	2	3	7	1	0	E	E	2	39
103	44/F	T8 ~ T10	14	CAPP	29	2	4	8	1	0	C	D	2	38
104	47/M	L4□ L5	14	CAPP	17	5	5	9	3	2	E	E	2	42
105	48/M	L2□ L3	14	CAPP	28	4	6	8	2	1	E	E	2	52
106	56/F	L3□ L4	15	CAPP	21	2	4	7	1	0	E	E	2	56
107	54/F	T9□ T10	6	AP	20	3	4	7	1	1	E	E	2	36
108	56/F	L3□ L4	5	CAPP	25	6	6	7	1	0	E	E	1	45
109	53/M	L2□ L3	5	AP	19	5	6	7	2	1	E	E	1	49
110	55/F	L4□ L5	14	CAPP	15	2	2	9	3	1	E	E	1	57
111	66/F	T12□ L1	13	AP	22	6	8	8	1	0	D	E	2	53
112	52/M	L2□ L3	6	CAPP	20	4	4	8	1	0	E	E	1	39
113	57/F	T9□ T10	12	AP	18	3	4	7	1	0	D	E	2	50
114	60/F	L3□ L5	11	CAPP	22	5	6	7	1	0	E	E	2	50
115	28/M	T7□ T8	6	CAPP	23	4	4	8	1	0	C	D	1	47
116	23/M	L2□ L3	3	CAPP	25	2	3	9	2	1	E	E	2	40
117	55/F	T10□ T11	7	AP	12	2	3	7	1	0	D	E	1	52
118	60/M	T8□ T9	7	AP	16	5	6	9	2	2	D	E	2	38
119	21/F	T12 ~ L3	9	CAPP	25	6	7	6	1	0	D	E	2	54
120	68/F	L2□ L3	8	CAPP	23	2	2	7	1	1	E	E	3	54

FFU = final follow-up; AP = anterior procedure; CAPP = combined anterior and posterior procedure

Case No.	Age(Y) /Sex	Level	Duration of disease(mo)	Surgical procedure	Kyphotic angle			VAS pain score			Neurologic status(ASIA)		Fusion grade	Follow-up (months)
					Pre-op	Post-op	FFU	Pre-op	Post-op	FFU	Pre-op	FFU		
121	50/M	T11□ T12	10	AP	16	2	4	7	1	0	E	E	2	49
122	26/M	T6□ T7	14	CAPP	27	5	5	8	2	0	E	E	1	45
123	25/M	T7□ T8	15	CAPP	24	5	5	8	1	0	D	E	1	57
124	69/M	T10□ T11	12	AP	20	6	6	7	2	0	C	E	3	56
125	47/M	T10□ T1	3	AP	15	6	7	8	1	0	D	E	1	43
126	62/M	T12□ L1	13	AP	18	5	7	7	1	0	D	E	2	36
127	49/M	L2□ L3	15	AP	18	2	4	8	2	1	E	E	1	57
128	44/M	L4□ L5	9	CAPP	21	3	3	9	3	1	E	E	2	41
129	59/M	T8□ T9	13	CAPP	20	4	5	8	1	0	B	B	2	48
130	63/F	L2	7	AP	14	5	6	9	2	1	E	E	2	56
131	20/M	T12 ~ L2	7	CAPP	22	4	4	9	1	1	E	E	1	46
132	42/F	L3□ L4	3	CAPP	27	3	4	9	2	1	D	E	2	49
133	54/M	T8 ~ T10	4	CAPP	29	4	5	7	1	0	E	E	2	36
FFU = final follow-up; AP = anterior procedure; CAPP = combined anterior and posterior procedure														

There were 276 involved vertebral bodies, with a single level involvement in 13 patients, two levels in 102 patients, and three levels or more in 18 patients. Patients with thoracic (n = 27), thoracolumbar (n = 36), and lumbar (n = 70) involvement were comparable in regards to kyphosis angle and deformity correction. Patients with neural deficits were graded according to the ASIA scale [15]. 44 of the 132 patients (33.3%), 4 ASIA B, 10 ASIA C, and 30 ASIA D. The diagnostic characteristics and clinical outcome of patients were listed in the Table 1.

