

Clinical Efficacy of Percutaneous Osteoplasty Under Fluoroscopy and Cone-Beam CT Guidance for Painful Sternal Metastases: A Case Series

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Background: Although percutaneous osteoplasty (POP) has been widely accepted and is now being performed for the treatment of painful bone metastases outside the spine. It is emerging as one of the most promising procedures for patients with painful bone metastasis who are unsuitable for surgery or who show resistance to radiotherapy and/or analgesic therapies. However, there are only scarce reports regarding osteoplasty in painful sternal metastases.

Subjects and Method: We report four patients with sternal metastases suffered with severe pain of anterior chest wall. The original tumors included lung cancer and thyroid cancer. For the initially pain medication failing, all the four patients received POP procedure under fluoroscopic and cone-beam CT (CBCT) guidance, and obtained satisfying resolution of painful symptoms at 6-month postop follow-up.

Conclusion: POP is a safe and effective treatment for pain caused by metastatic bone tumors in the sternum. In practice, however, percutaneous puncture of pathologic sternal fractures can be a challenge because of the long flat contour and the defacement by lytic tumor of bony landmarks. We find that the use of fluoroscopic and CBCT can facilitate POP for flat bone fractures with displacing the trajectory planning, needle advancement, and cement delivery in time.

Keywords: osteoplasty, bone metastasis, Pain, palliative care, sternum

Introduction

Bone metastasis is a common condition in patients with cancer, especially in patients with breast, lung, and prostate cancers.¹ The most frequent symptom from bone metastasis is severe pain that can affect the quality of life of patients and usually limits patients' mobility.²⁻⁴ Most of these patients are in a poor health status with high medical comorbidities. Radiation therapy (RT) may be effective for pain relief and is a standard palliative treatment for metastatic bone tumors. Nonetheless, up to 20–30% of patients treated with RT do not respond to the treatment. Once the pain recurs at a previously irradiated site, RT cannot be performed again due to dose limits in normal tissues.⁵ It is desirable for these patients to have minimally invasive approach to treat the severe pain from bone metastases and gain life quality for their remaining life span.

In recent years, percutaneous osteoplasty (POP), or combining with percutaneous thermal ablation, a technical extension of percutaneous vertebroplasty, has been broadly used in treating painful bone metastases outside the spine.⁶⁻¹³ However, there are only scarce reports regarding osteoplasty in painful sternal metastases. The inserting the needle and placing the bone cement are important for achieving the effectiveness of the cement augmentation in POP of the sternum with the flat shape. We present here four patients with painful sternal metastases who were successfully treated by POP under fluoroscopic and cone-beam computed tomography (CBCT) guidance.

Subjects and Method

Subjects

The indication of the four patients for POP was nonsurgical candidates due to poor performance status or patient's refusal for surgery intervention; severe bone pain caused by sternal metastatic disease effected the life quality of patient severely, and pain unresponsive to conventional therapy, including various analgesics and chemotherapeutic regimens. Pain intensity was assessed by using a 10-point numeric rating scale (NRS scores) with values from 0/10 (no pain) to 10/10 (maximum pain intensity). For rapidly relieving severe bone pain caused by metastases and improve life quality of those patients, POP was offered as a treatment to the patients with a mutli-interdisciplinary consensus among a team of surgeons, oncologists, interventional radiologists and radiotherapists.

Method

POP procedures were performed by interventional radiologists with more than 5 years of experience in bone procedures in a digital subtraction angiography system with CBCT. Conscious sedation was achieved just before the procedure and patients were placed in a supine position with neck in slight extension. After chest wall sterile preparation and draping, CBCT was performed to identify the margins of the metastases and the scheme for POP was made with analyzing the lesion and its adjacent structures. The numbers of puncture the lesion site and the trajectory of puncture needle were selected to get a homogeneous, sufficient distribution of the bone cement and to improve the procedure safety. Under local anesthesia, a 13-gauge bone-beveled needle was punctured into the sternum, and gently advanced into the lesion under direct real-time fluoroscopic guidance and cardiovascular monitoring. Bone cement (polymethyl methacrylate, PMMA) was mixed to a semiliquid consistency. Cement injection was performed by means of 1-mL syringes with a maximal possible amount via the needle and the cement contained in the lumen of the needle was delivered into the lesion by introducing a stylet into the needle under real-time fluoroscopic guidance. If cement achieved satisfactory filling in the metastatic area, or reached the anterior and posterior cortical margin, or started to leak, the injection would be stopped. The volume of injected cement was determined and recorded. Additional CBCT or CT scan was performed to evaluate the distribution of cement in the lesions. At 1-week, 1-month, 3-month and 6-month post-procedure follow-up were performed, the NRS scores and complications were observed and recorded.

