Initial experience with the use of an expandable titanium cage as a vertebral body replacement in patients with tumors of the spinal column: a report of 95 patients

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Abstract

Objective Vertebral body resection to treat spine tumors necessitates reconstruction to maintain spinal stability. The durability of reconstruction may be a challenge in cancer patients as treatment with chemotherapy and/or radiation coupled with poor nutritional status may compromise bone quality. We present a series of patients who underwent implantation of an expandable titanium cage (ETC) for reconstruction after vertebral body resection for primary or metastatic spine tumors. We report the functional outcome, assess the durability of reconstruction, and describe complications associated with this procedure.

Methods A retrospective review of patients undergoing placement of ETC after vertebrectomy for spinal tumor at our institution was performed.

Results From September 2001 to August 2006, 95 patients underwent implantation of an ETC for reconstruction of the anterior spinal column following vertebrectomy for tumor (75 one-level, 19 two-level, 1 three-level). All patients

underwent spinal stabilization as well. The median survival after surgery was 13.7 months; 23 patients had primary spinal tumors and 72 had metastatic tumors. Numerical pain scores were significantly improved postoperatively indicating a palliative benefit. No new neurological deficits were noted postoperatively, except when intentional neurological sacrifice was performed for oncologic reasons. Median height correction of 14% (range 0–118%) and median improvement in sagittal alignment of 6° (range 0–28°) were demonstrated on immediate postoperative imaging. Three patients experienced hardware related complications, one of which had posterior migration of the ETC. On postoperative imaging, 12 patients demonstrated subsidence of greater than 1 mm, but none required operative revision.

Conclusion Use of an ETC for spinal reconstruction in patients with spinal tumors is safe, decreases pain associated with pathologic fracture, protects neurologic function, and is durable. We found a very low incidence of cage-related construct failures and no significant problems with subsidence.

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Introduction

The major indications for the surgical management of primary and metastatic spinal tumors include spinal cord compression, spinal instability, and intractable pain [1]. In the case of primary spinal tumors, surgical resection may achieve local tumor control or even cure [2–6]. Metastatic spinal disease and particularly metastatic epidural spinal cord compression (MESCC) is an increasingly common

entity as the survival rates for cancer have improved. Up to 70% of patients with systemic cancer may harbor metastatic spinal disease [7, 8], and approximately 25,000 patients are diagnosed with MESCC annually [9, 10]. Historically, the initial management of MESCC was posterior decompressive laminectomy followed by radiation therapy [11–13]. Modern surgical procedures employ more sophisticated techniques, which enable tumor removal from the anterior column and subsequent reconstruction. These techniques have translated into better functional outcomes (e.g. ambulation and continence) and survival [14].

Resections requiring removal of the vertebral body (in either an en bloc or an intralesional fashion) necessitate reconstruction. Several options exist for restoring support to the anterior column after tumor resection including autograft bone such as iliac crest or rib, allograft bone such as femoral shaft [15], methylmethacrylate cement [16], static cages (titanium, polyetheretherketone (PEEK), or carbon fiber), and expandable cages [1, 17–19]. Each reconstruction option is associated with its unique benefits and challenges. The potential advantages of the expandable titanium cage (ETC) include the ability to use the implant to correct sagittal alignment, restore vertebral height, as well as ease of use. Since the cages expand to fill the vertebrectomy defect, there is less carpentry required to obtain a satisfactory fit. This is particularly helpful when the spine is rigid from previously placed posterior instrumentation. Finally, the ability to expand the device in situ facilitates placement via a posterior approach [20]. The efficacy of ETCs in the setting of the cancer patient requiring spinal reconstruction has not been widely reported in the medical literature. Here we show that in a large series of patients requiring reconstruction after vertebral body resection, ETCs are safe, can be used to achieve satisfactory spinal reconstruction, and are durable.

