360-degree osteosynthesis via a posterolateral transpedicular approach in high-risk patients

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Received: 7 September 2011 / Revised: 2 January 2012 / Accepted: 3 January 2012 / Published online: 11 January 2012
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Abstract

Purpose Patients requiring anterior–posterior thoracic spine stabilization and suffering from concomitant cardiopulmonary disease are at increased risk to develop procedure-related complications. In order to reduce cardiopulmonary complications, the efficacy of a posterolateral transpedicular approach for 360-degree fusion was investigated.

Methods Fourteen consecutive patients presenting with spinal cord compression from osteoporotic, metastatic and tuberculous fractures were treated. Spinal cord decompression was achieved by laminectomy, facetectomy and corpectomy with subsequent posterior instrumented fusion using a screw–rod system.

Results The procedure was successfully performed in 14 high-risk patients. Preoperatively, all patients presented with thoracic and lower back pain and nine patients with a paraparesis (Frankel grade C). The implants were introduced monoportally or biportally. In all cases, neurological symptoms moderately improved.

Conclusion The posterolateral transpedicular approach might be a safe, less-invasive and efficient alternative to anterior–posterior fusion. However, biomechanical efficacy and long-term outcome as compared to the transthoracic technique remains to be studied in a larger patient cohort.

Keywords Posterolateral approach · Osteosynthesis · Spine · Spine metastasis

Objective

Spine tumors and fractured spines cause pain, neurological deficit or loss of mobility as a result of epidural spinal cord compression combined with spinal instability. Despite radiation therapy, surgery is often indicated for spine tumors. Metastatic spine tumors involve the vertebral body in 70% of cases and spare the posterior column [3]. Compression of spinal cord is frequently anteriorly or bilaterally, and additionally compression and instability due to fractures often lead to an anterior transthoracic approach. Frequently this has to be combined with a posterolateral decompression and circumferential fixation via a subsequent surgery through a posterior approach. Combined, single-stage anterior–posterior approaches are associated with an increase of perioperative morbidity, especially in patients with poor medical conditions due to cardiopulmonary diseases [20]. However, spinal cord decompression and fusion in these patients is increasingly performed [5] to improve or retain neurological function, improve quality of life and to reduce pain, preferably by minimizing surgical invasiveness.

Therefore we investigated the efficacy and feasibility of a single-stage, circumferential spinal cord decompression via a solely posterior approach, as a less-invasive alternative procedure to standard combined anterior–posterior approaches.

Clinical materials and methods

Patient population

Eleven patients with spinal metastases from different primary tumors and three patients with tuberculous or

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osteoporotic fractures underwent surgery via the posterolateral transpedicular approach to achieve 360-degree fusion. Patients were eight male and six female with mean age of 65.6 years (range 43–81 years). Mean follow-up was 7 months (range 3–14 months). The surgical procedure was chosen on the basis of neurological deficit, tumor manifestation and systemic disease. All patients were evaluated by visual analog scale (VAS) [18] and Frankel grade pre-and postoperatively [10]. Patient characteristics are illustrated in Table 1.

Preoperative diagnostics

All patients received preoperative magnet resonance imaging (MRI) of the entire spinal axis and additional computerized tomography (CT) scanning with coronal and sagittal reconstructions at the levels of the underlying pathology.

Surgical technique

All patients were operated under general anesthesia with continuous neuromonitoring (somatosensory and motor evoked potentials) in prone position. In patients with thoracic spine metastasis, the index level was preoperatively marked with computed tomography-guided placement of a hooked-wire needle system [19]. For localization of lumbar pathologies, intraoperative fluoroscopy was used.

After midline incision, the posterior aspects of the laminae were exposed, with a lateral extent to the corresponding transverse processes. Posterior multi-segmental fixation was then performed, using a screw-rod system (Expedium, DePuy Spine, Raynham, MA, USA). Polyaxial pedicle screws (DePuy spine, Raynham, MA, USA) were usually applied two levels above and below the pathology. A rod was fixed on the side with lesser tumor extension. Subsequently, the thecal sac, i.e. the spinal cord was decompressed from posterolaterally via laminectomy, facetectomy and resection of the pedicle; For thoracic pathologies, partial costotransversectomy was additionally performed in one case. The thecal sac and nerve roots were then identified and posterior epidural tumor and infiltrated bone was resected. Anterior epidural tumor along with infiltrated posterior longitudinal ligament was then removed to achieve anterolateral spinal cord decompression. The infiltrated vertebral body was removed using curettage and drilling. Here, rod-assisted intervertebral distraction helped to better appreciate the previous tumor cavity. During this stage of tumor resection significant bleeding commonly occurred but instantly diminished when gross total resection was achieved. Preoperative embolization may be considered to decrease hemorrhage risk. Then one or two Harms titanium mesh cages (DePuy

