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CLINICAL INVESTIGATION NON-VASCULAR INTERVENTIONS

Application of Percutaneous Osteoplasty in Treating Pelvic Bone Metastases: Efficacy and Safety

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Abstract
Background Percutaneous vertebroplasty has been a good option to treat vertebral metastases. The pelvic bone is a common site of spread for many cancers. Using follow-up data for 126 patients, we evaluated the safety and efficacy of percutaneous osteoplasty (POP) to treat pelvic bone metastases.
Materials and Methods In this retrospective study, 126 patients (mean age 57.45 ± 11.46 years old) with 178 lesions were treated using POP. The visual analog scale (VAS), Oswestry Disability Index (ODI), and the changes in the patient's use of painkillers were used to evaluate pain and quality of life before the procedure, and at 3 days and 1, 3, 6, 9, and 12 months after the procedure.
Results Technical success was achieved in all patients. The mean VAS scores decreased significantly from 6.87 ± 1.33 before the procedure to 3.33 ± 1.94 by day 3 after the procedure ($P < 0.05$), 2.26 ± 1.59 at 1 month ($P < 0.05$), 1.89 ± 1.53 at 3 months ($P < 0.05$), 1.87 ± 1.46 at 6 months ($P < 0.05$), 1.90 ± 1.47 at 9 months ($P < 0.05$), and 1.49 ± 1.17 at 12 months ($P < 0.05$). The ODI also changed after the procedure, with significant differences between baseline scores and at each follow-up examination ($P < 0.05$). Pain relief was achieved in 118 patients (93.65%); however, pain relief was not obvious in seven patients (5.56%), and pain was aggravated in one patient (0.79%). Extraosseous cement leakage occurred in 35 patients (27.78%) without causing any clinical complications.
Conclusion Percutaneous osteoplasty is a safe and effective choice for patients with painful osteolytic pelvic bone metastases. It can relieve pain, reduce disability, and improve function.
Level of Evidence Level 3b, retrospective study.

Keywords Pelvic bone metastases · Percutaneous osteoplasty · POP · Interventional therapy

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Introduction

Bone metastases are a common feature of advanced cancers and are associated with significant morbidity and mortality. When malignant tumors invade the pelvis, they can cause great pain to the patient and seriously affect their quality of life. These effects mainly include: (1) unbearable pain; (2) nerve compression, especially of peripheral nerves, after tumor enlargement, resulting in incontinence and lower limb dysfunction; and (3) organ compression, in which tumors can grow into the pelvic cavity and press on nearby organs. For example, compression of the bladder leads to a decrease in bladder capacity and frequent urinary symptoms and compression of the rectum affect defecation.

As an extension of percutaneous vertebroplasty, percutaneous osteoplasty (POP) is considered an option when the pain response to the above treatment methods is insufficient. POP is a minimally invasive procedure involving injection of polymethylmethacrylate (PMMA) into the bone destruction zone and can be used as an analgesic [1–5]. In this retrospective study, we evaluated the safety and efficacy POP to treat pelvic bone metastases in 126 patients with 178 lesions who were treated using POP.

Materials and Methods

Patients

This observational retrospective study reviewed the medical records of patients who had received POP from January 2005 to December 2017. The Institutional Ethics Committee of our hospital approved this study, and informed consent about the potential complications related to POP, including generalized complications (such as bleeding, nerve injury, and wound infection) and specialized complications (such as sensory motor abnormality or abnormal bowel function) according to each procedure, had already been obtained. POP was used to treat 126 patients with pelvic metastatic bone tumors involving 178 lesions. The patients comprised 65 males and 61 females, aged between 23 and 90 years, with a mean age of 57.45 ± 11.46 years. All patients were referred to our institution because of pain or inability to walk that had not responded to conventional treatments, such as opioids, chemotherapy, and radiotherapy.

