Eur Spine J
DOI 10.1007/s00586-015-4154-0

GRAND ROUNDS

Anterior column reconstruction with PMMA: an effective long-term alternative in spinal oncologic surgery

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Received: 3 May 2015 / Revised: 17 July 2015 / Accepted: 19 July 2015

Abstract

A number of anterior reconstruction options are available in patients managed for symptomatic metastatic spinal column disease. Polymethylmethacrylate (PMMA) has been traditionally used as a reconstruction option in patients with limited life expectancy as an anterior fusion is not expected. In this article, we present the outcome of a 13-year follow-up of a long anterior reconstruction using PMMA of the upper thoracic spine in a myelopathic female secondary to a compressive breast metastasis affecting the upper 4 thoracic vertebrae. We discuss the use of PMMA in spinal oncological surgery and review the evidence pertinent to its use.

Keywords Polymethylmethacrylate · PMMA · Anterior column reconstruction · Spinal oncology

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Case presentation

A 49-year-old patient was referred to the spine clinic for upper back pain and progressive deterioration in her gait with a recent onset of bladder and bowel dysfunction. She had recently been diagnosed to suffer with breast cancer with bony metastases limited to the upper thoracic spine and no evidence of visceral deposits. Her past medical history was unremarkable other than a unilateral mastectomy with axillary nodes negative.

Because of her upper thoracic metastases, she had received conventional radiotherapy to her upper thoracic spine approximately 2 weeks prior to her spine clinic review. Unfortunately, stability issues related to the upper thoracic spine had not been considered. On her initial spine service consultation, her clinical evaluation was consistent with mechanical back pain and an upper thoracic myelopathy, ASIA D with abnormal proprioception. Upper limb neurological examination was normal.

Diagnostic imaging section

Figure 1 demonstrates the involvement of the upper 4 thoracic vertebrae (T1–T4) with tumor metastasis with collapse of the vertebral bodies mainly at T2 and T3. The combination of the anterior extra-dural tumor and exaggerated local kyphosis between T1 and T4 resulting in

