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Cost Analysis With Use of Expandable Cage or Cement in Single level Thoracic Vertebrectomy in Metastasis

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Abstract

Study Design: Retrospective case series.

Objective: Patient with metastatic cancer frequently require spinal operations for neural decompression and stabilization, most commonly thoracic vertebrectomy with reconstruction. Objective of the study was to assess economic aspects associated with use of cement versus expandable cage in patients with single level thoracic metastatic disease. We also looked at the differences in the clinical, radiological, complications and survival differences to assess non-inferiority of PMMA over cages.

Methods: The electronic medical records of patients undergoing single level thoracic vertebrectomy and reconstruction were reviewed. Two groups were made: PMMA and EC. Totals surgical cost, implant costs was analyzed. We also looked at the clinical/radiological outcome, complication and survival analysis.

Results: 96 patients were identified including 70 one-level resections. For 1-level surgeries, Implant costs for use of cement—$75 compared to $9000 for cages. Overall surgical cost was significantly less for PMMA compared to use of EC. No difference was seen in clinical outcome or complication was seen. We noticed significantly better kyphosis correction in the PMMA group.

Conclusions: Polymethylmethacrylate cement offers significant cost advantage for reconstruction after thoracic vertebrectomy. It also allows for better kyphosis correction and comparable clinical outcomes and non-inferior to cages.

Keywords

economic value, expandable cage, polymethylmethacrylate cement, cost analysis, metastasis, vertebrectomy

Introduction

Spine is the most common site for osseous metastasis. Vertebral metastasis may lead to spinal column instability, cord/thecal sac compression and neurologic injury.[1] The treatment goal for vertebral metastasis is preservation of neurological function, improving the quality of life, and easing pain. Surgery typically calls for decompression, stabilization and often consists of a corpectomy with reconstruction of the anterior column.[2]

Anterior or anterolateral approached provide a good access for tumor resection and also for spinal column reconstruction. Lesions of T1-2 can sometimes be reached through the standard Smith Robinson approach or may necessitate a sternotomy. T3-4 may either be reached through sternotomy, thoracotomy or posteriorly. T5-10 may either be reached anteriorly via a thoracotomy or posteriorly via the transpedicular, costotransversectomy or extracavitary approach. T11-L1 can be accessed via the thoracoabdominal approach.[3-6] Approaches through the thoracic cavity are often associated with complication associated with vascular, visceral and pulmonary structured including pneumothorax, pneumonia, respiratory insufficiency, CSF leak to the thoracic cavity.[3-6] These often cannot be contemplated in patients with poor pulmonary reserve or pre-existing medical

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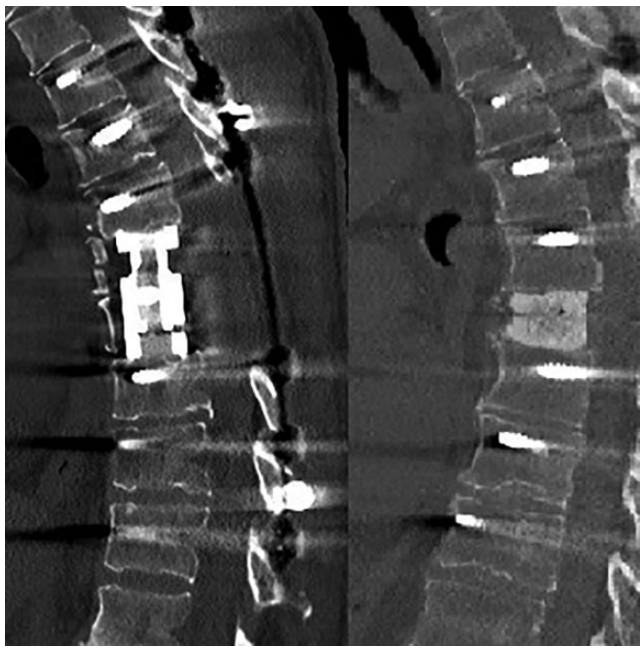

Figure 1. Representative postoperative sagittal CT images of vertebrectomy reconstruction with an expandable cage (left) and polymethylmethacrylate cement (right).