The inclusion criteria for POP were a history of pain in a dependent position; osteolytic bone destruction occurring in the lesion; local tenderness or rebound tenderness on physical examination; and corresponding radiological images, including computed tomography, magnetic resonance imaging, and bone scans. Patients were eligible for inclusion in the study if they had a life expectancy ≥ 3 months, were ≥ 18 years old, and were willing to sign the consent form. Exclusion criteria were the presence of a non-correctable coagulation disorder (platelets < 90,000/mL, international normalized ratio > 1.50) and systemic infection. Clinical data for the patients are shown in Tables 1 and 2.

Table 1 Location and number of lesions

Lesion site	Ilium	Acetabulum	Ischium	Pubis	Sacrum
Number of lesions	81	70	8	3	16

POP Procedure

Procedures were performed under single-plane fluoroscopic guidance (Innova 3100-IQ, GE Healthcare, Chicago, IL, USA) and biplane fluoroscopic guidance (Innova IGS 630,GE Healthcare). According to the targeted lesion, patients were placed in a prone, supine, or lateral decubitus position to expose the targeted structures.

After aseptic draping, 5 mL of 1% lidocaine was injected, layer-by-layer, into the targeted periosteum using a 5-ccm syringe. In all procedures, a 10-cm 13-gauge bone puncture needle (Cook, Inc., Bloomington, IN, USA) or a 13.8-cm 15-gauge C1616A Bard® TruGuide® Disposable Coaxial Biopsy Needle (Bard Peripheral Vascular Inc. Tempe, AZ, USA) was inserted close to the lesion under imaging guidance. Generally, the principal approaches for the POPs were chosen as the shortest distance to the targeted osteolytic lesion, while preventing nerve or vessel damage.

Mixed radiopaque bone cement (OSTEOPAL®V, Heraeus Medical, Wehrheim, Germany) was injected into the lesion through the bone needle under fluoroscopic guidance. The amount of bone cement was determined by measuring the tumor size, and the appropriate place to inject was determined using computed tomography. After the puncture needle was confirmed in place, it was injected with bone cement. Injection was stopped when substantial resistance was met or when the PMMA cement reached the posterior margin of the bone.

Technical success and complications were recorded for all patients. Technical success was defined as follows: (1) With the cooperation of the patient, the doctor carried out the operation competently and according to institutional and international guidance. (2) Bone cement injection covered $\geq 80\%$ of bone failure areas. (3) There were no serious surgical complications during the intervention, such as paraplegia and pulmonary embolism.

Data Collection

All patients underwent clinical examination by two of the attending physicians (T.W. and F.Y.). Each patient was asked to quantify his or her pain on the visual analog scale (VAS) and Oswestry Disability Index (ODI) before the procedure and 3 days after the procedure. Subsequently, VAS scores and ODI were evaluated at 1, 3, 6, 9, and 12 months after the intervention at follow-up outpatient office visits or by telephone interviews (Table 3). In the VAS, a score of 0 indicated "no pain," and a score of 10 indicated "worst pain ever." The functional status of

Table 2 Primary tumor

Primary tumor	Number	Primary tumor	Number
Lung cancer	50	Parathyroid carcinoma	2
Cancerous goiter	29	Retroperitoneal malignant tumor	1
Mammary cancer	13	Fibroma sarcomatosum	1
Liver cancer	12	Nasopharyngeal darcinoma	1
Prostatic cancer	4	Rectal carcinoma	1
Renal carcinoma	4	Lymphoma	2
Carcinoma of urinary bladder	2	Carcinoma sarcomatodes	1
Carcinoma of colon	2	Soft-tissue sarcoma	1

Table 3 Statistics of postoperative follow-up time

Follow-up time(month)	9	12	13–18	19–24	25–36
Number	33	30	37	22	4

patients for walking, standing, and sleeping was measured using the ODI [6]. The effect of POP was also judged by comparing the dosage changes of painkillers before and after treatment, and the changes in painkiller category. In addition, the success of POP could be judged by following

