Six-year outcome of thoracoscopic ventral spondylodesis after unstable incomplete cranial burst fractures of the thoracolumbar junction: ventral versus dorso-ventral strategy

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Abstract

Purpose The purpose of this study is to determine the long term-results after thoracoscopic spondylodesis particularly with respect to a ventral versus dorso-ventral treatment strategy.

Methods In this prospective cohort study, a follow-up examination was performed in 19 patients (seven men, 12 women, average age: 37.7 years, follow-up rate: 79 %), six years after ventral thoracoscopic spondylodesis of unstable, incomplete burst fractures. Nine patients received a ventral monosegmental spondylodesis with iliac crest bone graft. The other ten cases were treated dorso-ventrally, five undergoing a ventral monosegmental treatment with iliac crest bone graft; the other five a ventral bisegmental treatment with expandable titanium cage.

Results The complication rate was 15.7 %, the rate of revision of 10.5 %. No complication was related to the ventral thoracoscopic approach, whereas all of them were related to the iliac crest bone graft. The operative bisegmental kyphotic reduction was higher in the dorso-ventrally treated group. Afterwards, the loss of reduction was similar in both study groups. The mean VAS spine score summed up to more than 80 in both groups. The mean PCS scores were comparable to a normal healthy collective of the same age.

Conclusions The ventral thoracoscopic approach to the spine seems to be a safe therapeutic strategy. A dorso-

ventral treatment concept goes along with a higher operative reduction potential.

Introduction

What becomes apparent from the numerous recent studies on treatment strategies for acute thoracolumbar vertebral fractures [1–12] are controversies about the optimal treatment strategy for incomplete burst fractures, some favoring a conservative therapy, others dorsal or ventral therapy strategies or a dorso-ventral approach. The scientific evidence is largely based on retrospective case series [10]. Only a limited number of prospective studies deals with thoracolumbar fractures [2, 8, 11, 12].

The ventral thoracoscopic spondylodesis of the thoracolumbar spine is a relatively new and elegant treatment strategy for unstable fractures of the thoracolumbar spine [13, 14]. To compare different therapy strategies, it is necessary to include specific fracture types according to an accepted classification, such as the classification of the Arbeitsgemeinschaft Osteosynthese (AO) [15]. Some authors merely included burst fractures of the A3 type [1, 2, 4, 8–10, 16] without further differentiation.

The aim of this study was to evaluate the long term-results after thoracoscopic spondylodesis of unstable incomplete cranial burst fractures of the thoracolumbar junction, particularly with respect to a ventral versus dorso-ventral treatment strategy.

Material and methods

Inclusion criteria for this prospective cohort study are listed in Table 1. All patients were included in the years 2002 and 2003.

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Table 1 In- and exclusion criteria

Inclusion Criteria	Exclusion Criteria
Cranial incomplete burst fracture type A3.1.1	Prior pathologies at the vertebral spine
McCormack: ≥ 6 points	Age: <18 and >60 years
Thoracolumbar junction: Th10-L2	Contraindication for a thoracoscopic approach
Acute trauma: ventral spondylodesis within four weeks after trauma	Posttraumatic neurologic Deficit (ASIA A to D)
High energy trauma	ASA >3

ASIA American Spinal Injury Association (ASIA) Score; ASA American Society of Anesthesiologists (ASA) Score

During both years a total of 364 patients with acute vertebral fractures of the thoracolumbar spine received inpatient treatment. 63 of them suffered of isolated incomplete burst fractures. 76 % were localized at the thoracolumbar junction. Overall, 24 patients fulfilled all of our inclusion criteria (Table 1).

The final follow-up examination was performed in 19 patients (seven men, 12 women) after a mean of 77.4 months (± 6.6 months) including a clinical and radiological examination. The follow-up rate was 79 %. Five patients were lost to follow-up. Two patients could not be reached because of incorrect mailing address and phone number. Three patients had moved away and were not able to come for re-examination. All five followed a broadly similar course in respect of fracture type, inpatient time, inpatient VAS spine score, and intraoperative reduction. Table 2 sums up our patient collective. Ten patients (four women and six men) were treated with additional dorsal instrumentation (Fig. 1). Initially, a bisegmental dorsal stabilization was performed 1.6 days (range:

zero to three days) after trauma. Ventral thoracoscopic spondylodesis was performed after another 5.5 days (range: three to eight days) monosegmentally in five patients, with a bisegmental spondylodesis in the other five (Fig. 2). A ventral approach was performed in nine patients (eight women, one man) (Fig. 2), 6.5 days (range one–15) after trauma. The study protocol was approved by the Regional Ethics Committee.