issues. Choosing the appropriate surgical approach for the patient is an ongoing challenge even for the experienced surgeon. Patient anatomy, pathology, comfort level of the surgeon, comorbid condition, availability of expertise/ adjuvant therapy and patient's wishes all play a major role in this decision. A posterior approach based transpedicular approach allows for ventral column and can negate the need for a separate anterior surgery. This approach has been utilized extensively in tumor and non tumor surgeries. Numerous studies have reported lesser operative time, lesser hospital stay, lesser morbidity with this approach over anterior or a combined approach. to perform a corpectomy achieves the purpose of an combined surgery with lesser morbidity and mortality.[2,6-8]

Anterior column reconstruction is feasible with an expandable metallic cage (EC) or polymethylmethacrylate (PMMA) cement (Figure 1).

PMMA is easy to manipulate into the corpectomy defect due to its semi liquid state and offers a wide foot print. PMMA usage is technically demanding and the main disadvantage include exothermic reaction, risking injury to tissues, and the cement expansion risking injury to the neural elements if not addressed during surgery.[9,10] Furthermore, PMMA will not achieve fusion. EC, on the other hand is widely used and familiar among surgeons. In certain pathologies, fusion is a possibility with the use of EC.

Improvements in cancer care, including advances in chemotherapy and radiation, have led to an increased incidence of cancer patients presenting with spinal metastases. As novel treatments improve longevity, integrity of the spinal construct becomes more of a concern.[11]

Cost involved in spine tumor metastatic surgery have been looked in few studies globally.[12-15] With prolonged life expectancy, the overall cost of cancer treatment incurred can be manifolds. Significant efforts are being made to make spine surgery cost effective without compromising outcomes.

We hypothesized the use of PMMA for anterior construct should offer significant cost advantage and non inferior to other reconstruction methods. Based on this, we compared the economic differences with the use of EC and PMMA in patients undergoing single level transpedicular vertebrectomy for metastatic disease as the primary outcome and compared clinical outcomes, radiological outcomes, complication and survival as the secondary outcome measures.

Materials and Methods

With IRB approval by Ohio State University, the electronic medical records of patients undergoing transpedicular vertebrectomy for metastatic disease from 2008-2016 were accessed. A total of 96 patients underwent surgery; in which single level vertebrectomy was done in 70 cases. EC was used in cases of limited disease where long-term survival was expected and bony fusion was expected. All cases were discussed in detail in the tumor board meeting to have a combined opinion of medical/ radiation oncologist including medical suitability and survival assessment.

The surgical technique for the 2 procedures is described in detail in prior publications.[2,11,16] Briefly, the spine was exposed posteriorly and pedicle screws were inserted bilaterally into several vertebras above and below the metastatic site. The posterior decompression consisting of laminectomy and facetectomy above and below the corpectomy site was completed. A temporary rod was used in all cases, and the corpectomy was performed with curettes and drills. All soft tissue was removed from the endplates abutting the defect.

Reconstruction was performed with EC or PMMA. For EC, the defect was sized and an appropriately sized titanium cage was inserted via the posterolateral corridor. The medial aspect of the ribs was removed as needed to allow cage insertion without compressing the spinal cord. For PMMA group, the cement (Confidence®, DePuy, Raynham, MA) was prepared with a viscosity slightly higher than that of toothpaste. It is injected into the defect and molded to fit as the cement hardens (Figure 1).

For all patients, the operating time and days in hospital were recorded directly from the medical record. The costs for EC, PMMA, and operating room time were drawn from institutional costs at the Ohio State University—James Caner Hospital.

Clinical outcomes were assessed using change in Frankel grade and VAS scores. Anteroposterior dimension of thecal sac, a measure of epidural spinal cord compression (ESCC) before and after surgery was measured based on axial T2 W MRI at the level of vertebrectomy. Change in kyphosis was assessed using Cobb angle based on CT images.