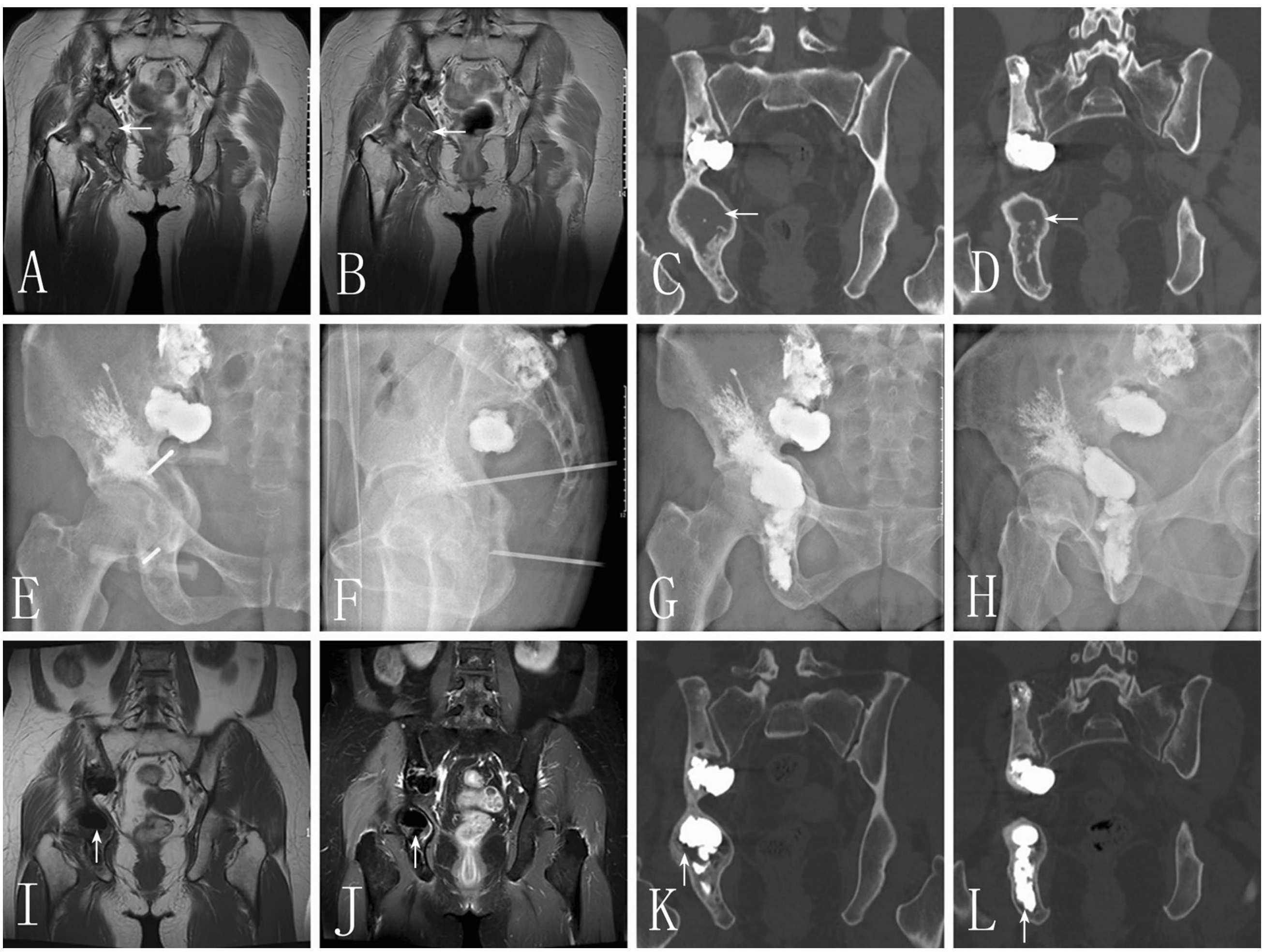

Fig. 1 A case of a 48-year-old female with lung cancer bone metastases, pain in the right hip, and lower right limb for 1 year. Preoperative imaging data: **A**–**D**, coronal T1-weighted (**A**) and coronal post-contrast T1-weighted (**B**) MRI images showing an abnormally low signal (←) in the right acetabulum and right ischium with edge enhancement. Coronal CT (**C**, **D**) images showing bone destruction (←) of the right acetabulum and right ischium. Images of the POP procedure (**E**–**H**) showing that the bone cement (↑) is well filled in the lesion. Six months after the POP procedure, the imaging tests (**I**–**L**) show that the lesion (↑) was well filled with cement and no significant progress was observed in the tumor tissue

up the filling condition of the bone cement and the tumor activity (Fig. 1I–L).

