Titanium Cage-assisted Polymethylmethacrylate Reconstruction for Cervical Spinal Metastasis: Technical Note

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OBJECTIVE: Reconstruction and stabilization of the cervical spine after vertebrectomy is an important goal in the surgical management of spinal metastasis. The authors describe their reconstruction technique using a titanium cage-Silastic tube construct injected with polymethylmethacrylate (PMMA) augmented by an anterior cervical plate. The surgical results using this technique are reviewed.

METHODS: Six patients ranging from 43 to 70 years of age underwent resection of metastatic tumor in the cervical spine followed by cage-assisted PMMA reconstruction of the anterior spinal column. The following reconstruction technique was performed. A Silastic tube is incised longitudinally and placed circumferentially around a titanium cage with the opening facing anteriorly. The cage-Silastic tube construct is carefully tapped into the corpectomy defect and filled with PMMA. The final construct is then augmented with anterior cervical plate fixation.

RESULTS: Two patients required additional posterior stabilization with lateral mass screws and rods. All patients achieved immediate stabilization, restoration of vertebral body height and normal lordosis, and preservation of the ability to walk independently. Five patients experienced significant palliation of biomechanical neck pain. There were no complications of neurological worsening, postoperative hematoma, wound infection, subsidence, graft dislodgement, or construct failure during a follow-up period of 1 to 19 months (mean, 6.8 mo).

CONCLUSION: Titanium cage-assisted PMMA reconstruction augmented with an anterior cervical plate is an effective means of reconstruction after tumor resection in patients with cervical spinal metastasis. The Silastic tube holds the PMMA within the cage and protects the spinal cord from potential thermal injury.

KEY WORDS: Cervical spine stabilization, Metastatic spine tumor, Polymethylmethacrylate reconstruction, Titanium mesh cage

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Metastatic tumors are the most common type of malignancy in the spine, with the vertebral column being the most common site of skeletal metastasis. Nearly 5 to 10% of patients with systemic cancer develop spinal metastases (37, 43). Ten percent of spinal metastases involve the cervical spine. Significant bone destruction can progress to fracture, instability, deformity, and neurological compromise. Failure of a vertebral body to support a segment of the spinal column requires effective reconstruction and stabilization. Surgical intervention should be considered for patients who harbor intractable pain, spinal cord compression, and the need for stabilization of impending pathological fractures. The primary goals of surgery are not necessarily for cure but rather to provide palliation of pain, to preserve neurological function, and to restore stability to allow early walking and mobilization without external orthosis (6, 11, 43). These are important considerations for patients who desire comfort and mobility during their remaining life expectancy.

Reconstruction and stabilization of the cervical spine after tumor resection can be performed technically in several different ways, each with advantages and disadvantages (2–6, 13, 19, 23, 28, 33, 35, 36, 44–46). Generally, the vertebral body defect is reconstructed with bone autograft or allograft, polymethylmethacrylate (PMMA), cervical prostheses, Silastic tubes, interbody spacers, titanium cages, or a combination of the above. Stabilization is then achieved with anterior instrumentation, usually anterior cervical plate fixation, to prevent distraction failure and to provide increased rigidity. In addition, posterior instrumentation with or without bone grafting may be necessary to supplement the anterior construct. We describe our technique for PMMA-assisted reconstruction and stabilization after cervical corpectomy for metastatic tumor using a combined titanium mesh cage-Silastic tube construct supplemented by an anterior cervical plate (*Figs. 1* and 2).

PATIENTS AND METHODS

Patient Population

We retrospectively reviewed the hospital records and x-rays of 6 patients who, between 2002 and 2003, underwent anterior corpectomy and tumor resection for cervical spinal metastasis followed by reconstruction using PMMA augmented by a titanium cage and an anterior cervical plate (*Table 1*). The patient population consisted of four women and two men whose ages ranged from 43 to 70 years (mean, 57 yr). Follow-up ranged from 1 to 19 months (mean, 6.8 mo). Three patients had renal cell carcinoma, two had non–small cell lung carcinoma, and one had colon carcinoma. All six patients were ambulatory at the time of surgery. Preoperative imaging, including plain x-rays, computed tomography, and magnetic resonance imaging, revealed pathological fracture and vertebral body collapse in five of six patients. The surgical indications included intractable neck pain associated with pathological fracture, severe kyphotic deformity, spinal instability, neurological compromise, and progressive epidural compression refractory to medical therapy.