The classification of vertebral body fractures was performed according to Magerl et al. [42] and McCormack [17] on the basis of the post-traumatic computer tomographic (CT)-examination. In cases of suspicion of intervertebral disc lesions or lesions of the dorsal column, an MRI examination was performed.

We saw an indication for an operative therapy strategy in cases of unstable fracture types based on the load sharing classification of McCormack [17]. McCormack classified fractures according to the comminution and involvement of the vertebral body, the apposition of fragments, and the

Table 2 Patient collective

Patient	Age (years)	ISS	McCormack ¹⁷	Location	Surgical Approach	Concept of Spondyl	Vert Body Replace	Op Time (mm)
1	38	9	7	L 1	Dors-ven	Monoseg	Bone graft	198
2	43	9	6	L 1	Dors-ven	Monoseg	Bone graft	310
3	31	4	7	Th 12	Dors-ven	Monoseg	Bone graft	269
4	51	9	7	L 1	Dors-ven	Monoseg	Bone graft	189
5	30	13	7	L 1	Dors-ven	Monoseg	Bone graft	228
6	55	13	8	L 1	Dors-ven	Bisegine	Cage	170
7	43	9	7	L 1	Dors-ven	Bisegme	Cage	220
8	47	9	7	L 1	Dors-ven	Bisegme	Cage	225
9	36	9	7	Th 12	Dors-ven	Bisegine	Cage	190
10	46	19	8	Th 10	Dors-ven	Bisegine	Cage	225
11	23	9	6	L 1	Ventral	Monoseg	Bone graft	205
12	24	9	6	Th 12	Ventral	Monoseg	Bone graft	215
13	22	9	7	L 1	Ventral	Monoseg	Bone graft	300
14	46	9	7	L 2	Ventral	Monoseg	Bone graft	200
15	43	17	7	L 1	Ventral	Monoseg	Bone graft	255
16	23	4	7	L 1	Ventral	Monoseg	Bone graft	180
17	32	9	6	L 1	Ventral	Monoseg	Bone graft	205
18	53	9	7	Th 12	Ventral	Monoseg	Bone graft	280
19	31	9	6	L 1	Ventral	Monoseg	Bone graft	230

Fig. 1 31-year-old male patient fell while paragliding from a height of about 5 metres. He was transferred to our hospital one day after trauma. The conventional x-ray examinations of the spine illustrated the incomplete fracture of the 12th thoracic vertebral body (in **a**, **b**). There were no further injuries, particularly no neurological deficit. The dorsal bisegmental stabilization was performed one day after being transferred to our clinic. Another four days later, the ventral monosegmental thoracoscopic spondylodesis (Th11-Th12) with iliac crest bone graft and plate was performed (**c**, **d**). After six years, a complete osseous consolidation of the bone graft is visible (**e**, **f**). The patient had no limitations and no discomfort with a full range of motion

kyphotic correction. Vertebral body fractures scored six or higher were defined as unstable. We saw an indication for ventral reconstruction in accordance to Gonschorek et al. [18]. Dorsal stabilization was initiated in all vertebral body fractures involving more than 60 % of the vertebral body, representing a kyphotic malalignment of more than 15°, and in cases of an additional lesion of the dorsal column. All other fractures were treated by a ventral-only strategy.

All patients, who received a combined dorso-ventral approach, were treated dorsally first. In prone position, bisegmental instrumentation, anatomic reduction, and stabilization with *fixateur interne* (USS®, Synthes, Oberdorf, Switzerland) were performed in the manner of Knop et al. [7]. The ventral stabilization was done one to 15 days after surgery in the technique described below.