Statistical and Quantitative Assessments

Means and standard deviations were reported for normally distributed continuous variables. The statistical analysis software used was IBM SPSS Statistics 22 (IBM Corp., Armonk, NY, USA). In cases of non-normality, we reported the median and interquartile range (IQR). Independent samples *t*-tests were used to compare the mean differences between groups, and Chi-squared tests were used to assess differences in proportions. *P*-values smaller than 0.05 were considered to indicate statistical significance.

Results

No major complications were encountered during the procedure or over the long term in any of the patients. The amount of injected bone cement was 3–60 mL, with a mean of 13.21 ± 9.50 mL. The bone cement lesion filling effect was assessed as perfect when more than 90% of the bone failure area was filled with bone cement (Fig. 1). Bone cement leakage occurred in 35 patients (27.78%). Leakages were into the surrounding soft tissue ($n = 18$), the peripheral vein ($n = 11$), the joint space ($n = 2$), and the puncture path ($n = 4$).

The mean VAS score and ODI index before treatment were 6.87 ± 1.33 (range 4–10) and 71.73 ± 8.76 (range 62.22–91.11), respectively. At 3 days after treatment, the indices had improved to 3.33 ± 1.94 (range 0–7) and 45.29 ± 18.41 (range 11.11–77.78), respectively ($P < 0.05$). The mean VAS scores and ODI indices improved to 1.89 ± 1.53 (range 0–7) and 31.50 ± 14.56 (range 11.11–73.33) at 3 months, and to 1.87 ± 1.46 (range 0–7) ($P < 0.05$) and 31.53 ± 14.58 (range 11.11–73.33) ($P < 0.05$), respectively, at 6 months. The average follow-up was 14.79 ± 5.59 months (range 9–36 months). Figures 2 and 3 show the changes in the VAS score and ODI index during follow-up.

Among the 126 patients, 118 (93.65%) reported pain relief immediately after the intervention, 7 (5.56%) reported no obvious pain relief, and 1 (0.79%) reported increased pain at 6 months after intervention. The remission rate was 93.65%. Table 4 shows statistical analysis of the changes in ODI index and VAS score before and after intervention. Data on the changes in analgesic use before and after treatment were available at the 3-month follow-up for 126 patients. Administration of narcotic analgesia had been suspended in 53 patients (42.06%), 36 patients (28.57%) reduced their level of painkillers, 29 patients (23.02%) reduced their dose of painkillers, 7 patients (5.56%) reported no change in their painkiller use, and 1 patient (0.79%) increased their dose of narcotic at 6 months after intervention because of general progression of the neoplastic disease.

Discussion

When osteolytic bone and soft-tissue mass destruction occurs in the pelvis, it leads to a reduction or loss of skeletal support in the patient's diseased site, which results in severe pain and affects the quality of life of the patient [7, 8]. Reduced mobility and pain are common symptoms in patients with advanced cancer with bone metastases. Generally, the pain becomes more intense when pathological fractures occur. The aim of treating pelvic bone metastases is to restore the pelvic mechanical properties and reduce the invasion of surrounding tissues. More than 80% of patients do not meet the inclusion criteria for surgical treatment because of their physical condition and tumor stage [9–12]. Systemic chemotherapy and radiotherapy can kill tumor cells and reduce pain, but do not improve bone loss [13, 14]. At the same time, they might induce further bone loss, which increases the risk of fracture [15]; indeed, Prieto-Alhambra's research showed a 2.4-fold increase in the risk of death from fractures [16].

Percutaneous osteoplasty (POP), as a development of percutaneous vertebroplasty, is often carried out under fluoroscopy guidance [17], under which the length and angle of the puncture needle can be observed in real time. The POP procedure provides immediate pain relief and better physical performance results in patients with painful bony metastasis when the patient changes position or moves into a dependent position. The application of POP for bone tumors is based on the following principle: (1) Bone cement can stabilize bones and prevent pathological fractures by strengthening the bone defect [18–20]. (2) POP can induce necrosis of neural tissue by the exothermic polymerization of the cement [21, 22]. (3) Bone cement can also produce a mass effect by blocking the blood circulation, heat effect, and cytotoxicity of the tumor, thus resulting in a tumor-suppressive effect [23, 24].