Preoperatively, all patients were evaluated with radiographic examination and computed tomography (CT) and most of the patients were evaluated magnetic resonance imaging (MRI). Radiographic examination revealed vertebral destruction/collapse, kyphotic deformities and paravertebral abscess. CT scans mostly revealed the extent of bony destruction and location of abscess. MRI revealed vertebral destruction, collapse, paravertebral and/or psoas abscess, and spinal cord compression. The kyphosis deformity was measured on lateral radiographs according the angle between the superior endplate of the first upper uninvolved vertebra and the first lower uninvolved vertebra. In the lumbosacral region, the kyphosis angle was measured by two lines along the posterior border of the first normal vertebra above the level of the lesion and posterior margin of sacrum on lateral radiographs.

All patients underwent antituberculous chemotherapy (Rifampicin, 450 mg/d; Isoniazid, 300 mg/d; Ethambutol 750 mg/d) before surgery for 3 weeks, except those who need urgent decompression for recently developed progressive neurologic deficits. All procedures were performed by the same surgeon (YM.L). A transpleural or retroperitoneal approach was used according to the location of infection. Perioperatively, frozen-section histopathological examination was performed to confirm the diagnose of tuberculosis, according to the presence of Langerhans giant cells, granuloma, and caseating necrosis on the histopathological sections. After radical debridement and decompression, we used titanium cages filled with crushed cancellous allograft for anterior column reconstruction. Structural stability was secured with the anterior instrumentation when one vertebra has been removed or posterior instrumentation when two or more vertebrae have been removed resulted from radical debridement. Postoperatively, patients were mobilized for six weeks with the aid of a molded Boston type brace. Postoperatively, histopathological examination and cultures of material obtained from the debridement confirmed the diagnosis of

tuberculosis. All patients received antituberculous chemotherapy up to 12 months postoperatively. Liver and renal functions were monitored regularly throughout this period. Erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) were also monitored regularly to exclude the presence of infection activity.

Anteroposterior (AP) and lateral radiographs were taken immediately after surgery, 3 months, 6 months, and 12 months postoperatively, and subsequently at yearly intervals. All radiographs were evaluated by the same observer (X.W), who was blinded to the clinical outcome. The presence of allograft incorporation was determined by plain radiographs and was further verified by CT scans in some patients.

Clinical evaluation was done by another observer (H.C.C), who was blinded to the radiographic outcome. The patients' preoperative and postoperative neurologic status was evaluated and documented according to the American Spinal Injury Association (ASIA) Impairment Scale (AIS) [15]. Clinical evaluation of back pain was evaluated and documented according to VAS pain score [16].

Descriptive statistics were used for all variables with distributions assessed for normality. The paired *t*-tests were conducted to compare pre-operative and post-operative changes of kyphosis and VAS pain score. The Statistical Package for the Social Sciences (version 17.0 for Windows; SPSS Inc, Chicago, IL) was used for statistical analysis. The difference was considered to be statistically significant at the $p < 0.05$ level.

Results

The average operating time was 2.4 hours (range, 1.9 to 4.1 hours) for anterior surgeries, and 5.3 hours (range, 4.2 to 7.1 hours) for combined anterior and posterior surgeries. The average perioperative blood loss was 700 ml (range, 471 to 1193 ml) for anterior surgeries, and 1145 ml (range, 864 to 1393 ml) for combined anterior and posterior surgeries. The average postoperative hospitalization was 16.8 days (range, 12 to 21 days).

The preoperative kyphosis deformity improved in all patients postoperatively from a mean of 20.8° (range, 12° - 35°) to 3.9° (range, 2° - 7°), with the average deformity correction of 16.1° ($t = 38.59$, $p < 0.0001$). At the final follow-up, the average kyphosis was 4.7° (range, 2° - 9°), which corresponded to a mean angular loss of correction (increase in kyphosis) of 0.8° ($t = -11.1$, $p < 0.0001$).