Cases Presentation

Case 1

A 71-year-old man complained of persistent pain of anterior chest wall and braced himself, when coughing. Upon examination, there was pinpoint tenderness over the sternum. On CT scan, there was a lesion measured $5.4 \times 4.7 \times 3.9$ cm in left lung hilum, and an osteolytic destructive lesion was located at the sternal manubrium. The lesion of the sternum was approximately $2.5 \times 4.1 \times 2.4$ cm in size and was surrounded by partially destroyed anterior and posterior cortical bone. The biopsy of lung lesion confirmed squamous cell carcinoma. The patient had a numerical rating scale (NRS) of 9, and no symptom improvement was obtained with oral narcotic. POP was performed with two puncture the lesion sites. Two needles were inserted into the lesion successively at a 45° inclination using an inferior to superior approach, and 2.5 mL of cement was injected into the sternal lesion. The immediate post-procedure CT scan demonstrated a good distribution of the cement in the lesion and only a slight leakage along the posterior cortical margin (Figure 1). After the procedure, the patient gained a significant pain relief, and the NRS scores were decreased to 4, 3, 3, and 3, at the 1-week, 1-month, 3-month, and 6-month follow-up, respectively. No complication occurred.

Case 2

A 57-year-old woman had a five-year history of right pulmonary adenocarcinoma and treated with neoadjuvant chemotherapy followed by radiotherapy. One month ago, she had severe pain in the anterior chest wall that often affected her sleep. The patient had a NRS score of 8, and the pain was refractory to oral narcotics. CT scan showed there was a diffuse osteolytic destructive lesion in the sternal body and manubrium. The lesion measured $10.3 \times 3.5 \times 3.5$ cm in size and cortical disruption, anterior and posterior, was identified. POP was performed with three puncture the lesion sites. Three needles were advanced into the lesion successively, at a 20° , 45° , 35° inclination using an inferior to superior

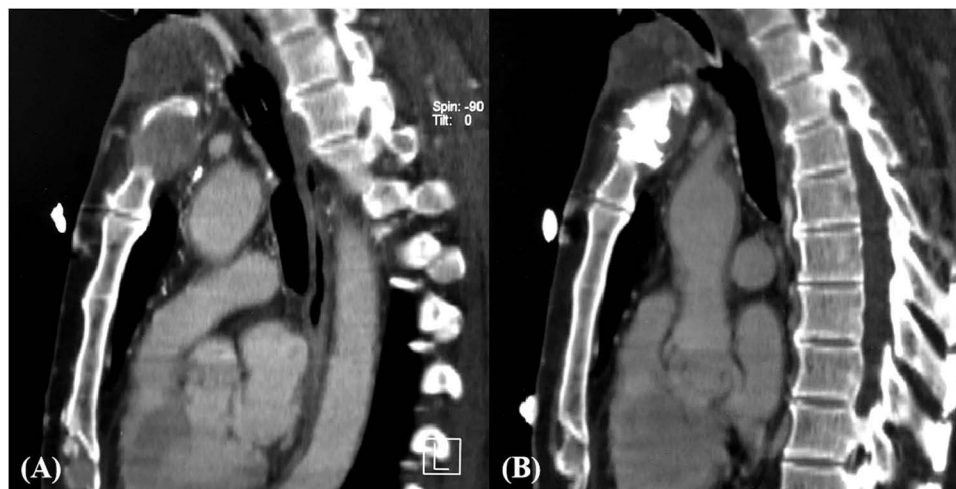


Figure 1 (A) A CT sagittal image demonstrated an osteolytic metastatic lesion in the sternal manubrium with anterior and posterior cortical disruption. (B) A CT sagittal image demonstrated a good cement distribution in the lesion and a slight leakage along the posterior cortical margin.