In our series, 118 (93.65%) patients reported pain relief immediately after the intervention. However, seven (6.35%) patients reported no obvious pain relief, and one (0.79%) patient reported pain increase at 6 months after intervention. Further analysis led us to believe that this was caused by the compression or accumulation of peripheral nerve tissue by the tumor tissue. Improved quality of life is of paramount importance for patients in whom survival might be prolonged, despite the presence of bone metastases. Patients with stage IV cancer often develop painful

Fig. 2 Course of pain in patients treated with POP. Decrease in pain (as evaluated using the VAS) was observed during the follow-up period

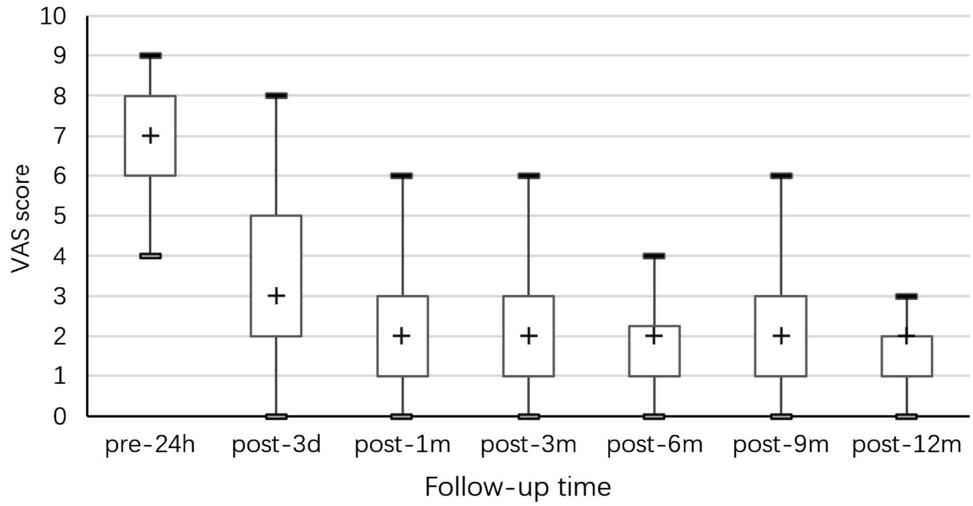

Fig. 3 Changes of ODI during the follow-up period

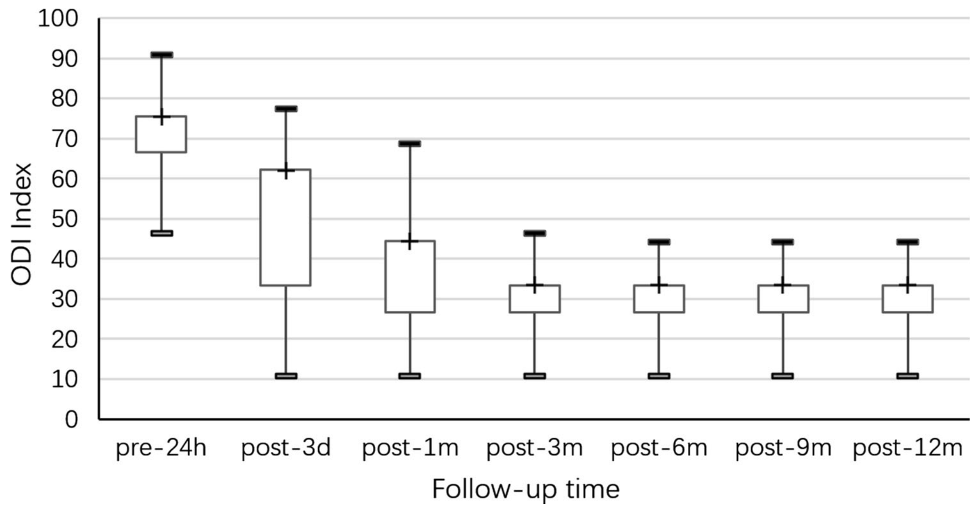

Table 4 Clinical assessment data before and after surgery

	Pre-1 day	Post-3 days	Post-1 month	Post-3 months	Post-6 months	Post-9 months	Post-12 months
ODI	71.73 ± 8.76	45.29 ± 18.41	35.54 ± 15.31	31.50 ± 14.56	31.53 ± 14.58	31.54 ± 14.58	28.84 ± 12.75
VAS	6.87 ± 1.33	3.33 ± 1.94	2.26 ± 1.59	1.89 ± 1.53	1.87 ± 1.46	1.90 ± 1.47	1.49 ± 1.17

*$P < 0.01$ compared with value before treatment at each follow-up point

metastases, which, over time, become more painful, resulting in increased ODI scores. However, in the present study, most patients showed a steady improvement in pain and ODI scores over time. These results might have been affected by the fact that the patients received systemic treatment, such as chemotherapy, and took targeted drugs. This suggested that patients with bone metastasis could achieve successful long-term pain relief with regular systemic therapy in addition to POP.

For the patients with painful osteolytic pelvic bone metastases, we believe that the coverage of bone cement affects the postoperative outcome. In our studies, 100% of the patients achieved 80% of the bone cement coverage, 80% of the patients achieved 90% of the bone cement coverage. We believe that the coverage of bone cement is related to the following two points: (1) selection of puncture channels during operation and (2) bone cement infusion technique.

The pelvis has an irregular shape; therefore, for successful intervention, it is necessary to determine an ideal puncture channel. Surgeons should determine the thickness, shape, and curvature of the metastasized bone, the precise location of the metastasized bone causing the pain, and the vital nervous and vascular network surrounding the pathway of the needle approach. Generally, for acetabular and