spine, Raynham, MA, USA) were inserted in the previous vertebral bodies, from posterolaterally. The cages were filled with bone or synthetic bone graft (Actifuse, Apatech, Berlin, Germany) (Figs. 1b, 4b). In the thoracic spine, this maneuver sometimes required sacrifice of one nerve root. The distance between two adjacent lumbar nerve roots was always sufficient to introduce cages without any root compromise, because the thecal sac might be gently retracted in contrast to the thoracic level. The cage position was controlled under fluoroscopy and the second rod was then inserted. Ultimately, the rods were slightly compressed and horizontal bars were fixed at the levels of laminectomy to increase stability.

Results

A total of eight men (57%) and six women (43%) were treated. Surgery was performed in patients with spinal metastasis from renal cell carcinoma (4), malignant melanoma (1), cancers of unknown primary (2), plasmocytoma (3) and undifferentiated carcinoma (2). Additionally one patient with tuberculous fracture and two patients with osteoporotic fractures and subsequent spinal cord compression were treated. Mean operation time was 189.3 ± 31.7 min. Mean blood loss amount was $1,096.4 \pm 319.5$ ml. Preoperative kyphosis was generally not reduced in postoperative CT scanning. One slight cage dislocation was detected without the need of revision. Preoperative pain, as measured by VAS improved significantly ($p = 0.012$, t test). Pre- and postoperative Frankel score improved in 43% and remained constant in 57% of the patients (Table 1). Two patients died of their primary tumor disease after 1 and 3 months and two more patients were lost to follow-up after the fourth and fifth month, respectively.

Discussion

The present feasibility study found that the application of the posterolateral transpedicular approach for decompression and fusion in patients with concomitant cardiopulmonary disease constitutes a fast, save and sufficient surgical procedure for this subgroup of patients. All patients with severe preoperative pain improved in the early postoperative course (mean preoperative VAS: 5.86, mean postoperative VAS: 3.21 $p = 0.012$, t test). The Frankel score improved in 43% and no patient deteriorated, postoperatively (same Frankel grade pre- and postoperatively, 57%).

The most common complications resulting from posterior approaches are wound infections, with a range from 10 to 62% [9, 21]. In the presented series with a selected cohort of patients with additional comorbidities the rate of

Table 1 Study population characteristics

Case no.	Age (year)/sex	Pathology	Medical history and comorbidities	Kamofsky index (%)	Preop. reduction of spinal canal diameter (%)	Replacement level/cage cross section dimension/length (mm)	Operation time (min)/blood loss (ml)	VAS ¹⁸ preop./postop.	Neurological Grade ¹⁰ preop./postop.	Last follow-up
1	50/F	Tuberculous fracture	Tuberculosis	70	50	T2/two cages à 12 × 29	220/1200	6/3	D/D	Ambulant
2	69/F	Pancreatic carcinoma	COPD, acute pulmonary insufficiency, arterial hypertension	40	40	T3&4/one cage 20 × 45	180/1350	5/2	C/D	Ambulant with cane
3	73/F	Osteoporotic fracture	COPD, arterial hypertension, pulmonary embolism	80	40	T7&8/one cage 20 × 43	240/1400	7/4	D/D	Ambulant
4	81/M	Renal cell carcinoma	COPD, coronary artery disease	60	40	T11/one cage 20 × 19	170/1000	7/4	D/D	Ambulant, VAS 0
5	56/M	Undifferentiated carcinoma	Coronary artery disease, Pneumonia	40	50	T3/one cage 14 × 20	200/1100	8/3	C/C	CNS metastasis, Korsakow-Syndrom
6	60/M	Renal cell carcinoma	COPD, Ascites, Congestive heart failure	40	50	L2/one cage 14 × 40	160/1350	6/4	C/D	Died from primary disease
7	69/M	Plasmocytoma	Rheumatoid arthritis, acute pulmonary insufficiency	40	60	T3/one cage 14 × 35, partial T1	220/1500	7/4	C/D	Ambulant with cane
8	60/F	Melanoma	Pneumonia	80	50	T6/one cage 14 × 25	170/900	5/1	D/D	–
9	71/F	Plasmocytoma	Arterial hypertension, previous thoracic operation	40	60	T6/one cage 14 × 25	190/900	4/2	C/D	Ambulant with walker
10	75/M	Plasmocytoma	Acute pulmonary insufficiency, COPD, renal insufficiency (dialysis)	40	70	L2&3/one cage 14 × 40	240/1400	7/5	C/D	Died from primary disease
11	68/M	Undifferentiated carcinoma	COPD, pleural effusion	40	40	T11/one cage 14 × 37	160/800	3/0	C/C	Ambulant with walker on short distances
12	75/M	Renal cell carcinoma	Arterial hypertension, COPD, lung cancer	50	60	T3/one cage 14 × 38	200/1350	6/5	B/B	–
13	68/M	Osteoporotic fracture	Pneumonia, COPD	40	50	L1/one cage 14 × 25	160/500	5/5	C/C	Ambulant with walker
14	43/F	Renal cell carcinoma	COPD	40	60	T3/one cage 14 × 24	140/600	6/3	C/D	Ambulant with walker