Four patients underwent two-level corpectomies, and two underwent one-level corpectomies (*Fig. 3*). Two patients had additional posterior stabilization with lateral mass screws and rods. Postoperative plain x-rays were evaluated for restoration of vertebral column height and cervical lordosis and correction of kyphotic deformity. Patients were assessed for improvement of biomechanical neck pain, preservation of neurological function, and ability to walk independently postoperatively.

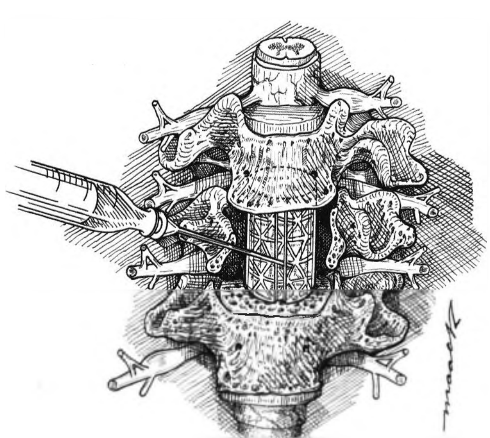

FIGURE 1. *Illustration depicting titanium cage-assisted PMMA reconstruction technique. The titanium cage-Silastic tube construct is placed into the corpectomy defect. PMMA is then injected into the cage through the incised opening of the chest tube.*

Surgical Technique

Tumors involving the vertebral body of the subaxial spine can be approached via a standard anterior neck dissection with a transverse cervical incision (29). Intraoperative planning includes the consideration of fiberoptic intubation, skeletal traction, and spinal cord monitoring. We generally perform preoperative embolization for extremely vascular tumors, such as thyroid or renal metastases, to minimize intraoperative blood loss. All surgeries are performed in the standard supine position with intraoperative fluoroscopy.

After the exposure, complete adjacent-level discectomies are performed before corpectomy to minimize blood loss and to assess the depth of the spinal canal. A corpectomy is then performed using a high-speed drill and Kerrison punches. The endplates above and below the corpectomy are squared with minimal disruption of the subchondral bone surface by use of a high-speed drill. The length of the defect is measured with a caliper, and a Pyramesh titanium cage (Medtronic Sofamor Danek, Inc., Memphis, TN) is fashioned to the appropriate size of the defect. Then, a 32-French chest tube is cut to the same length as the titanium cage. The chest tube is incised longitudinally and placed circumferentially around the cage with the opening facing anteriorly (*Figs. 1* and 2). A suture is placed across the incised ends of the chest tube to secure the cage (*Fig. 2*). The chest tube is positioned so that the radiopaque line is in the most posterior aspect of the cage-chest tube construct. This line can be visualized on postoperative lateral x-rays to verify that the cage-chest tube construct is not compromising the spinal canal (*Fig. 3B*).

The cage-chest tube construct is carefully tapped into the corpectomy defect. Alternatively, the cage-chest tube construct can be keyholed into the vertebral bodies above and below the corpectomy defect; however, we prefer not to perform this because of the concern for potential subsidence. The titanium cage is then injected with PMMA through the incised portion of the chest tube (*Figs. 1* and 2). The chest tube functions as a trough to prevent leakage of PMMA and to protect the spinal cord against thermal injury from the exothermic polymerization reaction of the PMMA. Once polymerization is complete, an anterior cervical locking plate is fixed to the vertebral bodies above and below the interbody graft.

RESULTS

All six patients achieved immediate stabilization, obviating the need for external orthoses. Circumferential stabilization with additional posterior instrumentation was performed in two patients (Patients 3 and 4) (*Table 1*). Patient 3 underwent a posterior approach to remove tumor involving the posterior elements causing epidural compression, followed by a C4–C6 fusion with lateral mass screws and rods. Patient 4 had significant kyphotic deformity secondary to a pathological fracture at the cervicothoracic junction that required both anterior and posterior stabilization.