ischial lesions, treatment occurs using an anteroposterior approach. Ilial lesions are usually approached in a posteroinferior direction along the long axis of the ilium. Preoperative imaging examination is also very important for the choice of surgical puncture path. Computed tomography is the first choice to evaluate the incidence of bone invasion around the lesion. Magnetic resonance imaging can accurately determine the tumor boundary and its invasion of surrounding soft tissue (with 92% sensitivity and 96% specificity), allowing determination of the safe boundary of tumor operation [25, 26].

To strengthen the bone, the cement should fill the defect as much as possible. The injected bone cement can easily break through the bone area and enter into the soft tissue or joint space, resulting in compression of adjacent tissues or limited joint function. During intervention, the operator should adjust the position and orientation of the puncture needle according to the direction and distribution of the bone cement and establish a new puncture channel if necessary [27]. If the bone cement leaks into the surrounding tissue, injection should be stopped immediately.

Burgard et al. [28] performed a retrospective analysis of 14 patients with painful extraspinal osteolysis who underwent CT fluoroscopy-guided osteoplasty and reported a low complication rate and high technical success. In a study of 47 patients with painful bony metastasis treated with POP,Lee et al. [29] reported that pain due to metastatic lesions was reduced significantly immediately after the POPs and the reduction was sustained until the end of their lives. Other studies have yielded similar results [30–33]. These promising outcomes collectively show that POP can be useful for reducing pain and improving quality of life in patients with painful osteolytic pelvic bone metastases.

To the best of our knowledge, the present study is one of the largest studies of POP performed on the pelvis, comprising 126 patients. In the present study, pain relief occurred early and was prolonged. The VAS scores decreased significantly at day 3 after intervention and remained low throughout the follow-up period. The differences between VAS and ODI scores before and after the procedures were significant at all study time points ($P < 0.05$).

This study has some limitations. First, our study was a single-center, retrospective study. Second, the bone metastases treated in our series were heterogeneous and related to various primary neoplasms. However, our results could be used as a basis for the design of future clinical trials.