Preop preoperative, Postop postoperative, VAS visual analog scale, CNS central nervous system, COPD chronic obstructive pulmonary disease

Fig. 1 Illustrations showing the 360-degree fusion technique via a posterolateral transpedicular approach. **a** Tumor pattern with vertebral body disease extending into the pedicle and epidural space. **b** Titanium

mesh cage placed in the vertebral body defect and posterior segmental fusion with a screw-rod system

wound dehiscence was 21% but no meaningful wound infection was seen. However, there may be a higher wound complication rate in patients who had prior conventional radiation therapy [21]. Aggravation of the cardiopulmonary disease was only seen in one patient in our series, as compared up to 50% respiratory complications in patients who underwent transthoracic surgery [16].

Despite improved surgical techniques for patients with spine tumors, radiation therapy remains the first-line therapy for many patients with metastatic spine tumors. Radiation therapy has confirmed effectiveness in avoiding neurological deterioration and long-term tumor control in patients without epidural compression [14]. However, decompression and stabilization is indicated in patients with spinal metastases or nonpathological fractures who have high-grade epidural compression with or without neurological deficit and three-column instability. Metastatic spine tumors involve the vertebral body in 70% [3] and a resection of more than 50% of the vertebral body diameter usually requires reconstruction of the body, as the main axial load is transmitted through the anterior column [21]. Here, an anterior, transcanthary approach is often favored because of excellent exposition and resection of the affected vertebral body [11]. Frequently the anterior approach has to be combined with posterolateral

decompression in case of circumferential or dorsal epidural mass. Then a 360-degree decompression and fixation via a second dorsal approach might be required. Among many, the major disadvantage of a two-staged surgery is the higher morbidity due to longer operation time and increased blood loss [8]. For patients with poor medical conditions or in a palliative situation because of their primary tumor disease an extensive two-stage approach may be contraindicated. In these cases minimization of the surgical treatment but with a maximum benefit in terms of neurological improvement and mechanical stability of the spine is mandatory. Hence, our proposed single-stage procedure may contribute to a reduced operation time and decrement of blood loss. Preoperative embolization of hypervascular spinal metastases may additionally reduce the risk of significant bleeding. This may result in shortened hospitalization time and finally better clinical outcome as compared to the more invasive procedures.

The decision making process to use a particular surgical approach depends on the localization of the tumor, bone quality, previous intervention, type of required reconstruction, patient's medical conditions and not least on surgeon's familiarity with the technique. All fourteen patients were considered for an anterior approach because of extensive vertebral body involvement. Of these, three

patients were urgently decompressed (laminectomy and dorsal or dorsolateral tumor debulking). Due to residual anterior tumor compression pain and neurological symptoms only slightly improved after the initial emergency procedure. Additionally, instability of the spine persisted or increased after the first surgery and instrument fusion was required. This is in contrast to Bauer's results who found that solely dorsal epidural decompression lead to improve neurological functions in the same way than an anterior procedure [2]. Polly concluded a strong recommendation for posterior based approaches to the upper thoracic spine and for the use of either anterior, posterior or circumferential surgery for lesions from T6 to L5 with very low quality of evidence [17]. In most series similar to ours the decision for a single-stage posterolateral transpedicular approach with or without reconstruction of the ventral column based on the coexistence of poor medical conditions [1, 3, 13, 21].