The ventral approach is performed by way of the thoracoscopic-assisted surgery analogous to Beisse et al. [19] using a left lateral approach. Usually an endoscopic splitting of

Fig. 2 55-year-old male patient who fell while sliding. He was initially transferred to our hospital. An incomplete burst fracture of the first lumbar vertebral body was diagnosed (**a**, **b**). On the 2nd day after trauma, the dorsal reposition and stabilization with a *fixateur interne* (Th12 to L2) was performed; four days later, a bisegmental thoracoscopic spondylodesis from Th12 to L2 was done (**c**, **d**). The conventional radiological examination after six years is visible in (**e** and **f**)

the diaphragm is necessary for the ventral thoracoscopic approach of the vertebral bodies L1 and L2 [19]. In cases of monosegmental spondylodesis, a partial corpectomy was performed, maintaining the anterior and posterior wall, as well as the intact portion of the fractured vertebral body. Additionally, a discectomy of the affected intervertebral disc was performed (Fig. 3). The ventral column was reconstructed with an adjusted autologous tricortical iliac crest bone graft and a ventral angular stable plate (MACS TL®, Aesculap, Tuttlingen, Germany) [13]. In cases of bisegmental spondylodesis a discectomy of the cranial and caudal intervertebral disc was performed. The adjacent endplates were kept intact. A distractible titanium cage for vertebral body replacement (Synex I®) was implanted according to Knop et al. [7]. The reconstruction of the ventral column was completed by implanting a ventral plate (MACS TL®). The diaphragm was closed by suture if splitting was necessary. All patients received a chest tube after surgery.

Fig. 3 Intraoperative thoracoscopic view of the spine, while measuring the size of the partial corpectomy of L1 to adjust a tricortical iliac crest bone graft, after uncompleted ventral instrumentation of T12 and L1

The iliac crest bone graft was performed as follows: Approach parallel to the spina iliaca superior and 2 cm lateral to the spina iliaca anterior superior preposition of the iliac crest; osteotomy of an adjusted tricortical bone graft after injection of 1 ml of 5 % procaine. Afterwards, a four-hole plate (BOS[®], Synthes) was implanted to cover the edges of the iliac crest.

The removal of the fixateur interne was performed in all five patients who had received ventral monosegmental treatment as well as in one who had undergone ventral bisegmental treatment because of pain over the palpable implant and persistent problems when lying on the back. The removal of the implant was performed after an average of 9.5 months (range: eight–14 months) after instrumentation.

Intensive monitoring for 24 hours was performed in all patients after ventral spondylodesis. The chest tube was removed after 24 hours. Early functional mobilization without cast or prosthesis was started on the first postoperative day. The individual physiotherapeutic training program was based on vertebral spine-compatible standards. A CT-examination to control the implant position and the vertebral alignment was performed on the second postoperative day.

Data acquisition was performed pre- and postoperatively, after three, six, 12, and 18 months, as well as after six years. The radiological parameters of interest were the bisegmental and monosegmental kyphotic end plate angles. These measurements were based on a standardized CT-examination of the injured portion of the vertebral spine according to Reinhold et al. [12]. A radiological follow-up examination consisting of a CT examination was carried out after six years on all 14 patients who had undergone ventral monosegmental treatment, as well as on one patient who had been subjected to a ventral bisegmental treatment and suffered slight discomfort. A conventional radiological examination was performed in the other four patients. Further outcome parameters are the

Short Form 36 (SF-36) score [20], the Visual Analogue Score (VAS) of the spine [21], the reintegration to work, as well as the morbidity of the surgical approaches.

Statistics

All data underwent statistical analysis using standardized SPSS software 17.0 (SPSS[®], Inc. Chicago, USA). Statistical analysis was made using descriptive statistics for comparing both study groups and Kendall's tau correlation coefficient (R) for comparison of different parameters within each group of patients with a level of significance $P < 0.05$.

Results

Our patient collective had a mean age of 37.7 years (± 6.6 years) (Tables 2 and 3). The mean age of the ten patients who had received ventral treatment was 33.0 years (± 11.6 years), whereas the nine patients treated with an additional dorsal instrumentation had a mean age of 42.0 years (± 8.2 years). At the six-year follow-up examination, three patients (15.8 %) showed complications including an irritation of the N. cutaneous femoris lateralis after removal of an iliac bone graft, an incisional hernia, and one dislocation of the iliac bone graft after dorso-ventral treatment, all of them being evident at the 18-month assessment. An operative revision was necessary in two of them (10.5 %). All of the complications and revision surgeries were related to the iliac crest bone graft.

The bisegmental kyphotic end plate angles depending on the treatment strategy are illustrated in Fig. 4 and Table 3. The operative correction was higher in the patient group subjected to the dorso-ventral treatment. In both groups, a high percentage of the operative correction was lost after six years (Fig. 4, Table 3). This was slightly higher in the collective that had received dorso-ventral treatment.