Materials and methods

Data collection

The study period was between September 2001 and August 2006. A retrospective review of the prospectively collected Brain and Spine Center Database at our institution and other patient records was performed. Demographic data, indications for surgery, location of the disease in the spine, and history of other treatment modalities were obtained. The preoperative and postoperative evaluation included neurological examination, assessment of pain, plain radiography, magnetic resonance imaging, and computerized tomography scanning. Preoperative and postoperative

numerical pain scores were statistically compared using the non-parametric Wilcoxon signed-rank test with a significance level of 0.05. Complications during the 30-day postoperative period were recorded. We obtained approval from the institutional review board for this study.

Radiographic interpretation

Preoperative, immediate postoperative, and the most current radiologic studies available were used to determine the height correction attained, restoration of sagittal alignment, and subsidence. As differing imaging modalities were often available preoperatively and postoperatively, the percentage of height correction was calculated using a normalized value. Specifically, the preoperative height of the diseased segment was measured from the inferior endplate of the vertebral body above to the superior endplate of the vertebral body below at the midbody position. This preoperative height was then normalized to the height of the normal vertebral body below. Likewise, the postoperative height of the reconstructed segment was calculated and normalized to the height of the vertebra below. A percentage of height correction was then determined from these normalized values (Fig. 1).

Restoration of sagittal alignment was calculated as the change in sagittal angulation between preoperative and postoperative imaging studies [21]. The sagittal angulation was measured as the angle formed by the superior endplate of the vertebral body above the level of the vertebrectomy and the inferior endplate of the vertebral body below the level of the vertebrectomy.

Subsidence was calculated as the ratio between the amount of cage settling (depth in mm into the adjacent vertebral body) and the total height of the affected vertebral body. This percentage was measured on both the immediate postoperative and the latest obtained imaging study. For the purpose of this study, patients were classified as exhibiting subsidence if the cage settling was greater than 1 mm as this was the minimum amount detectable on radiographic review. Given the metal artifact associated with MRI, subsidence measurements were only calculated for patients with postoperative X-ray or CT imaging. Mean height correction and mean correction in sagittal angle were compared between patients who demonstrated subsidence of the ETC and those who did not. The means were compared using Student's *t* test and a *p* value of <0.05 was considered significant.

Technique of placement of the expandable titanium cage

The ETC utilized in this study was the Synex® (Synthes USA, West Chester, PA, USA) cage. Following vertebral

Fig. 1 Methodology for determining percentage of height restoration. This patient underwent an L1 vertebrectomy for sarcoma after previous kyphoplasty. **a** Preoperative X-rays were used to measure the preoperative height of the diseased vertebral segment (L1) and the height of the normal vertebral body below (L2) at the midbody position. The preoperative normalized height was then calculated as a ratio $L1/L2$ ($33.9/32.8 = 1.03$). **b** Similarly, the postoperative sagittal CT reconstruction was used to calculate the normalized height after reconstruction $L1/L2$ ($37.8/23.4 = 1.62$). The percentage height correction is therefore $100 \times (1.62 - 1.03)/1.03 = 57.3\%$

Fig. 2 Posterior approach for the placement of ETC in the thoracic spine. **a** Intraoperative photograph demonstrating placement of the ETC through a posterior approach after circumferential decompression. **b** Postoperative lateral X-ray demonstrating posterior stabilization and satisfactory positioning of ETC

resection, the ETC was placed from an anterior, lateral, or posterior approach depending upon the site of disease and approach for resection. Intraoperative somatosensory-evoked potentials were used on every procedure and motor-evoked potentials were used on select cases as well.

After the corpectomy and tumor resection was performed, the endplates were prepared by removing the superficial cartilaginous layers. Violation of the cortical subchondral endplates was avoided in order to minimize subsidence of the cage into the adjacent vertebral bodies. The maximal implant size and appropriate end-cap angles were then selected to optimize contact with the vertebral endplates, and the cage was packed with either allograft/demineralized bone matrix or autograft. The cage was then placed into the vertebrectomy defect (Fig. 2) and expanded

to the appropriate height. When necessary, the ETC was released for repositioning. Intraoperative X-rays confirmed satisfactory positioning. Once fully expanded, additional graft material was packed to fill the cage as well as the space around the cage anteriorly and laterally. Supplemental stabilization was then performed with either a plate or a screw-rod construct anteriorly, or posterior pedicle screw fixation. It should be noted that in cases with significant coronal deformity, an irregularly shaped vertebrectomy defect, or with endplates that were in very poor condition precluding the cage from making satisfactory contact with the adjacent endplates, we opted for methylmethacrylate reconstruction which could be better molded to match the anatomic configuration. These patients were not included in this study.