The earliest radiologic evidence of allograft incorporation was identified between 18 and 24 months after surgery, and bony fusion was seen in all patients at final follow-up. Based on the criteria of Bridwell et al [17], we put forward our criteria to classify allograft incorporation at the last follow-up. Grade 1 (Fig. 1) fusion with healing of compromised vertebra (49 patients); Grade 2 (Fig. 2) graft intact with no lucencies at the top or bottom, but without full healing of compromised vertebra (73 patients); Grade 3 (Fig. 3) fusion, graft intact but definite lucency at the top or bottom of the graft (11 patients); Grade 4 not fusion with resorption of bone graft or collapse (no patient).

Back pain greatly relieved in all the patients. The average VAS pain score was 7.7 (range, 6–9) preoperatively, and decreased to 1.4 (range, 1–3) 3 months after surgery ($t = 97.88$, $p < 0.0001$ vs. initial). At final follow-up, the average VAS pain score was 0.5 (range, 0–2).

Of the 44 patients who developed neural deficits before their operations, 41 patients improved according to the ASIA AIS. Three patients did not have substantial improvement and remained Grade AIS B.

There were no major complications, such as implant failure, wound infection and iatrogenic neurovascular injuries. Infection control was achieved in all patients except for tuberculosis recurrence in one patient.

Discussion

The present study suggests that radical debridement followed by allograft with titanium cage in reconstruction of the anterior spinal column offers very satisfactory results in patients with tuberculous spondylitis who need for surgical intervention. It provides immediate sagittal stability, offers lasting kyphosis correction, bypasses the donor site morbidity and difficulties involved in obtaining structural autograft.

Early initiation of the proper antituberculous chemotherapy coupled with immobilization leads to a favorable outcome in most patients with spinal tuberculosis [5]. Failure of nonsurgical treatment, abscess formation, neurological deterioration and progressive kyphotic deformity or instability are all indications for surgical intervention [2, 6]. Goals of surgical intervention for spinal tuberculosis include alleviation of pain, spinal cord decompression, prevention and correction of deformity with spinal stabilization, and resection of the infectious paraspinal component to allow antituberculous chemotherapy to work more effectively [18].

Anterior radical debridement and fusion has been advocated for the treatment of patients with tuberculous spondylitis since 1960 [13, 19, 20]. Surgical debridement of the compromised anterior column results in a further loss of structural integrity that requires anterior reconstruction. Structural autograft continues to be the historical standard in anterior reconstruction [21]. However, there may be substantial morbidity

associated with the harvest of large structural autografts, such as infection, pain, and loss of structural support at the harvest site, in addition to the limited supply of structural autograft that makes it difficult or impractical in many patients with tuberculous spondylitis who require surgical treatment [22]. Other options available for anterior column reconstruction include structural allograft or titanium cages filled with crushed cancellous allograft and autograft [14, 23]. Titanium cages have been shown to be effective for anterior column reconstruction of spine in traumatic, pathologic and infection [23–26]. The titanium cage can be filled with autograft in addition to crushed cancellous allograft that can allow rapid incorporation of the graft. The cage with bone grafts allows for a more solid fixation construct and minimizes the risk of graft dislodgement or subsidence that are well documented complications when structural bone graft alone is used [11, 12, 27–29]. It also provides safer stability than structural bone graft alone in the infection region that allows tissue rest and earlier mobilization [12, 27]. Our consideration for using titanium cages filled with crushed cancellous allograft/and autograft was to overcome the morbidity associated with structural autograft and the slow rate of graft incorporation associated with structural allograft. This study identified a correction of kyphosis from preoperative 20.8° to immediate postoperative 3.9°, and a final kyphosis of 4.7°, which corresponded to a mean loss of correction of 0.8°, resulted from subsidence of titanium cage. This has shown that the titanium cage is effective in maintaining sagittal alignment over a long postoperative period.