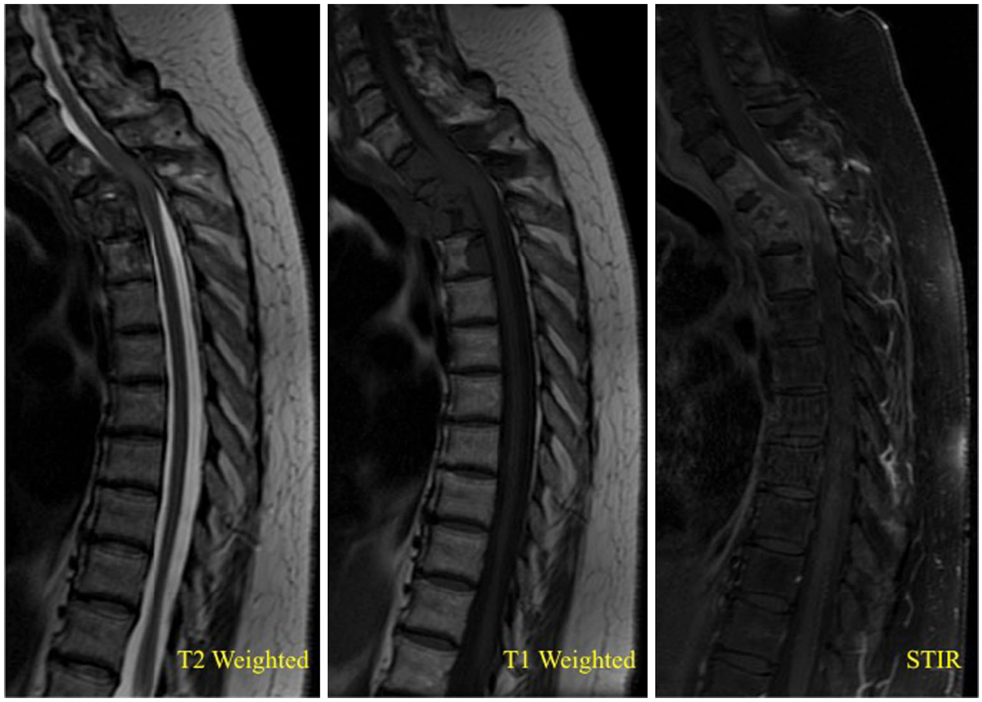

Fig. 1 Sagittal MRI scan of the thoracic spine demonstrating the upper thoracic spine involvement

significant spinal cord compression and cord signal changes (Myelomalacia).

Historical review of the condition, epidemiology, diagnosis, pathology, differential diagnosis

Over the last few years, the management of metastatic spinal disease has been revolutionized by a better understanding of the role of surgery, advances in instrumentation techniques and a better appreciation of the biomechanical aspects of spinal load transfer and stability concepts. All this has helped to better inform the spinal surgeon's management choices and approach in treating this fairly complex cohort of patients.

Reconstructive surgery following tumor decompression in the spine aims to restore the spinal stability under load. Such load can be substantial in the setting of a kyphotic spinal column and destruction of the posterior bony and ligamentous structures. Although the thoracic spine "normal alignment" is kyphosis, when this kyphosis is exaggerated resulting in the sagittal vertical axis being positive, the biomechanical stress to the pathologic region is dramatically increased. This was appreciated by spine surgeons and reflected in a number of techniques for anterior column reconstruction ranging from a vertebroplasty to the substitution of the vertebral body with a spacer [1]. A number of options have been used as anterior spacers constructs including, tri-cortical bone grafts (auto- or allogeneic) which are not routinely used in tumor surgery, Polymethylmethacrylate (PMMA) with/without reinforcement and cages manufactured from a number of materials such as metal alloys, carbon fibers, synthetic plastics, or ceramic.

Irrespective of the spacer chosen, the principles of the anterior reconstruction remain; to use a well-fitting spacer (both in height and diameter), which allows adequate endplate contact both proximally and distally and is capable of load transfer with minimal subsidence. Second, to protect/restore the posterior tension band and prevent graft instability particularly against rotational forces, best achieved using additional posterior instrumentation, particularly with long spacers [2]. A third principle, that of obtaining fusion, becomes very complicated in the spine metastases population. Often these patients have limited life expectancy and fusion probably is not an issue. In patients with longer life expectancy, bony fusion should be a desired outcome—but is it necessary? Indeed, the biologically hostile environment secondary to radiation, chemo and soft tissue defects makes the likelihood of fusion unlikely.

Scoville et al. first described PMMA-assisted anterior reconstruction in a 71-year-old patient suffering with lymphoma involving vertebral bodies in the cervical spine in 1967 [3]. In their technical note, the authors described the advantage for the use of "acrylic plastic for vertebral replacement in spinal metastatic disease where the patient has only a limited life expectancy and should not spend his last months immobilized in bed in casts or traction".

Additional PMMA advantages include ease of use, low cost, avoids donor site morbidity, conveys immediate stability, because of apposition with entire endplate, force per unit area of endplate is reduced so less chance for subsidence, has minimal imaging artifact and allows for the elution of local antibiotics. Risks include graft dislodgement, cement migration and thermal damage to the spinal cord or nerves [4, 5].

To improve PMMA spacer stability and prevent graft migration, a number of techniques were proposed such as notching endplates prior to pouring PMMA, the use of Steinmann' s pins, Kirschner wires or small fragment screws as anchors into both the cephalad and caudal endplates. In a series of 101 patients managed with corpectomy and PMMA anterior reconstruction with Steinman pins for metastatic spinal tumor, Sundaresan et al. reported one dislodgment and one visceral injury/perforation over a follow-up period ranging from 10 months to 4 years. Interestingly, the low dislodgment rate was reported despite the authors using additional posterior instrumentation in only 10 % of their cases [6]. Other methods included the use of Harrington distraction rods anchored to prepared endplates with hooks and distracted out to length before PMMA was poured into the corpectomy space [7] and the use of a chest tube as an anchor and cement containment device. PMMA was also used as part of a hybrid cage/cement construct to fill a ceramic or metallic cage after its implantation [5].