Statistical Analysis

Cost analysis was done using t test. Survival probabilities and quartiles were estimated using Kaplan—Meier/product-limit estimates. 95% Hall—Wellner confidence band was used for the survival curve. Sign test was done to assess change (pre-operative to postoperative) in Frankel grade, cord diameter, and Cobb angle. We assessed differences by the construct type (cage or cement) in the change of Frankel grade, cord diameter, and Cobb angle using the Kruskal-Wallis Test. Fisher test was used to assess differences in rates of complications for the 2 different construct types.

Table 1. Levels Resected.

Number of tumor levels	Sample Size	Percent (%)
1	70	76
2	18	20
3	3	3
4	1	1
Total	92	100

Case numbers by number of levels resected.

Descriptive statistics and 2 sample t-tests were completed using SAS software version 9.4 (Cary, NC USA)

Results

A total of 96 patients were identified. Seventy patients (76%) had vertebrectomy performed at 1 level, 18 patients (20%) at 2 levels, 3 patients at 3 levels, and 1 patient at 4 levels (Table 1). The average length of stay was 8 days.

Of the 70 one-level surgeries, 7 subjects had missing data for operating room utilization and were excluded from the analysis (Figure 2). Ten patients had an expandable cage placed; in 53 patients the vertebrectomy was performed using PMMA. Mean OR time did not differ significantly between the 2 groups: 454 +/− 125 minutes for EC group versus 437 +/− 93 minutes for cement placement ($p = 0.619$) (Table 2) (Figure 3).

The implant cost for cement was significantly less than a cage—$75 for cement compared to $9000 for cage. Cost for operating room time at our institution was estimated at $200 per minute (Table 3). Comparing overall costs, there was a