All patients achieved satisfactory restoration of vertebral column height and cervical lordosis as well as correction of preoperative

TABLE 1. Titanium cage-assisted polymethylmethacrylate reconstruction in six patients

Patient no.	Age (yr)/ sex	Primary tumor	Presentation	Deformity	Location	Posterior fusion	Neurological outcome	Complications	Discharge to home	Follow-up (mo)	Status
1	58/F	Renal cell	Neck pain	No	C4	No	Improved	None	Yes	3	Dead
2	70/F	Renal cell	Neck pain	No	C3–C4	No	Improved	None	Yes	5	Alive
3	58/M	Renal cell	Neck pain	Yes	C5	Yes	Improved	None	Yes	1	Alive
4	46/F	Lung	Neck pain, arm weakness	Yes	C6–C7	Yes	Stable	None	Yes	1	Dead
5	70/F	Lung	Neck pain	Yes	C6–C7	No	Improved	None	Yes	12	Alive
6	43/M	Colon	Neck pain, numbness, hand weakness	No	C7–T1	No	Improved	None	Yes	19	Alive

FIGURE 2. A, *photograph of the Pyramesh titanium mesh cage placed inside a Silastic chest tube. Note the anterior defect in the chest tube for injection of PMMA. A suture is placed across the incised ends of the chest tube to secure the cage within the tube.* B, *titanium cage and chest tube construct filled with PMMA. Note the suture placed across the incised ends of the chest tube.*

deformity, documented on plain x-rays (*Fig. 3*). All patients except Patient 4 had significant palliation of biomechanical neck pain. Patient 4 continued to have persistent neck pain and arm weakness and died of rapidly progressive cancer that became widespread within 1 month of surgery. Patient 6 had neurological improvement of hand weakness and numbness. All patients maintained stability of neurological function and preoperative ambulatory status and were discharged home. There were no complications of neurological worsening, postoperative hematoma, wound infection, subsidence, graft dislodgement, or construct failure.

DISCUSSION

In the past 2 decades, surgical therapy of cervical metastatic disease has undergone a gradual evolution from primarily decompressive laminectomy to a more direct anterior approach to vertebral body metastasis (15, 16, 20, 21, 28, 42, 44). Metastatic disease most commonly involves the vertebral body, and reconstruction after anterior corpectomy is required for stability. Scoville et al. (40) described the initial use of PMMA for anterior cervical reconstruction after tumor resection in 1967. In their original article, a thick strip of Gelfoam was placed anterior to the dura to protect the neural and vascular structures from thermal injury. A piece of thin tantalum foil shaped into a half cylinder was placed over the Gelfoam to serve as a trough for the PMMA. Stainless steel screws were placed into the adjacent endplates of the corpectomy defect to augment fixation of the PMMA and to prevent the graft from slipping out. Since then, various modifications of PMMA-assisted reconstruction after tumor resection have evolved, including the use of Steinmann pins, Kirschner wires, Knodt distraction rods and hooks, cervical prostheses, and Silastic tubes (1, 8, 13, 18, 27, 28, 33, 35, 36, 44).

We describe a technique using PMMA injected into a combined titanium interbody cage-Silastic tube construct for reconstructing the cervical spine after metastatic tumor resection (*Fig. 1*). Titanium cages filled with bone graft for cervical spine reconstruction after corpectomy have been reported in pa-

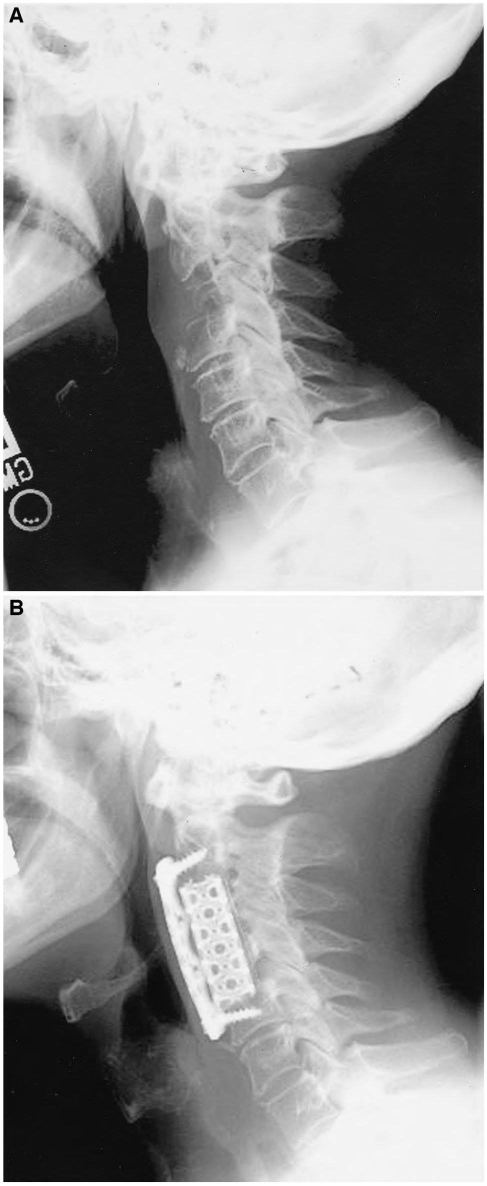

FIGURE 3. A, *preoperative lateral cervical x-ray in Patient 2 demonstrating pathological fracture and vertebral body collapse at C3 and C4 from renal cell metastasis.* B, *postoperative x-ray showing reconstructed spine after C3 and C4 corpectomies using the cage-Silastic tube construct filled with PMMA with anterior cervical plate fixation. Note the radiopaque line of the chest tube just posterior to the titanium cage. This line helps verify that the cage-tube construct is not compromising the spinal canal.*