PMMA cures through an exothermic reaction [8]. Belkoff and Molloy used fresh vertebral bodies harvested from human cadavers to study the temperature variations in a procedure resembling vertebroplasty. The authors immersed the specimens in a 37 °C water bath and injected them with PMMA. They recorded a temperature rise above 50 °C in the epidural space and above 100 °C in the center of the vertebral body [9]. This is clearly a substantial thermal hazard to the delicate neural structures nearby but at the same time thermo-toxic to residual tumor cells in its vicinity and has been credited to improve local tumor control, as did the monomer chemical cytotoxicity [10]. From a practical viewpoint, maintaining a 2–3 mm gap between the PMMA and Dura and/or using a barrier such as Gelfoam, fat or a fashioned rubber sheet might minimize the thermal risk. Additionally, saline irrigation to dissipate the heat might be beneficial but there is no evidence to date to support one technique over another.

PMMA spacer use for anterior reconstruction does not readily allow for the use of bone graft anteriorly and therefore an anterior bony fusion is not the primary objective. Therefore, such reconstructions have been largely preserved for patients with a short life expectancy. More recently, Chen et al. described a simple method for creating a PMMA cylinder using two syringes. The cylinder is then fashioned to fit the corpectomy defect and its hollow center allows it to be packed with bone graft [11].

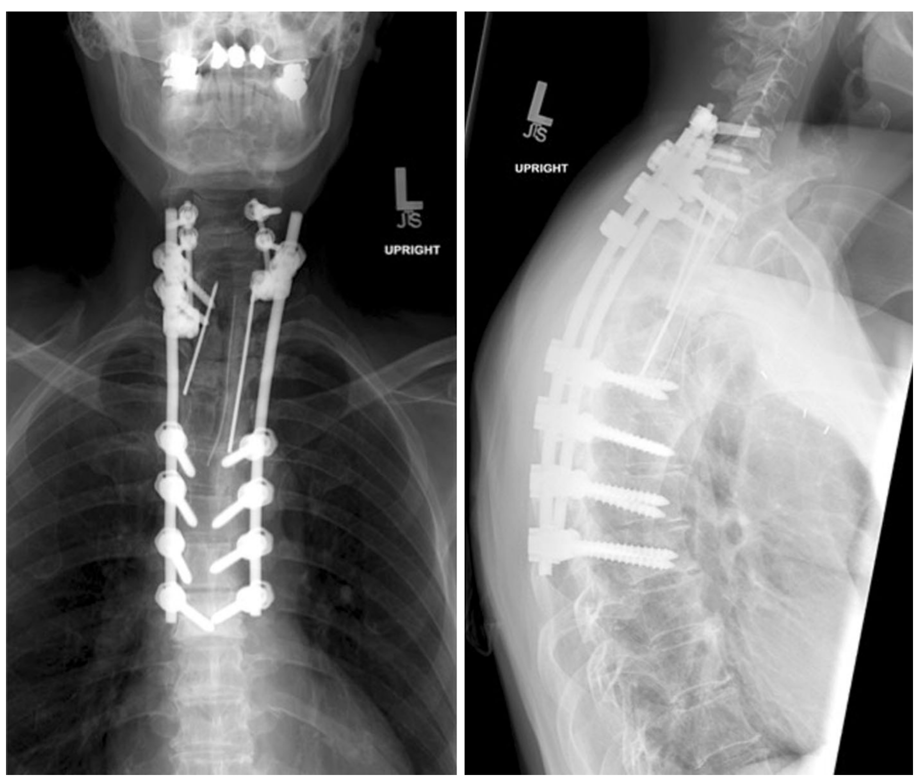

Fig. 2 Postoperative standing X-rays of the thoracic spine

Fig. 3 CT scans of the upper thoracic spine confirming showing a well-maintained anterior PMMA spacer with no evidence of failure