Results

A total of 95 patients underwent resection of a spinal column tumor with subsequent placement of an expandable titanium cage during the study period. Thirty (32%) patients were women and sixty-five (68%) were men. The median age at the time of surgery was 59 years (range 20–84 years). The median survival following surgery was 13.7 months (range 1–102 months).

Twenty-three tumors (24%) were of primary origin and seventy-two (76%) were metastatic. The majority of the metastatic tumors were renal cell carcinomas. The primary tumors included sarcomas, chordomas, and other pathologies. The distribution of the various tumor histologies is listed in Table 1. Of the 23 primary tumors, 11 were resected in an en bloc fashion. Among patients with primary tumors, the median survival was 59 months (range 1.6–102 months).

Of the patients, 75 underwent a one-level vertebrectomy, 19 patients underwent a two-level vertebral body resection, and 1 patient had a three-level vertebrectomy. Figure 3 depicts the distribution of the 116 affected vertebral bodies. All patients had supplemental hardware placed in addition to the ETC. Fifty-nine patients underwent supplemental posterior fixation using pedicle screw instrumentation, and forty-four patients underwent supplemental anterior instrumentation either with an anterior plate or with a screw-rod construct. Eight patients had both anterior and posterior hardware placed. In the subgroup of 11 patients who underwent an en bloc resection for a primary spinal tumor, 10 patients had solely posterior stabilization and 1 patient had both anterior and posterior instrumentation. The majority (80/95) of patients had the ETC placed from an anterior approach. However, 15

patients underwent ETC placement from a posterior approach (either a transpedicular or a lateral extracavitary approach). No intraoperative adverse events were noted.

Complications and hardware failure

There was one death (1.1%) in the 30-day postoperative period from a pulmonary embolus. This patient had an intraoperative durotomy, underwent placement of a lumbar drain and was maintained on bed rest to prevent a spinal fluid leak, which might have contributed to the formation of a deep venous thrombosis.

In addition, there were 16 surgery-related complications. These complications included three patients with postoperative pneumonia, three patients with deep venous thrombosis, two patients with cerebrospinal fluid leak (including patient described above), two patients with urinary tract infections, and one patient with a pulmonary embolus. Two patients had postoperative infections requiring operative intervention, but neither required removal of hardware.

Three patients (3.2%) experienced hardware related complications. The first underwent operative revision of a suboptimally placed T11 pedicle screw. The second patient had failure of posterior lateral mass instrumentation in a cervico-thoracic construct following en bloc resection of a chordoma involving C7 and T1. This patient underwent operative revision to sublaminar wires with no further complications. The final patient who developed hardware failure was a patient with metastatic breast cancer involving T10. She had progressive disease at T10, and underwent a T10 vertebrectomy, placement of an expandable titanium cage, and anterior supplemental hardware. She did not undergo posterior fusion. Immediate postoperative X-rays revealed satisfactory positioning of the ETC. X-rays taken 3 weeks later however, revealed posterior migration of the titanium cage (Fig. 4). This complication was related to a failure to recognize tumor involvement of the posterior elements which would have warranted adding supplemental posterior pedicle screw fixation in addition to anterior stabilization.