tients with degenerative disease, trauma, and nonmetastatic spine tumors (10, 12, 30, 34). To the best of our knowledge, the use of titanium cages filled with PMMA for reconstruction in patients with cervical spine metastasis has not been described previously.

Titanium mesh cages are rigid cylindrical interbody devices that facilitate reconstruction of the anterior vertebral column after corpectomy (10). They are available in several shapes, configurations, and diameters and can be easily trimmed to fit the vertebrectomy defect. The titanium cage provides rigid anterior column support to restore physiological height and correct kyphotic deformity. Although cage implants increase the costs of surgery, they offer excellent biomechanical resistance to axial loading forces (10, 30, 34, 38). Cage-assisted reconstruction augmented by an anterior cervical plate provides the strongest and most rigid construct and may also prevent graft extrusion and subsidence (34, 41).

Although the cage can be filled with autograft or allograft bone (10, 12, 30, 34), we prefer to use PMMA in patients with metastatic cancer (*Fig.* 2). PMMA is a reasonable alternative to bone grafting for cancer patients with limited life expectancy because it achieves immediate stabilization after radical tumor ablation without the need of an external orthosis (18, 19). PMMA is relatively inexpensive, is easy to use, and avoids donor-site complications (4, 11, 13, 19, 31). Unlike bone graft, PMMA is unaffected by tumor invasion and seems to be safe in patients who subsequently undergo radiation therapy. For effective spinal reconstruction, the PMMA must be securely anchored to the vertebral bodies encompassing the corpectomy defect.

We place an incised chest tube wrapped around the mesh cage before implantation to prevent leakage of PMMA through the mesh interstices. The chest tube serves as a barrier to protect the dura and neural elements from direct thermal injury and compression during the exothermic solidification and cement expansion of PMMA (33). The addition of the chest tube also increases the surface area of the interbody construct to reduce the risk of telescoping. The cages that we have placed are 13 mm in diameter, and the 32-French chest tube is 1.1 mm in thickness, thereby providing a total diameter of 15.2 mm of the cage-tube interbody construct.

The use of Silastic tubing packed with PMMA (chest tube techniques) for vertebral body reconstruction was initially described by Errico and Cooper (7, 14) for metastatic tumor of the thoracic and lumbar spine. This technique, which involves keyholing chest tubes into the adjacent vertebral bodies and impregnating them with PMMA, has yielded excellent clinical results, particularly when combined with anterior plating and/or posterior instrumentation as needed (7, 17). Miller et al. (33) described a coaxial, double-lumen modification for cervical spine PMMA reconstruction. In addition to the previously described technique, a strip 1 cm wide is removed longitudinally from a larger (40-French) outer chest tube and is placed between the inner chest tube filled with PMMA and the dura. This outer chest tube serves as a trough and catches PMMA that has extruded and spilled over from the inner chest tube during PMMA injection.

Supplementing the PMMA reconstruction with an anterior cervical locking plate and screw fixation provides additional rigid stability, restoration of normal lordosis, and a markedly reduced rate of construct failure (2, 33). An additional posterior approach for tumor resection and/or stabilization should be considered if there is radiographic evidence of tumor involving three columns, significant vertebral instability, marked kyphotic deformity, or solitary metastasis in which a total spondylectomy is warranted (5, 16, 26, 28, 45). Posterior stabilization is particularly important for lesions at the cervicothoracic junction because of the higher risk of progressive kyphosis with anterior reconstruction and stabilization alone (24). In patients who undergo a two-level corpectomy, an anterior stabilization may be sufficient; however, in patients who undergo a three-level corpectomy, an additional posterior stabilization should be performed because there is a higher incidence of early construct failure in patients who undergo a three-level corpectomy followed by an anterior stabilization (22, 39). Supplemental posterior stabilization should also be considered in those patients who have poor bone quality.