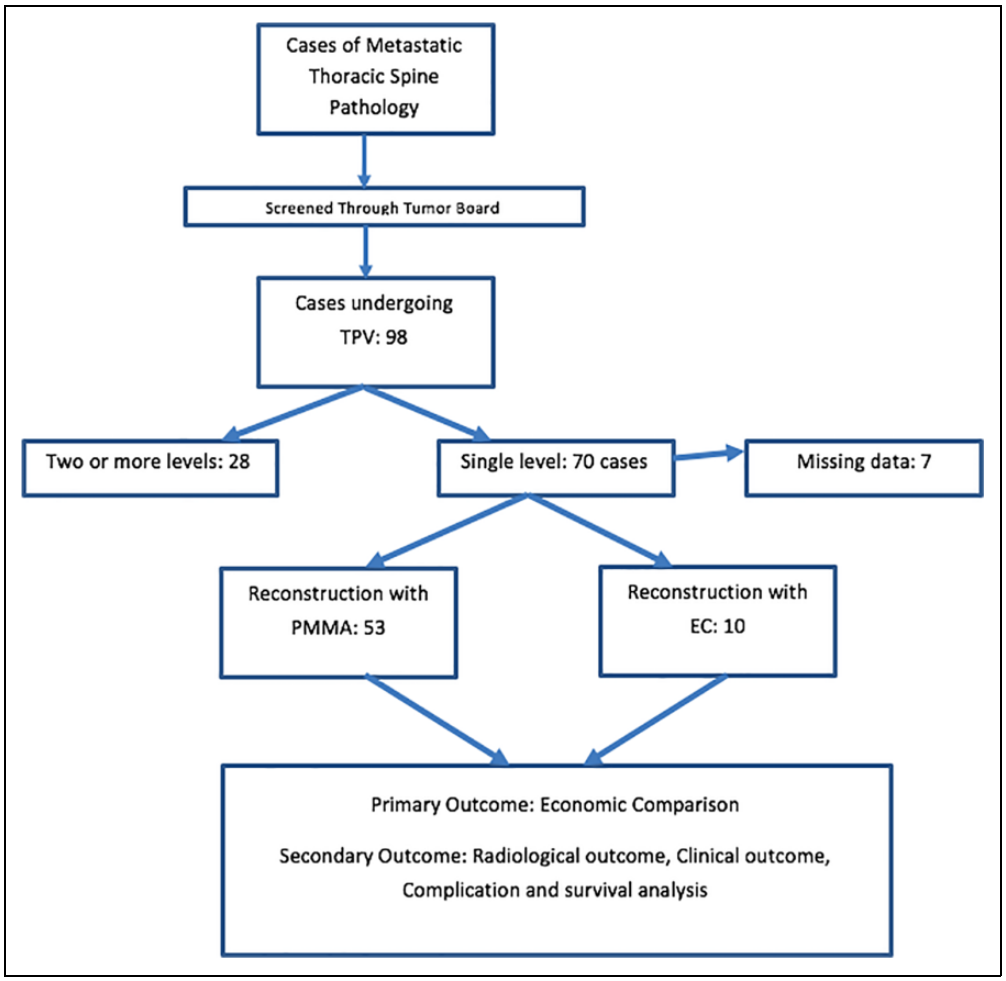

Figure 2. Study algorithm including number of cases evaluated.

significant cost difference with cement utilization ($82,280 as compared to $102,789.28 for cage, p = 0.0348) (Table 4)

Clinical/Radiological Outcomes and Complications

Frankel grade change was seen in 14 cases. Improvement by at least 1 grade was seen in 12 (85.7%) cases. Sign test showed significant improvement in postoperative Frankel grade (P = 0.0013). Pain scores assessed using VAS changed from a median of 7 (IQR: 5, 8; range: 2–10) to 2 (IQR: 1, 3; range: 0-8) (P < 0.0001), which was expected, as these variables reflect the intended outcomes of the surgical procedure.

The median difference between pre- and postoperative cord diameter of the overall cohort was 5.9 mm (P < 0.0001) and the Cobb angle improved by a median of 7.58 (P < 0.0001). In regard to the construct type, there was no difference in the degree of cord decompression. The difference in the correction of kyphosis, however, was significantly more in the cement group (Median: −3, Mean: −5.8 degrees ± by a mean of 4.3 degrees (P = 0.012) compared to the cage group (Median: 0, Mean −1.5 ± 4.08). There were total of 14.28% surgical complications observed, of which 15.4% were major complications. Neurological deterioration was seen in 2 cases. First, was following a dorsal cement dislodgement from improperly prepared disc space. This was subsequently revised with complete neurological recovery (Figure 4). Other case was following a hematoma formation in the EC group which was emergently operated with complete recovery to baseline. No significant differences was seen in the occurrence of complications with regard to the use of PMMA versus titanium cage (Table 5).

Survival

39 deaths were observed in the data set. The median survival time was estimated to be 6 months (95% CI: 5, 10). 25% of patients died prior to 3 months (95% CI: 2, 5) and 25% of patients survived at least 22 months (95% CI: 12, 48). It was not possible to assess differences in survival based on construct type because of small numbers involved in the cage group.

Discussion

In this article, we present the cost analysis of surgical treatment of metastatic spine disease using either expandable cage or cement reconstruction. Cement reconstruction is associated with significantly less implant cost and overall cost of operation. Approximately, $ 20,509 (p = 0.0348) were saved for each single level vertebrectomy with usage of PMMA over

Table 3. Institutional Costs.

Item	Cost ($)
OR time	200/min
Cage	9,000
Cement	75

Average cost for elements associated with vertebrectomy surgery.

Table 2. Operating Room Time for Single Level Surgeries.

Construct	Sample Size	Mean OR time (min)	St. Dev.	p value
Cage	10	454.5	125.3	0.6193
Cement	53	437.5	93.7	

Detailed comparison of operating room time utilization for cement and cage during 1 level surgery.

Table 4. Totals Costs for Single Level Surgeries.

Construct	Sample Size	Total Cost ($)/surgery	St. Dev. ($)	p value
Cage	10	102,789.28	19,703.75	0.0348
Cement	53	82,280	6,321.39	

Detailed comparison of total costs for cage or cement use during single level surgery.