Neurological and pain outcome

No new neurological deficits were noted within the 30-day postoperative period, except for those which were associated with intentional neurological sacrifice for oncologic purposes. Seven patients had transient psoas weakness after a retroperitoneal approach. Twenty-seven patients (28%) presented with neurological deficit, preoperatively [Frankel grade A ($N = 2$), C ($N = 13$) or D ($N = 12$)]. Of this group, eight patients regained one Frankel grade by the time of discharge, and one patient with grade A was a

Table 1 Distribution of tumor histology

Metastatic	72
Renal	41
Lung	4
Gastrointestinal	4
Prostate	4
Melanoma	3
Myeloma	2
Other ^a	14
Primary	23
Sarcoma	14
Chordoma	5
Other ^b	4

^a Other metastatic tumors included thyroid cancer, breast cancer, neuroendocrine tumor, lymphoma, carcinoid, and neurofibroma

^b Other primary tumors included osteoblastoma, hemangioendothelioma, and giant cell tumor

Fig. 3 Site of disease in the vertebral column ($N = 116$ levels) in 95 patients

Fig. 4 A 62-year-old woman with metastatic breast cancer who underwent a T10 vertebrectomy and supplemental anterior plate. **a** Immediate postoperative X-rays demonstrating adequate cage position. **b** Sagittal CT reconstruction three weeks postoperatively demonstrating posterior migration of the ETC. Arrow denotes tumor involvement of the posterior elements, which contributed to ETC dislodgement

Frankel E at discharge. The remaining 18 patients had a stable neurological exam.

In addition, among the 84 patients for whom numerical pain scores were recorded, there was a statistically significant improvement in the median preoperative numerical pain scale score (6) as compared with that at the time of discharge (2) ($p < 0.05$; Wilcoxon signed-rank test). Importantly, only three patients reported worsened pain at the time of discharge and two remained the same. The rest had improvement in their numerical pain scores at discharge.

Radiographic outcome

Among the 91 patients (96%) for whom evaluable imaging studies were available, the median height correction

achieved between preoperative and immediate postoperative imaging was 14% (range 0–118%).

There were 90 patients (95%) for whom preoperative and postoperative sagittal alignment could be measured. In this group, a median improvement of 6° (range 0 – 22°) was noted between preoperative and immediate postoperative imaging. There were 68 patients (72%) with sufficient follow-up imaging (greater than 30 days, postoperatively) to determine if the correction in sagittal alignment was durable. During a median radiographic follow-up period of 7.4 months (range 1–62 months), the median improvement in sagittal alignment from the preoperative condition remained 6° (range 0 – 20°).

Ninety-four patients (99%) were evaluated for initial subsidence of the ETC based on immediate postoperative X-ray or CT. Of this group, four patients demonstrated greater than 1 mm of subsidence into either the upper or lower vertebral body (see Table 2). Sixty-six patients (69%) had postoperative CT or X-ray at greater than 30 days follow-up permitting delayed evaluation for radiographic evidence of subsidence. The median radiographic follow-up interval for these patients was 8.1 months, (range 1–62 months). Of the 66 patients, 11 (17%) showed greater than 1 mm of subsidence. Table 2 details the characteristics of the patients in whom cage subsidence was noted. Neither tumor histology nor the level of the ETC correlated with the development of subsidence. Among the patients in whom the ETC demonstrated subsidence, the mean height correction was $27.8 \pm 9.7\%$ ($n = 10$), which is not statistically different ($p = 0.26$; Student's t test) than the non-subsidence group in whom the mean height correction was $22.6 \pm 2.7\%$ ($n = 81$). Similarly, among patients who developed

Table 2 Characteristics of 11 patients who developed cage subsidence

Patient	Histology	Level of cage	Immediate postoperative subsidence (%)	Interval to final imaging (months)	Final postoperative subsidence (%)
1	Chordoma	C7, T1	0	53.7	29.6 (lower)
2	Chondrosarcoma	T7	0	26.8	23.0 (lower)
3	Renal cell carcinoma	T12	0	22.9	20.5 (upper) 18.3 (lower)
4	Osteosarcoma	T8	0	1.4	13.5 (lower)
5	Multiple myeloma	T7	16.4 (upper)	62	19.6 (upper)
6	Lymphoma	L1	10.8 (lower)	3.9	10.9 (upper) 11.2 (lower)
7	Lung cancer	L2	13.3 (lower)	No further imaging	
8	Prostate cancer	L4	0	6.6	28.5 (lower)
9	Renal cell cancer	L3	0	4.5	24.2 (lower)
10	Hepatocellular carcinoma	L3	21.7 (upper)	1.7	25.0 (upper)
11	Renal cell carcinoma	T4, T5		3.7	15.6 (upper)
12	Breast cancer	T10, T11, T12	0	17.8	42.0 (lower)