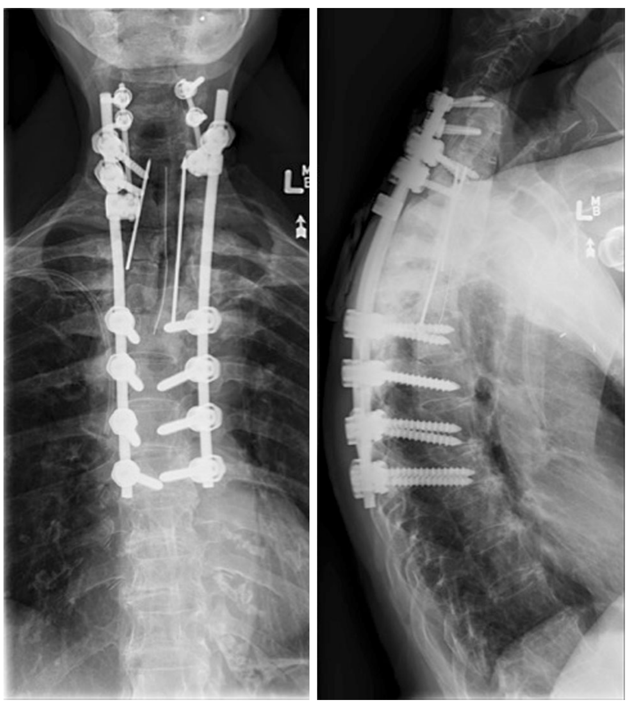

Fig. 4 Follow-up standing thoracic spine X-rays 13 years post initial surgery

Yet, the question remains: Is fusion necessary in patients surveyed for periods well beyond 12 months?

Rationale for treatment and evidence-based literature

In our case, the surgical aim was to achieve a complete decompression of the spinal cord and an extensive debulk of the tumor load in the vertebral bodies anteriorly. This requires a three-level corpectomy at T2, T3 and T4 which in turn necessitates a long anterior reconstruction in the upper thoracic spine. A posterolateral access to the vertebral bodies at this level is preferred due to the limited anterior window and anterior vascular anatomy [1]. We have reported on our experience of using a single-stage posterolateral vertebrectomy in the thoracic and lumbar spine in 96 patients surgically managed for metastatic spinal column disease showing a significantly lower blood loss, better patient performance, higher satisfaction and comparable neurologic recovery when compared to the combined (anterior and posterior) approaches [12].

It has been our experience that anterior reconstruction using PMMA contained in a large diameter chest tube provides a relatively easy alternative to large metal cages particularly when planning to bridge a significant anterior defect. The malleable chest tube can be passed between spared nerve roots before it is anchored into the vertebral bodies above and below through pre-prepared defects in the endplates. Once a satisfactory position of the tube is achieved, PMMA is injected into it allowing the cement to fill the tube and permeate into the vertebral bodies locking the construct in situ. This also avoids direct contact between the cement and the dura minimizing the thermal risk. Cement is mechanically robust under compression and we have not experienced a spacer fracture or failure with the technique [13]. We routinely support long anterior spacer constructs with posterior instrumentation to restore the posterior tension band and limit rotation [14, 15].