approach, respectively, and 6.3 mL of cement was injected. The immediate post-procedure CBCT demonstrated a good distribution of the cement in the lesion and only a slight leakage along the needle track (Figure 2). After the procedure, the patient felt obvious pain relief and was able to sleep well. Her NRS scores decreased to 3, 2, 2, and 2, at the 1-week, 1-month, 3-month, and 6-month follow-up, respectively. No complication occurred.

Case 3

A 72-year-old man had persistent pain of the anterior chest wall that worsened with body position change. The patient had a NRS score of 8, and the pain was refractory to transdermal narcotic treatment. On CT scan, there was a lesion measured $3.7 \times 5.5 \times 4.3$ cm in left lower lung, and an osteolytic lesion measured $3.2 \times 2.6 \times 2.8$ cm located at the sternal body with partially destroyed cortical bone. The biopsy of lung lesion confirmed adenocarcinoma. POP was performed with two puncture sites. Two needles were punctured into the lesion successively at a 15° inclination using an inferior to superior approach, and approximately 2mL of cement was delivered. As the trocar was removed, a small tail of cement was noted along the needle tracks. Fluoroscopy and a postoperative CT scan confirmed adequate fill of the tumor

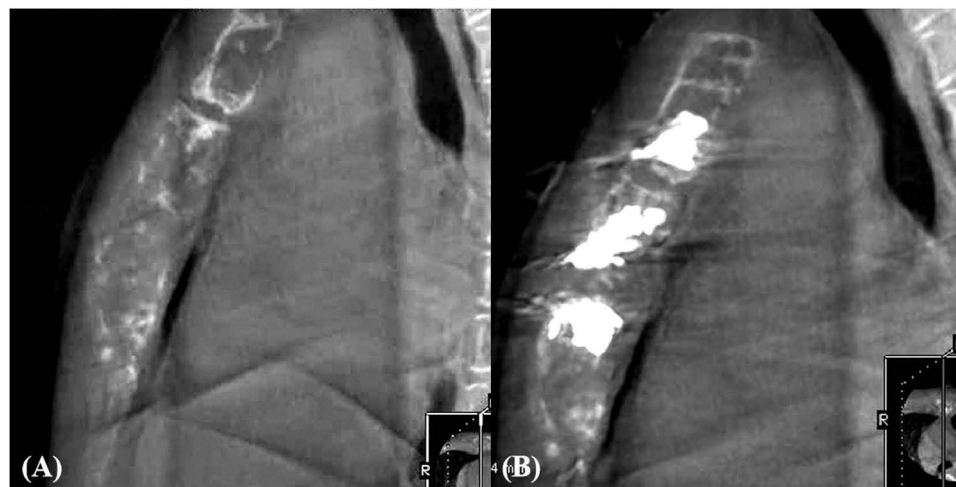


Figure 2 (A) A CBCT sagittal image showed a diffuse osteolytic lesion of the sternal body and manubrium with cortical disruption. (B) A CBCT sagittal image showed a good cement deposition in the lesion and a slight leakage along the needle track.