subsidence, the mean correction in sagittal angle was $6.5 \pm 1.4^\circ$ ($n = 10$), which was not statistically different from the non-subsidence group ($p = 0.45$; Student's *t* test) whose mean correction was $6.7^\circ \pm 0.6^\circ$ ($n = 80$). None of the patients with subsidence required operative revision.

Discussion

Surgical resection, followed by reconstruction and stabilization, plays an important role in the management of patients with spinal neoplasms. Surgery can lead to decreased pain, increased time ambulatory, and increased time continent [13, 14]. This was seen in the present study in which pain scores were significantly improved postoperatively and neurologic function was improved or stabilized. For primary spinal tumors, it can offer the best chance for local tumor control and possible cure. The spine surgeon has a variety of options for anterior column reconstruction after resection of a vertebral body. In treating patients with metastatic tumors of the spine, attaining a bony fusion has not traditionally been a primary goal of spinal reconstruction. These are palliative procedures, and stabilization is the main consideration as these patients often have limited life expectancy. Consequently, the use of bone cement (methylmethacrylate) with or without a scaffold (Steinman pin or chest tube) has been a commonly used technique [22]. This view may change as cancer therapies improve and patients live longer with metastatic disease. Indeed, 37 of 72 patients (51%) with metastatic tumors survived greater than one year in our series. Conversely, patients with primary spine tumors may benefit from an aggressive resection with the goal of stable

reconstruction as they may enjoy a long survival after optimal oncologic resection [23]. In the present series, the median survival of patients with primary spinal tumors was 59 months. Though an assessment of fusion was not performed, there was no increased incidence of hardware complications in this subpopulation.

There is a paucity of quantitative data regarding deformity correction, height restoration, and subsidence in patients treated with vertebral body replacements, particularly in those suffering from cancer. In sharing their experience with 30 cancer patients treated with cortical allografts, Lewandrowski et al. noted that “minimal” subsidence was frequently encountered [24]. Boriani et al. reported on 42 patients with spinal tumors treated with carbon fiber cages, noting no complications related to the implant; however, data on subsidence and deformity correction was not provided [25]. Dvorak et al. [26] used titanium mesh cages to reconstruct the thoracolumbar spine in non-cancer patients, and found a mean total subsidence rate of 4 mm, with a mean preoperative kyphosis of 25.4° and a mean postoperative kyphosis of 7.5° [26].

The literature regarding the efficacy and durability of ETCs when applied to spinal tumor resection is still developing as well [1, 17, 19, 20, 27, 28]. In their series of 15 consecutive patients with primary or metastatic spinal tumors, Thongtrangan et al., demonstrated an average correction of kyphotic angle of 20° , and no complications related to the placement of the expandable cage [1]. Ernstberger et al. reported their experience with an expandable vertebral body replacement device in the treatment of 32 patients with spinal tumors. They also reported no intraoperative complications or implant dislocations [17]. Details regarding height correction, sagittal angle correction and

subsidence were not reported. More recently, Shen et al. reported their experience in treating 21 patients with tumors of the vertebral body from a single posterior approach. They reported three cage-related complications including cage subsidence, iatrogenic traction injury to a lumbar nerve root during expansion of the cage, and one operative revision due to an obliquely placed cage [20]. Finally, in 2008, Arts et al., shared their experience with 60 patients who had undergone corpectomy followed by implantation with an expandable cage for a variety of indications, 22 of whom underwent reconstruction after tumor resection [27]. The authors report a mean preoperative angulation of 7° , which was corrected to a mean of 3.3° , postoperatively. In addition, they also report a mean preoperative height of 27.4 mm and a mean postoperative height of 30.8 mm. Forty-two percent of patients in their series exhibited subsidence of the ETC.