The criteria described by Bridwell *et al* is probably the gold standard in assessing the completeness of bony fusion for the high intraobserver and interobserver agreement [17, 30]. As the Bridwell criteria were initially described to identify bony fusion in cases of strut allograft rather than titanium cages, we modified it in this study considering that the achievement of bony healing of compromised vertebra despite the presence of remodeling may be the more important factor for the ultimate outcome of spinal tuberculosis. The duration of biologic incorporation of allografts is of clinical importance because it may be slow and unpredictable, resulted from immunological responses to donor antigens [31, 32]. This study identified a Grade 1 or 2 allograft incorporation in 92% of the patients, suggesting that immunological responses does not hinder the development of solid bony fusion, and that the achievement of this solid bony fusion despite the duration of allograft incorporation may be the more important factor for the ultimate outcome of spinal tuberculosis.

Implantation of metallic instrumentation into the infected region, however, is a matter of debate because although implants help provide structural stability, the presence of foreign material in an area of mycobacterial infection may interfere with successful eradication of infection [12, 27, 28]. There were experimental studies suggest that *Mycobacterium tuberculosis*, unlike pyogenic bacteria, has low adherence to metal and forms less polysaccharide biofilm [33, 34]. Therefore, the use of metal implants in the region of mycobacterial infection may be relatively safe [9]. This study identified tuberculosis recurrence only in one of 133 patients, suggesting that implantation of titanium cages into the region of mycobacterial infection have lower infection risk. Furthermore, we believe that the reconstruction of unstable spinal segments offered by this method may resulted in a more favorable environment for control of infection, graft incorporation, and solid bony fusion.

Although the anterior instrumentation offers more reliable restoration of structural stability compared with posterior instrumentation [35], in patients with two or more severe vertebral destruction that may lead to significant kyphotic deformity [36], either the anterior or posterior instrumentation alone may be insufficient theoretically, and a combined anterior and posterior instrumentation should be more reliable in preventing the development of kyphotic deformity [20, 37, 38]. There were researches suggest that when two or more vertebrae have been removed resulted from radical debridement, the grafts are prone to failure or resorption [12], and supplemental posterior fusion and instrumentation is an reinforcement to anterior instrumentation and helpful to arrest the infection, correct the kyphosis, prevent progression of kyphosis and promote early fusion [37–39]. Furthermore, the surgical dissection should be wider to fix the anterior plate to the adjacent unaffected vertebrae, which may lead to more complications or infection spread. In the current series, about 60 percent of the patients (80 of 133) had destruction of two or more vertebral bodies. And combined anterior and posterior procedure was performed for these patients. This study identified a correction of kyphosis in these patients from preoperative 23.3° to immediate postoperative 3.9°, and a final kyphosis of 4.5°, which corresponded to a mean loss of correction of 0.8°, resulted from subsidence of titanium cage. This has shown that although the combined anterior and posterior procedure was related with prolonged operating time, more blood loss, and increased postoperative complications [40], posterior stabilization with instrumentation after anterior spinal debridement and fusion is effective in maintaining sagittal alignment over a long postoperative period.

Our study is mainly limited by the retrospective study and the absence of a control group. As the result of infrequent condition of spinal tuberculosis, it is nearly impossible to conduct a prospective study with a rational timepoint for completion. The fact that all patients were operated on by the same surgeon and were observed for a mean > 3 years by two blinded independent observers may allow us to draw meaningful conclusions.

Conclusion

Radical debridement followed by allograft with titanium cage in reconstruction of the anterior spinal column offers very satisfactory results in patients with tuberculous spondylitis. It provides immediate stability, offers lasting kyphosis correction, bypasses the donor site morbidity and difficulties involved in obtaining structural autograft.

Declarations

ACKNOWLEDGEMENTS

Not applicable.

AUTHORS' CONTRIBUTIONS

YJW conceived and designed the study, analyzed the data and wrote

FUNDING

Not applicable

AVAILABILITY OF DATA AND MATERIALS

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable

CONSENT FOR PUBLICATION

Written informed consent for publication was obtained from all participants

COMPETING INTERESTS

The authors declare that they have no competing interests.

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Figures

Figure 1

Fusion with healing of compromised vertebra.

Figure 2

Graft intact with no lucencies at the top or bottom, but without full healing of compromised vertebra.

Figure 3

Fusion, graft intact but definite lucency at bottom of the titanium cage.