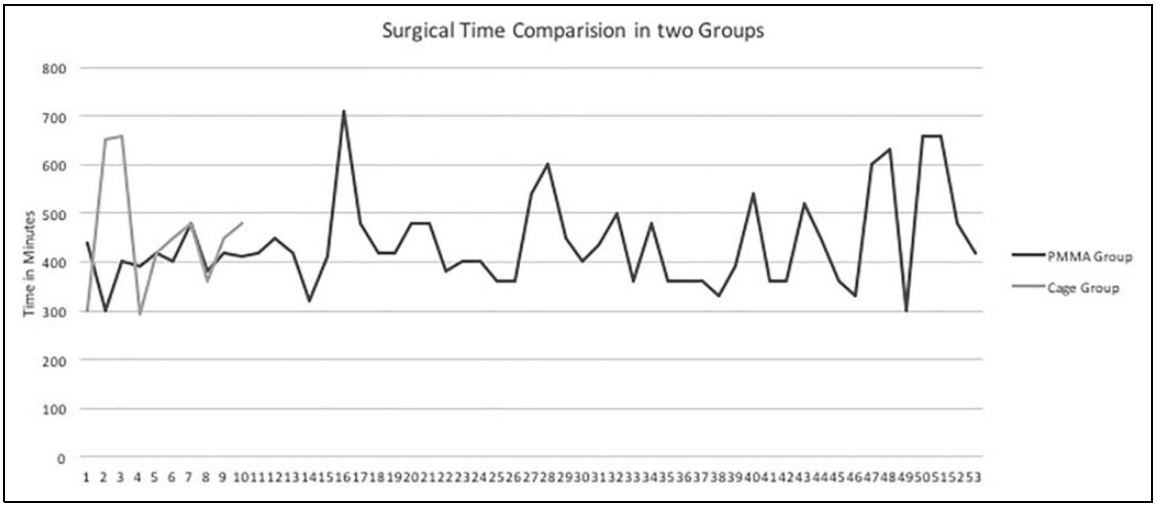

Figure 3. Duration of surgery in the 2 groups.

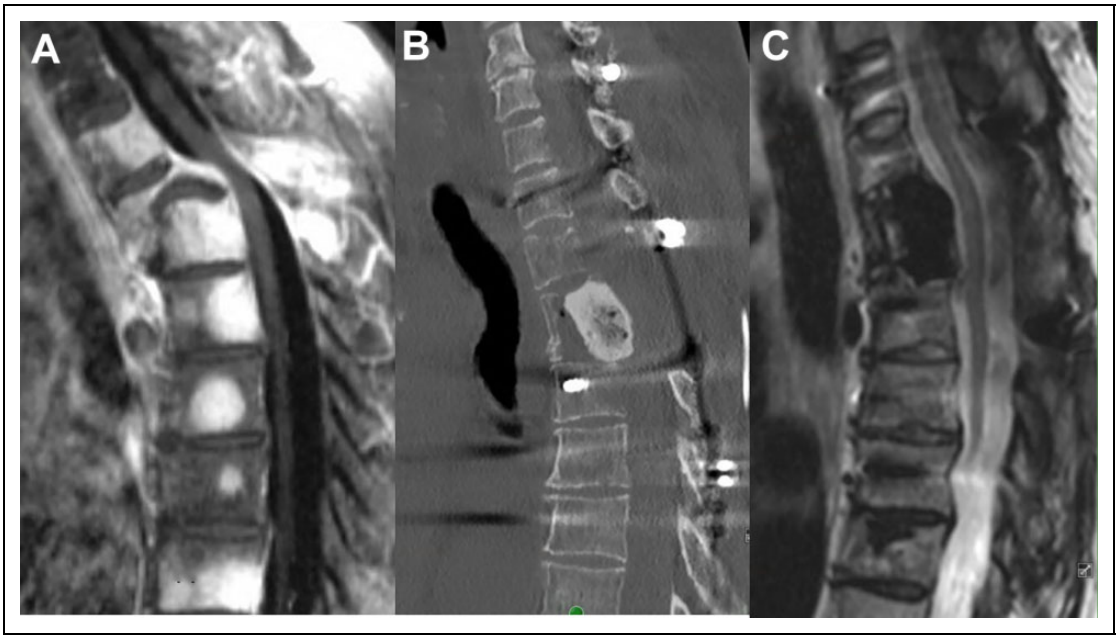

Figure 4. A, Post contrast T1 W image showing T3 fracture dislocation from breast metastasis. B, Post-operative CT image showing dorsal cage migration impinging the cord. This is due to incomplete disc preparation at the time of surgery. C, Post-operative T2 W MRI image following revision surgery showing cement retrieval and re-vertebrectomy and reconstruction with PMMA.