The monosegmental kyphotic end plate angles of the patients who underwent ventral monosegmental treatment (Table 2, Fig. 1) are illustrated in Table 3. Again, the operative correction was higher in the five patients treated dorso-ventrally. After six years, the persistent gain of correction in the patient group treated with an additional dorsal instrumentation was $4.0 \pm 2.3^\circ$, whereas the patients treated ventrally only offered a loss of reduction minimally higher than their initial gain of it ($-0.4 \pm 2.9^\circ$).

After six years, no serious problems related to the ventral and dorsal surgical approaches were seen. Eight of the ten patients treated dorso-ventrally reported no pain or limitations. Slight infrequent discomfort was reported by two patients, one treated ventrally, the other dorsally. Six of the patients who underwent ventral treatment were free of any

Table 3 The summary of accidents

Operative Strategy		N	Mean	Std. Deviation
Dorso-ventral	Age	10	42.0	8.2
	Injury Severity Score	10	10.3	3.9
	VAS Spine Score	10	84.1	11.5
	Physical Component Summary	10	47.1	13.6
	Mental Component Summary	10	54.6	4.7
	Bisegmental Operative Reduction	10	8.0	4.6
	Bisegmental Loss of Reduction	10	-6.2	3.3
	Monosegmental Operative Reduction	5	11.4	2.2
	Monosegmental Loss of Reduction	5	-7.4	2.3
Ventral only	Age	9	33.0	11.6
	Injury Severity Score	9	9.3	3.3
	VAS Spine Score	9	72.3	19.5
	Physical Component Summary	9	48.6	7.7
	Mental Component Summary	9	49.8	11.2
	Bisegmental Operative Reduction	9	4.3	2.9
	Bisegmental Loss of Reduction	9	-3.4	1.6
	Monosegmental Operative Reduction	9	3.7	2.7
	Monosegmental Loss of Reduction	9	-4.1	2.9

symptoms related to the ventral approach. The other three patients suffered from minor discomfort. Only four patients (29 %) who were treated ventrally with an iliac crest bone graft did not mention any discomfort related to the donor site [22]. Eight of them (57 %) reported slight intermittent pain without any need of analgesics, whereas two patients (14 %), irregularly taking non-steroidal anti-inflammatory drugs, suffered persistent pain.

Seventeen patients (89.5 %) were able to return to the same place of work without limitations. One patient had to find a new job because of persistent discomfort related to pain at the graft donor site. Another patient had to retire from work due to another injury.

Fig. 4 Depicts the course of the bisegmental sagittal alignment of the all patients. The patient group subjected to dorso-ventral treatment is presented by the *blue line*, the patients subjected to ventral-only treatment by the *red line*. The bisegmental kyphotic end-plate-angles were evaluated after trauma, postoperatively, after 18 months, and after six years

The VAS spine scores of our patients are illustrated in Fig. 5. In general, the pain situation was low without any relevant differences between both study groups.

The scores of the Physical Component Summary (PCS), as a part of the SF 36 score are shown in Fig. 6. Again, there were no obvious differences between both patient groups. Similarly no relevant differences were found between our study groups and a normal collective of the same age (German normal collective between 35 and 40 years) [23].

To evaluate any synergies between radiological measurements and the clinical outcome parameters, correlations were determined between surgical reduction and persistent gain of corrections, on the one hand, and all functional

Fig. 5 Box plot depicting the VAS spine scores of both patient groups

Fig. 6 Box plot illustrating the physical summary scores of both patient groups. Additionally the physical summary scores of a German normal collective of the same age (35–44) is presented

outcome parameters on the other. A significant correlation was found between the VAS spine score and the monosegmental angle ($p=0.036$).

Discussion

Reinhold et al. [12] reported on a prospective multicenter study (MCS II) of the German Society of Trauma Surgery. They performed a matched-pair analysis comparing operative versus non-operative treatment in cases of burst fracture types A3.1 and A3.2 of the thoracic and lumbar vertebral spine. Twelve of them were treated conservatively, 60 operatively. The period of return to work was twice as long in the patient group treated conservatively. The average gain of correction, which persisted for 15 months, was significantly better in the operatively treated patient group.