Here, we have presented a large series of patients with tumors of the vertebral column that were effectively reconstructed with an ETC. Given the limited quantitative data available on subsidence and deformity correction in the cancer patient treated with a vertebral body replacement, our series can serve as a baseline for future comparison. There was a low overall incidence of subsidence in this study compared to other large series [27], and none of these cases required operative revision. This is especially notable in a patient population receiving cytotoxic treatments including radiation and chemotherapy, and who may have compromised nutritional status, all of which can negatively affect bone quality. Among our patients who did exhibit subsidence of the titanium cage, the mean height correction and mean correction in sagittal angle were not statistically different from the non-subsidence group, indicating that the extent of correction did not affect subsidence.

The biomechanical properties of ETCs have been well described [29–31]. Studies in the thoracolumbar spine have shown that supplementary posterior instrumentation is superior to supplementary anterior instrumentation with regard to biomechanical stability after cage placement [32]. In our series of 95 patients, there were only two hardware failures. The first patient experienced pullout of lateral mass screws following a complex cervico-thoracic reconstruction after en bloc resection of a C7–T1 chordoma. The second hardware failure involved posterior migration of an ETC after an anterior vertebrectomy and anterior supplemental stabilization. This complication was a direct result of the failure to recognize disease in the posterior elements, creating an incompetent posterior tension band. This should have been managed with up front supplemental posterior stabilization. Neither of these failures is attributable to the use of an expandable cage in anterior column reconstruction.

Chou et al. [33] recently reported four cases of adjacent-level vertebral body fractures following the use of ETCs.

However, none of the patients they reported on underwent vertebrectomy for tumor; the generally poor bone quality of cancer patients makes adjacent-level fractures a possible complication of their use. Fortunately, this complication was not seen in our patients.

In the present series, 11 of 23 patients with primary spinal tumors underwent implantation of the ETC in conjunction with an en bloc tumor resection. Even after such a highly destabilizing procedure, the constructs proved durable. The majority of patients (10/11) had posterior instrumentation, while one patient had both an anterior plate and posterior instrumentation. As described above, one of our cases of hardware failure occurred in a patient who had undergone an en bloc resection and two-level reconstruction at the cervico-thoracic junction, a challenging scenario irrespective of the choice of construct.

The ETC also proved to be an effective tool for correcting segmental deformity, both in terms of height restoration and sagittal alignment. Expansion of the cage against the adjacent endplates seems to allow for gentle correction with even force distribution. Obviously, sound judgment must be used in determining the extent of correction, especially since the bony endplates of cancer patients may be of relatively limited strength. The median height correction of 14% and sagittal alignment correction of 6° underscores that our goal was for safe rather than complete correction. That our corrections were durable and that patients had good functional outcomes support this conservative approach. The ability to use the implant to gently correct spinal deformity is one key advantage of the expandable cage over methylmethacrylate when reconstructing the anterior column. Experience with adult spinal deformity suggests that improved spinal sagittal balance can lead to better patient functional outcomes [34, 35]. Further analysis is necessary to determine if this relationship is an important prognostic factor in spinal oncology as well.

Finally, 80 patients underwent placement of the ETC through an anterior approach, while 15 patients underwent placement through a posterior transpedicular/extracavitary approach. Overall, cage-related complication rates were low. Of note, there were no intraoperative or perioperative complications in the group of patients who underwent placement of the cage from the posterior approach. As previous authors have described, this technique is valuable in the upper thoracic spine or in any patient in whom an anterior approach may carry unacceptable morbidity [20, 36, 37].

Conclusions

In summary, use of an ETC is safe and effective as a vertebral body replacement in patients with malignancies

of the vertebral column at thoracic and lumbar spinal levels. When used in conjunction with supplemental instrumentation it provides for durable spinal reconstruction.

Conflict of interest None of the authors has any potential conflict of interest.

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