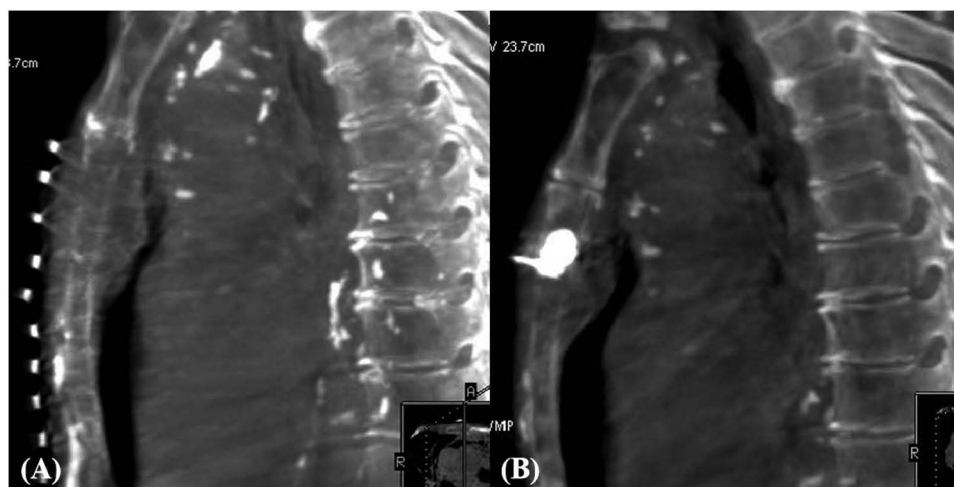


Figure 3 (A) A CBCT sagittal image showed a diffuse osteolytic lesion of the sternal body. (B) A CBCT sagittal image showed a good cement deposition in the lesion and a small tail of cement along the needle track.

(Figure 3). The patient reported his NRS scores reduced to 4, 3, 3, and 3, at the 1-week, 1-month, 3-month, and 6-month follow-up, respectively. No complication occurred.

Case 4

A 65-year-old man underwent a thyroidectomy 19 years ago for an undifferentiated carcinoma. He was hospitalized for his anterior chest wall severe pain with NRS score of 9, and no pain relief was gained with transdermal narcotic. A chest CT revealed an osteolytic lesion in the inferior part of the sternum. The lesion was approximately $6.8 \times 3.2 \times 3.5$ cm with destroyed cortical bone. POP was performed with two needles inserted from two puncture sites at a 30° and 45° inclination using a superior to inferior approach, respectively. Approximately 4.2mL of cement was delivered. The immediate post-procedure CBCT demonstrated a better deposition of cement in the lesion and a small amount of cement in front of the sternum (Figure 4). After the procedure, the patient felt his chest pain progressively reduce, and the NRS

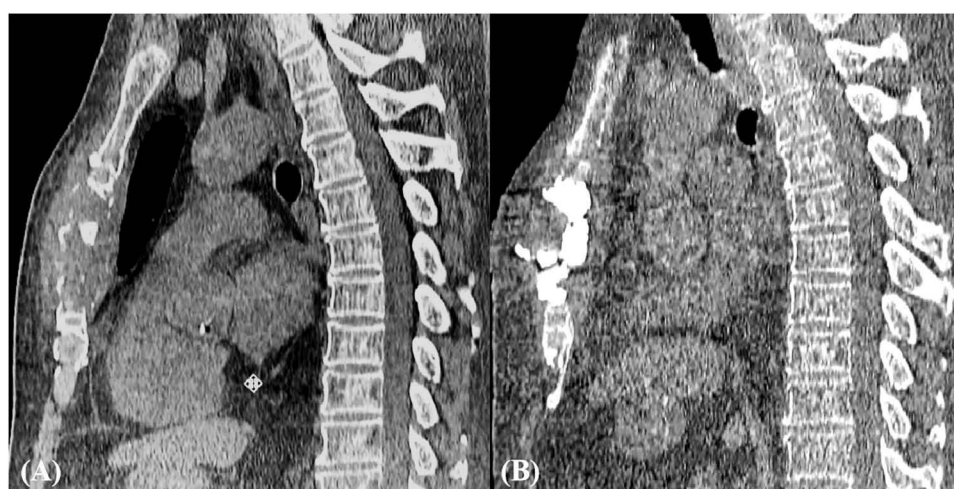


Figure 4 (A) A CBCT sagittal image showed a diffuse osteolytic lesion of the sternal body with cortical disruption. (B) A CBCT sagittal image showed a better deposition of cement in the lesion and a small amount of cement in front of the sternum.

Table 1 NRS Scores of Patients at the Baseline and Each Follow-Up Point

Case	Baseline	Follow-Up Point			
		1-Week	1-Month	3-Month	6-Month
1	9	4	3	3	3
2	8	3	2	2	2
3	8	4	3	3	3
4	9	3	2	2	2

scores decreased to 3, 2, 2, and 2, at the 1-week, 1-month, 3-month, and 6-month follow-up, respectively. No complication occurred.