The surgical technique as well as the indication of three-column tumor decompression and dorsal instrumentation via a single-stage dorsal or dorsolateral approach is similar in the majority of published series [1, 21]. Bridwell published a series of 25 patients without subsequent anterior reconstruction. Only one instrumentation failure could be detected in this series. However, the procedure was carried out exclusively by performing a hemi- or laminectomy [4]. Anatomically, circumferential tumor debulking does not seem to be feasible via this approach. Because of the high axial load on the anterior column an additional anterior procedure is needed after extensive dorsal decompression. Akeyson reported after the use of polymethylmethacrylate (PMMA) for reconstruction of the anterior column a 16% dislocation of the inserted PMMA from posteriorly [1]. How far this is due to insufficient compression of the PMMA by the posterior segmental fixation is not discussed. Bilsky and Wang used additional Steinmann pin technique to fix the PMMA [3, 21]. Using this technique with compression of the posterior construct, the failure rate of the anterior construct could be decreased to 1.4%. However, the use of Steinmann pins hampers adequate follow-up by magnetic resonance imaging (MRI) due to ferromagnetic artefacts. Using PMMA, bony reconstruction is critical. Titanium mesh cages or expandable cages filled with bone or synthetic bone graft provide better ossification in terms of long-term survivor [12]. Wang pointed out that the transpedicular approach in the thoracic spine does not allow passage of a cage or other strut graft [21]. However publications by Morales Alba, Eleraky and recently Hofstetter [6, 7, 12, 15] demonstrated clearly the possibility of this procedure in the cervical, the lumbar and the thoracic spine. Admittedly in the thoracic spine a costotransversectomy or resection of parts of the ridge were described. In the present study costotransversectomy

was only performed in one case. Using a uniportal or biportal technique with two titanium mesh cages with a small cross section dimension (Fig. 2) costotransversectomy is avoidable even in very small thoracic pedicles. Dislocation of the titanium mesh cage was seen in one case in which the dorsal instrumentation was performed percutaneously and a sufficient compression of the posterior construct not accomplished. An adequate compression through the dorsal instrumentation onto the anterior implants is essential as well as in PMMA insertion as in titanium mesh implantation. Because of the limited space for the insertion of a filled titanium mesh cage, rhizotomy may be considered in the thoracic spine. This maneuver had to be performed in only one of our cases.

Our proposed technique holds some limitation: first, during a transpedicular approach the ventral dura may not be visualized. However, since the posterior longitudinal ligament (PLL) is often well palpable and separates the tumor from the anterior dura, epidural tumor rests after resection of the PLL are unlikely. Second, metastatic tumor does often not involve the dorsal elements of the spine [3]. The transpedicular approach creates a new route through tumor-free and viable spine elements. For this reason, the transpedicular procedure was only performed in case of pedicle involvement and therefore existing tumor manifestation in the dorsal column (Figs. 1a, 3, 4a).

Third, the impact of the proposed surgical approach on prognosis must be clearly relativized: metastatic tumor in patients with larger paravertebral anterior tumor masses might not be resectable via this approach, i.e., a complete local tumor control may not be achieved. However, the main argument in metastatic spine tumor disease is the

Fig. 2 Axial CT scan showing the anterior column reconstruction by the use of two titanium mesh cages with a small cross section dimension due to small thoracic pedicles

Fig. 3 Initial MRI studies of patient number four. **a** Sagittal MRI showing the involvement of vertebral body (Th 11) and thecal sac compression. **b** Axial MRI demonstrating the destruction of both pedicles and the ventral tumor circumference

Fig. 4 **a** Initial axial CT scan illustrating the pedicle involvement as ideal passage for the insertion of the titanium mash cage. **b** Lateral X-ray showing the anterior column reconstruction with placement of the cage

reconstitution or preservation of neurological function, the reduction of pain and therefore improvement of short-term or mid-term quality of life. Lastly, the presented experience with this 360-degree osteosynthesis via a posterolateral transpedicular approach is limited and the follow-up period is quite short. Long-term clinical and biomechanical outcome data are not yet available but our interim results for palliative tumor patients are encouraging.

In conclusion, this single-stage technique represents a procedure, which allows a fast and save reconstitution/preservation of neurological function and biomechanical

stable gross total resection, especially for patients with concomitant cardiopulmonary disease. However, long-term efficacy and outcome, as compared to standard transthoracic approaches, remain to be evaluated in a larger patient cohort.

Acknowledgments We would like to thank Mrs. Christine Opfermann-Rüngeler, Anatomical Institute, Heinrich-Heine-University, Düsseldorf for preparing the illustrations.

Conflict of interest The authors declare that they have no conflict of interest.

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