Attenuation and scattering of electron or photon beam radiation have been reported when a high-density implant, such as titanium, is introduced into the target volume (9, 25, 32). If the target volume includes tissue positioned deep to the titanium implant, significant dose reduction ranging from 15 to 18% occurs with ipsilateral beam arrangements (32). This may result in subtherapeutic dose delivery to a tumor bed lying deep to a titanium construct, such as the interbody cage and anterior cervical plate. This phenomenon has been reported with titanium spinal rod stabilization systems and mandibular plates (25, 32).

CONCLUSION

Anterior cervical corpectomy followed by reconstruction and stabilization is an effective strategy in the management of spinal metastasis in some patients. Our technique for cervical spine reconstruction after tumor resection described here restores anterior column height, corrects kyphotic deformity, and achieves immediate stability, obviating the need for an external orthosis and allowing for early mobilization. The addition of anterior cervical plate fixation provides extra support to prevent distraction failure.

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COMMENTS

The authors describe six patients who underwent resection of their metastatic tumors in the cervical spine followed by cage-assisted polymethylmethacrylate (PMMA) reconstruction of the anterior spinal column and placement of an anterior cervical plate. Two patients required additional posterior stabilization. Apparently, stabilization of the anterior body and normal lordosis were restored immediately. There were no major complications. The authors emphasize that using a Silastic tube to inject the PMMA in patients with metastatic disease is a good technique, and I agree. Unless the operation is performed primarily for excruciating pain, this type of procedure should be considered only if a patient has a reasonable chance of living more than 3 to 6 months. The authors have done well in trying to use this technique to alleviate their patients' pain, deformities, and neurological deficits.

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This technical note is the natural capture of the ever-expanding array of implantable materials for spinal surgery. The use of PMMA for restoring axial support has a time-proven place in the management of metastatic disease of the spine. The authors suggest that they have improved upon earlier methods of securing the acrylic by "caging" it, because the cage, unlike acrylic alone, can be tightly impacted in the corpectomy defect. They think that the overall construct is further enhanced by the addition of a tension band in the form of a plate. It is cautioned, appropriately, that evidence of compromised stability may require a simultaneous posterior fusion, in that for an already weakened spine, the anterior construct may be inadequate for assured stability.

The foregoing notwithstanding, this article joins a literature that, although extensive, provides so-called lesser-quality evidence, opinion, personal bias, and small series. The spinal metastasis patient does have some unique considerations, however. Enlightened management acknowledges oncological realities: planning, perfect construct concepts, and surgical technique are critical to keeping surgical challenges simple for the frequently debilitated patient. Preoperative embolization, as mentioned by Liu and colleagues, is a case in point. Superficially, implanted hardware for such patients would seem attractive, but one is reminded that its use is ordinarily with the expectation of bony fusion. But the surgery of metastases is palliative surgery, and as such, bony fusion is not ordinarily achieved or expected. The plate is simply an internal orthotic. Ultimately, even minimal movement will loosen screws in the absence of bony incorporation. Accordingly, the need for and even prudence of plating can be called into question. My bias is that the track record for simple PMMA vertebral body reconstruction in metastatic disease is not bad, even in the rare long-term survivor. In that patient, avoiding the potential perils of chronic micromotion is not unimportant.

Cancer patients are often frail, especially when worn down by an overly protracted medical management. Ideally, surgical treatment is expeditious and simple. Because the biomechanical consequence of plating the longer construct mandates additional posterior stabilization even when stability is not the paramount issue, one could argue that this particular strategy is excessive. The biomechanics of a simple keystone PMMA block or cage strut do not require posterior augmentation when stability is not a primary concern. Current practice dictates that the use of hardware lessens the frequency of corpectomy graft displacement (2). However, when redo surgery is associated with hardware failure, it is potentially more complicated than that for a simple strut displacement, not a minor concern in the frail patient.

For several reasons, some good, some questionable, spinal surgery in general increasingly involves implanted hardware. This trend is of some concern (1). Spinal surgeons should be especially deliberate in their approach to spinal metastases.

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Liu et al. have provided us with a unique technique for dealing with an uncommon but challenging clinical problem. Protection of the dural sac and spinal cord from PMMA extrusion into the spinal canal as well as the obtaining of a solid construct are two major issues plaguing the spine surgeon dealing with cervical tumors. The strategy proposed by Liu et al. is a technique that may prove useful to many surgeons. It should therefore be in the armamentarium of surgeons dealing with such complex pathological conditions. We are pleased that the authors have introduced us to this technique.

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