Table 5. Operative Outcomes by Construct Type.

Variable	Cage (n = 10)	Cement (n = 53)	P-Value
Difference in Frankel grade#	0 [0, 0] (–1, 2)	0 [0, 0] (–1, 3)	0.3625
Cord decompression, mm#	5 [1.5, 7] (0, 8)	4 [2, 6] (0, 10)	0.8369
Cobb angle difference (Degrees)#	0 [0,0] (-12,0)	-3 [-11,0] (-18,0)	0.0631 (0.012)
Operative complications$	3 (30%)	6 (11.3%)	0.3910
Postoperative complications $	4 (40%)	16 (30%)	0.3836

#Values as median [IQR] (minimum, maximum). $: Values in N (percentage).

cage. Based on the clinical and radiological outcome, usage of PMMA was non-inferior over expandable cages.

We calculated the overall surgical cost based on the surgical time and the additional cost of the reconstruction material used. We did not find a significant difference in the surgical time, though it was less with use of PMMA. As seen in Figure 4, we saw a lot of variation in the surgical time. Unlike degenerative spine surgery, especially in minimally invasive surgery, where, the surgical duration gradually reduces over time as the surgeon and the team gets familiar, it may not be so in tumor surgeries.[17-19] In our 8 year long study including metastatic spine surgery, we saw a relatively consistent surgical duration with occasional variations in spite of being a single surgeon and single center series. A lot of variables play a role in this including years into practice, blood loss, tumor pathology, complexity of the case, amount of tumor adhesions, patient profile, presence of rotating residents and fellows to name a few. Hence the duration of surgery can have wide variation and it may not be possible to have a control on it.

Barlev et al in a 2010 study in US found cost of surgery in symptomatic spinal cord compression to be $43,691 for patients with multiple myeloma, $59,334 for those with breast cancer, and $59,788 for those with prostate cancer.[15] These values related to the overall cost of surgery and not specifically a type of procedure. Additionally, there are bound to be differences in the reimbursement (costing) based on region, type of institute, teaching hospital, west region, high volume center that also alter the cost.[12]

Type of pathology and comorbid conditions also influence overall surgical cost. A 2015 study in The United Kingdom found average cost of surgery for symptomatic metastatic lesion as GBP 16,885 (10,687) [Approximately USD 25,327 (16,030)].[14] They concluded patients in better health costs more probably they are capable of having bigger operations. As the life expectancy improves, so does the cost of surgery. The cost studies of Europe cannot be extrapolated to US since different treatment pathways, staffing levels, differences in reimbursement and insurance policies.[15,16,20,21]

Whitmore et al[22] found that presence of poor comorbid factors (ASA score) escalates the cost of hospitalization. It is based on more number of hospital days and prolonged treatment needed. On the other hand, studies found that cost of surgery with poor comorbid factors (ASA, Frankel and EQ_5D index) is lower since the surgeon chooses a surgical procedure which is less extensive and shorter procedures thus reducing the cost of surgery with poor comorbid factors.[14] There may be a lot of variables involved in the final surgical strategy adopted depending on the surgeon expertise, the back up support and the tumor board outlook, it is not possible to have a consistent surgical treatment.

Vertebrectomy with reconstruction, as compared to a posterior decompression and fixation alone is a more morbid procedure especially in high risk patients. However, we found no differences in the outcome or complications irrespective of the choice of material for anterior reconstruction. Given that with PMMA reconstruction there will be no interbody fusion, there is theoretical concern about instrumentation failure compared to EC. We found no difference in clinical outcome, radiological outcomes or complications rates between patients treated with PMMA compared to EC.[2]

Previous articles have analyzed the economic costs of the all-posterior approach compared to anterior and posterior approaches to metastatic spine disease and found that all-posterior was significantly less expensive.[6,23-25] With an increasing trend and popularity among surgeon using posterior approach to achieve circumferential stabilization, it is important to assess the economic aspect of available surgical technique and its role on overall outcomes.