Table 1 showed the NRS scores at baseline, and at each point in the follow-up period in all four patients.

Discussion

Osseous metastases are usually seen in cancer patients at advanced stage. It usually causes intractable pain, functional impairment, and worsening quality of life. Because most of the patients with intractable painful metastases are usually at the end stage of disease at the time of presentation, the goals of treating these patients should be the alleviation of pain, and improvement of life quality. The patients are either not a surgical candidate or refractory contraindicated to additional radiation therapy, chemotherapy, hormone therapy. In addition, these patients have complications for routine analgesic medications. Currently, radiation is recognized as the most effective treatment, however, 20–30% of patients with painful bone metastases are nonresponders. Furthermore, sternal radiation may result in devastating cardiac complications due to its proximity to the heart and large vasculatures. Patients can also develop acute pneumonitis and esophageal complications during and after radiation therapy.^{14,15}

At present, POP technique with the advantage of rapid relieve pain has been used to treat osteolytic lesions in clinical practice. The analgesic effect may be attributed to the stabilization of microfractures of the bone, the destruction of nerve endings through the exothermic reaction and cytotoxicity.^{16,17} It is now well established by some studies that combination therapy with percutaneous thermal ablation and POP is a attractive option for palliative care for patients with bone metastasis. Combination therapy not only had burn cancer structure and nerves but also improve bone stability.^{18,19}

The sternum is a blade-like flat bone, consisting of the manubrium, body and xiphoid process, only 2–3 cm in depth. A bevelled puncture needle is necessary to provide a safe trajectory. Multiple puncture of the lesions facilitates to get a homogeneous and sufficient distribution of the bone. Percutaneous puncture of pathologic sternal fractures can be a challenge because of the long flat contour and the defacement by lytic tumor of bony landmarks. These factors make it difficult to accurately and precisely perform POP. Fluoroscopic guidance with CBCT allows the real-time tracking of needles and demonstrating of cement distribution. The application of the interventional imaging technology may facilitate stabilization of pathologic flat bone fractures through minimally invasive means with displacing the trajectory planning, needle advancement, and cement delivery in time.

In this report, all patients had osteolytic lesion in the sternum and the invasion of the cortex caused great pain. The constant, repetitive movement of the rib cage with respiration was painful. Our use of POP on sternal metastases resulted in satisfying clinical outcome regarding analgesic therapy management, pain control and mobility improvement. We think that the deposition of bone cement (PMMA) within the lesion not only has analgesic effects through polymerization reaction and reinforce the bone, but also can delay the progression of metastatic lesions to some extent by blocking tumor blood supply. Our result showed that the analgesic efficacy rate was satisfying at following up 6 months. The technique seems to be a safe procedure, as it was technically successful in all cases, and there were no severe complications. Limitations of this report were POP without combining with percutaneous thermal ablation, and no comparison of therapeutic effects between POP alone and combination therapy.

Conclusion

The present report shows that POP to sternal metastases was an effective and safe palliative therapy for reducing pain and improving patients' quality of life and mobility. This report adds to the body of literature supporting the role of direct palliation, in complement or in lieu of other palliative therapies.

Ethics, Consent and Permissions

Written informed consent has been provided by the four patients to use their clinical data and pictures for the report. Ethics approval is not required for a retrospective report of anonymous patient data. No institution approval was required to publish the case details.

Acknowledgments

This paper has been uploaded to [Research Square] as a preprint: [<https://www.researchsquare.com/article/rs-576606/v1>].

Author Contributions

All authors have made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas. They have drafted or written, or substantially revised or critically reviewed the article, and agreed on the journal to which the article will be submitted. All authors have reviewed and agreed on all versions of the article before submission, during revision, the final version accepted for publication, and any significant changes introduced at the proofing stage. And all authors have agree to take responsibility and be accountable for the contents of the article.

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Disclosure

The authors report no conflicts of interest in this work.

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