Procedure

The patient was put under general anesthesia and positioned prone on a Jackson table. A midline posterior approach was used to expose the spine from C3 to T9. The spine was instrumented from C5 to T1 proximally and T5

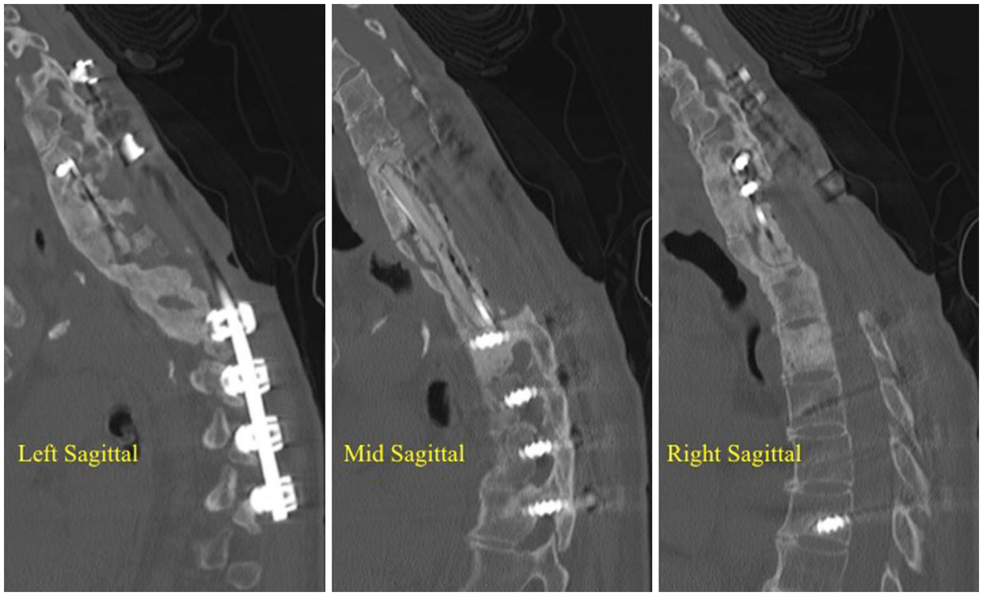

Fig. 5 CT Scan of the thoracic spine 13 years following initial intervention showing the anterior PMMA spacer incased in bone

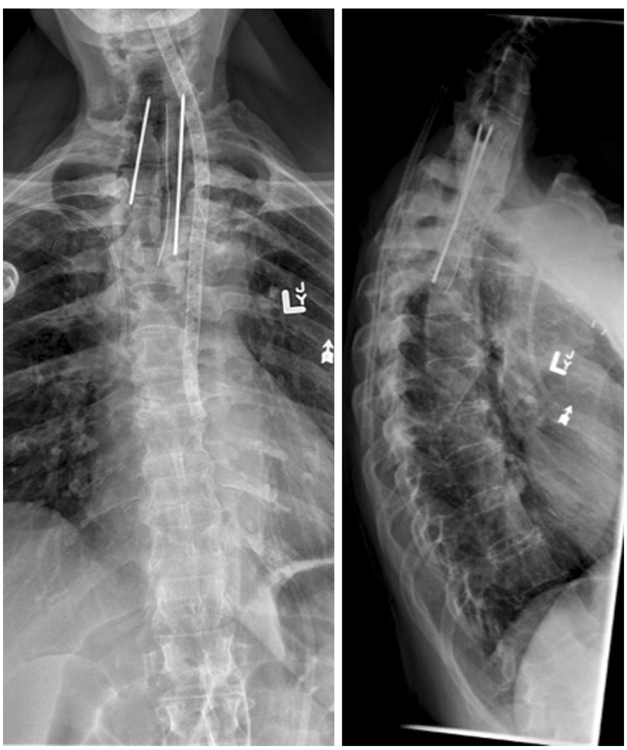

Fig. 6 X-rays of the upper thoracic spine after removal of the posterior instrumentation

Fig. 7 A well-healed local Trapezial flap covering the surgical wound at 1-year post surgery

to T8 distally before a posterior decompression through wide laminectomies was performed from C7 to T5. The Dura was circumferentially released from adhesions and the left T3 and T4 nerve roots identified and scarified to improve exposure. We described our technique in performing a costotransversectomy in an earlier publication [12].