The current study highlights the economic superiority of using PMMA over EC. The implant cost for PMMA is significantly less expensive than EC without increasing the length of the case. Given that clinical outcomes between the 2 implants are not different, routine use of PMMA for metastatic spine patients would result in significant savings. For example, if all patients in our series underwent reconstruction with EC instead of PMMA, the total implant cost for the series would have been $567,000 instead of $4,275.

There are indications for preferring EC over PMMA. Patients with limited disease where long-term survival is expected may benefit from use of EC to allow for interbody fusion to occur through the implant. Similarly, reconstruction after resection of a primary bone tumor with en-bloc resection should utilize EC given the expectation of long-term survival. Studies have also found EC preferable in the presence of significant kyphotic deformity.[26,27] These are in contrast to our finding where we found better correction of kyphosis with the use of PMMA. Although, the difference could be from a relatively small sample size in the EC group, we strongly feel, PMMA reconstruction offers a significantly wider cement foot print. This allows for a much easier and effective way to correct deformity by posterior column shortening without the rick of subsidence or anterior collapse.

There are technical considerations to using cement for reconstruction. As the cement hardens, it expands; the cement should be continuously tamped downward away from the spinal cord during hardening. This is contrary to pure vacuum mixed PMMA which shrinks by around 6% to 7% in volume during the curing process. In most clinical setting and in our cases as well, hand mixed cement is used which results in entrapment of air within the cement mix. The heat induced expansion of the air bubbles then results in less shrinkage or rather expansion of the cement mass.(9,10) In spine surgery, since the cement is in close proximity to the neural structures, it is important to be cognizant of this occurrence.[2] Additionally, the hardening process is an exothermic reaction and neural injury is possible if the cement contacts sensitive structures.[28] Neither of these complications occurred in our series. We prefer to allow the cement to mold against the adjacent endplates as it hardens. Previous authors have described fixating the cement into the vertebrectomy site using Kirschner wires or Steinman pins, or using a plastic syringe as a scaffold.[29-31] However, we did not use any of these techniques, rather only using posterior cross compression against the cement, with this technique we did not find cement migration to be a concern. (2) We had 1 case of cement dislodgement resulting in neurological compromise. This was following a technical error of inadequate preparation of disc space during end plate preparation (Figure 2).

Other authors have compared EC to PMMA, Eleraky et al. showed no difference in reoperation, stability and complications when comparing 16 patients who underwent tumor resection with the use of EC to 16 who underwent resection and reconstruction with PMMA.[27] Rajpal et al. reported on a series of 37 thoracolumbar corpectomies for metastatic spinal disease—5 patients were reconstructed using PMMA with no reoperation.[32] This was consistent with our findings.

Previous authors have found differences in operative duration when comparing EC to PMMA, we did not find a statistically significant difference in our cohort. As we were only able to compare operating room times, including anesthesia and nursing requirements, we were unable to tease out any differences in the exact surgical time between the 2 techniques.

Our overall complication rate was 14.8% which is lower than reported in other series. (2,29) This is probably from the fact that we chose only single level surgeries in our series compared to other studies looking at multi level vertebrectomies thus increasing the overall complication rate.

Our study have several limitations. It is a retrospective review of the individual medical records at a single institution. In comparing costs, we were naturally limited to compare the institutional price for implants at Ohio State University; possibly the price difference would vary based on locally negotiated rates. However, we expect the dramatic difference in cost for PMMA to be similar regardless of the specific price for EC. Similarly, the costs per minute of operative room utilization may differ among different institutions, but this should not affect our finding of decreased overall costs in using PMMA. It was just a crude method to look at the surgical cost for surgeries. We also did not do a direct cost—benefit or cost-survival analysis in this study. We only considered the overall

surgical time in estimating the cost of surgery. Additionally, we did not compare the cost differences including hospitalization and ICU. However, we feel that the ideology of the study was to observe for any non-inferiority of PMMA over cages in dealing with metastatic thoracic lesions.

Conclusion

Our data shows significant savings when using PMMA compared with a traditional expandable cage without increase in operating duration. With comparable clinical outcomes and complications rate, increased use of PMMA for reconstruction after vertebrectomy offers healthcare savings and non-inferior to expandable cages.

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Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Disclosures

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