But it remains unclear to what extent patients benefit from an anterior reconstruction or a combined anterior and posterior treatment strategy. A higher operative reduction of the posttraumatic kyphotic malalignment could be seen in the patients that were subjected to a combined dorso-ventral treatment strategy. This is consistent with a majority of published research studies [9, 12, 24]. On the other hand, Danisa et al. [4] and Verlaan et al. [10] reported no differences in kyphotic malalignment after dorsal, ventral, or combined dorso-ventral stabilization. In conformity with both studies, we found only minor differences in respect of the bisegmental kyphotic endplate angles six years after ventral or dorso-ventral treatment. In contrast, by comparing the monosegmental endplate angles of all patients who underwent ventral monosegmental treatment, a persistently improved gain of reduction was seen in the dorso-ventrally treated group, compared to the group subjected to ventral treatment only. In this regard, two points

ought to be discussed in more detail. First of all, the validity of the bisegmental kyphotic malalignment with respect to reduction and correction loss in patients treated monosegmentally appears to be doubtful. The variable height of the intact intervertebral disc happens to be a potential source of error with low reproducibility. Consequently, bisegmental measurements in cases of monosegmental spondylodesis might offer insufficient accuracy. Secondly, the indication for a dorso-ventral approach by definition implies a more serious lesion of the ventral column leading to a more unstable situation. Thus the conclusions that can be drawn by measuring the course of the bisegmental angles have to be well considered. Nonetheless, six years after surgery, our rate of the surgical reduction exceeded the loss of correction in the majority of our patients. And even though a high percentage of reduction was lost over the years, these radiological results outperform the conservative therapy strategy with its lack of an adequate reduction potential. It remains doubtful to what extent a dorsal-only approach is able to avoid higher correction loss in cases of severe lesions of the anterior column.

This notwithstanding, Reinhold et al. [40] found a higher loss of correction in cases of anterior spondylodesis by bone crest as opposed to cage implantation. Therefore, there might be some potential of radiological improvement by implanting cages instead. In addition to this, the surgical approach to the iliac crest is associated with relevant morbidity including persisting long-term graft donor site pain [25]. The six-year outcomes of our patients, who were treated with an iliac crest bone graft, has been published recently [22]. The proportion of our patients suffering from donor site pain is high (71 %). Similarly, Wipperfman et al. [25] reported a complication rate of 19.6 % and persisting pain in 55 %. Overall, all of our complications were related to the iliac crest bone grafts. Therefore we changed our therapy regime, using cages for both mono- and bisegmental vertebral replacement. We experienced no complications related to the ventral approach to the vertebral spine.

Some controversies exist about the correlation between functional outcome and kyphotic malalignment. Whereas some authors reported positive association [5], others did not observe any significant correlation [1, 8, 11, 12]. We saw a significant correlation between the monosegmental angle and the VAS spine score after six years in all patients who underwent ventral monosegmental treatment.

Overall the VAS and PCS scores of all other patients were promising. The PCS scores of both study groups, ventral versus dorso-ventral, were comparable to a normal collective of the same age. No significant differences could be seen between both study groups in terms of functional outcome parameters. This is consistent with the data found in literature [3, 9, 12]. At the six-year examination the morbidity of the ventral approach in our patient collection was negligible. Similarly, several other authors reported

good clinical outcomes after ventral-only stabilization using minimally invasive thoracoscopic approaches [12, 13, 16].

Limitations of this study are the lack of randomization leading to an inhomogeneous distribution of fracture patterns and its grade of instability between both study groups. Next, we performed the ventral monosegmental spondylodesis with an iliac crest bone graft. By using cages for mono- and bisegmental spondylodesis, we expect reduced correction loss, reduced operating time, and a considerably reduced complication rate. Besides the small-sized study group has to be discussed critically. Statistical differences such as the significant correlation between the sagittal alignment and the VAS spine score may very well be caused by the low number of patients included in this study. In addition, other co-variables not been taking into account by simple paired statistics may confound clinical findings. Thus, the statistical analysis between both study groups was done on a descriptive basis only. Last but not least the important effect of depression and anxiety in respect of pain levels has not been considered at all.

The strengths of this study are the prospective data acquisition, the long follow-up period of more than six years and its strict inclusion parameters such as incomplete cranial burst fractures of the thoracolumbar junction only. But further studies are necessary to improve our understanding of the best treatment strategies for this fracture type.

Conclusion

The surgical approach to the iliac crest is accompanied by a relevant complication rate, whereas the ventral-thoracoscopic approach to the spine after unstable, incomplete cranial burst fractures of the thoracolumbar junction offers a safe therapeutic strategy leading to mainly good and very good long term results. In comparison to the ventral-only therapy strategy, the dorso-ventral treatment concept seems to offer a higher operative reduction potential.

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