A temporary rod was secured on the right to allow for a generous anterior decompression through a four-level vertebrectomy of T1, T2, T3, and T4. A 8 mm hole was then created through the inferior endplate of C7 and superior endplate of T5 using a combination of an angled 6 mm osteotome and an angled curette. After confirming the sagittal and coronal alignment of cervico-thoracic junction using fluoroscopy, a 24 Fr chest tube was fashioned to bridge the vertebrectomy gap and allow for anchorage into the pre-prepared endplates. PMMA mixed with Vancomycin and Tobramycin was injected into the chest tube through a side orifice under image guidance. This allowed confirmation of a satisfactory fill of the tube and the vertebral bodies above and below. Additionally, 2 mm Steinmann pins were planted through the exposed endplates to secure additional cementation around the chest tube. Cement was irrigated to dissipate local curing temperature. We did not use bone graft anteriorly around the PMMA.

Definitive posterior rods were then secured to replace the temporary rod and the wound was washed out with 6 liters of normal saline before a gravity drain was inserted. The wound was closed in layers and the total blood loss was 2000 cc.

Procedure imaging section

Positioning of the PMMA tube spacer was determined using a combination of intraoperative AP fluoroscopic imaging and direct visualization of the tube in relation to the exposed endplates through the costotransversectomy exposure. Lateral fluoroscopic imaging of this area was severely compromised by the normal bony structures crossing the field namely the scapulae and humeri. Figure 2 demonstrates the first postoperative X-ray of the surgical site, while Fig. 3 outlines a series of computerized tomography (CT) scans of the upper thoracic spine over a period of 6 years showing no signs of failure of the PMMA spacer.

Outcome, follow-up

The early postoperative period was uncomplicated. The patient was discharged to a rehabilitation facility and progressed steadily to achieve independent mobilization with a slow shuffling gait and maintained normal bladder and bowel function. She experienced occasional upper back pain well managed with oral analgesics.

Approximately 7 months following surgery, she presented to the outpatient clinic with a posterior discharging upper thoracic surgical wound that grows methicillin-resistant staphylococcus aureus (MRSA). She underwent a debridement, washout and primary closure of the surgical wound followed by 6 weeks of intravenous antibiotics. Over the following 12 years, she was reviewed annually in the clinic and underwent two additional debridement procedures and a flap cover for persistent infection. Unfortunately, the infection persisted and she required long-term suppressive antibiotic therapy. She maintained her neurological improvement and reported a very satisfactory quality of life but was growing tired of the need to take antibiotics and have dressings over a superior intermittently discharging sinus. Approximately 11 years following her initial surgery, the soft tissue coverage over the upper part of the implants broke down. Serial X-rays of the upper thoracic and lower cervical spine confirmed no metal work loosening or failure (Fig. 4). She remained oncologically well with evidence of only abdominal metastasis that responded well to hormonal therapy (Anastrozole).

The aim of the initial surgical intervention was to achieve adequate decompression, local tumor control and stabilization but a bony union in a hostile, previously irradiated bed with additional postoperative chemotherapy and radiotherapy was not anticipated. A CT scan done 13 years post initial surgery demonstrated a solid anterior bony fusion with the cement entirely surrounded by bone. This is likely the product of residual anterior column bone and the relative stability of the construct and time (Fig. 5). We, therefore, felt that it would be feasible to perform a more definitive debridement of the surgical wound including the removal of the posterior instrumentation (Fig. 6). This was performed and the wound was packed with antibiotic beads and covered with a vacuum-assisted dressing. The plastic surgery team inspected the wound a week following the debridement and performed definitive cover with a local Trapezial flap (Fig. 7). At 1 year follow-up post removal of metal work, the patient has no evidence of infection or axial spine pain and remains neurologically normal.

Compliance with ethical standards

Conflict of interest None.

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