In conclusion, POP is an effective, safe, and minimally invasive procedure for treatment of painful osteolytic pelvic bone metastases refractory to conservative treatments. It can provide marked reduction in pain and improvement in quality of life. Further research to address the limitations inherent in this study would be valuable.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

Human and Animal Rights All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

References

1. Galibert P, Deramond H, Rosat P, et al. Preliminary note on the treatment of vertebral angioma by percutaneous acrylic vertebroplasty. Neurochirurgie. 1987;33(2):166–8.
2. Tian QH, Wu CG, Gu YF, et al. Combination radiofrequency ablation and percutaneous osteoplasty for palliative treatment of painful extraspinal bone metastasis: a single-center experience. J Vasc Interv Radiol JVIR. 2014;25(7):1094–100.
3. Tian QH, He CJ, Wu CG, et al. Comparison of percutaneous cementoplasty with and without interventional internal fixation for impending malignant pathological fracture of the proximal femur. Cardiovasc Interv Radiol. 2016;39(1):81–9.
4. Sun G, Jin P, Li M, et al. Percutaneous cementoplasty for painful osteolytic humeral metastases: initial experience with an innovative technique. Skelet Radiol. 2011;40(10):1345–8.
5. Onate Miranda M, Moser TP. A practical guide for planning pelvic bone percutaneous interventions (biopsy, tumour ablation and cementoplasty). Insights Into Imaging. 2018;9(3):275–85.
6. Amin RM, Micheal R, Amit J, et al. Risk factors for nonroutine discharge in adult spinal deformity surgery. Spine J. 2018;19(2):357–63.
7. Baek SJ, Hur H, Min BS, et al. The characteristics of bone metastasis in patients with colorectal cancer: a long-term report from a single institution. World J Surg. 2016;40(4):982–6.
8. Rief H, Bischof M, Bruckner T, et al. The stability of osseous metastases of the spine in lung cancer–a retrospective analysis of 338 cases. Radiat Oncol. 2013;8(1):200.
9. Clarencon F, Jean B, Pham HP, et al. Value of percutaneous radiofrequency ablation with or without percutaneous vertebroplasty for pain relief and functional recovery in painful bone metastases. Skelet Radiol. 2013;42(1):25–36.

10. Botton E, Edeline J, Rolland Y, et al. Cementoplasty for painful bone metastases: a series of 42 cases. Med Oncol. 2012;29(2):1378–83.
11. Laitinen MK, Parry MC, Albergo JI, et al. Is computer navigation when used in the surgery of iliosacral pelvic bone tumours safer for the patient? Bone Jt J. 2017;99-B(2):261–6.
12. Puget J, Utheza G. Reconstruction of the iliac bone using the homolateral femur after resection for pelvic tumor. Orthop Traumatol Surg Res. 2014;100(1):43–7.
13. Matcuk GR Jr, Mahanty SR, Skalski MR, et al. Stress fractures: pathophysiology, clinical presentation, imaging features, and treatment options. Emerg Radiol. 2016;23(4):365–75.
14. Chow R, Hoskin P, Hollenberg D, et al. Efficacy of single fraction conventional radiation therapy for painful uncomplicated bone metastases: a systematic review and meta-analysis. Ann Palliat Med. 2017;6(2):125–42.
15. Chan S, Rowbottom L, McDonald R, et al. Pelvic insufficiency fractures in women following radiation treatment: a case series. Ann Palliat Med. 2016;5(3):233–7.
16. Prieto-Alhambra D, Avilés FF, Judge A, et al. Burden of pelvis fracture: a population-based study of incidence, hospitalisation and mortality. Osteoporos Int. 2012;23(12):2797–803.
17. Trumm CG, Pahl A, Helmberger TK, et al. CT fluoroscopy-guided percutaneous vertebroplasty in spinal malignancy: technical results, PMMA leakages, and complications in 202 patients. Skelet Radiol. 2012;41(11):1391–400.
18. Liu XW, Jin P, Liu K, et al. Comparison of percutaneous long bone cementoplasty with or without embedding a cement-filled catheter for painful long bone metastases with impending fracture. Eur Radiol. 2017;27(1):120–7.
19. Clarencon F, Jean B, Pham HP, et al. Value of percutaneous radiofrequency ablation with or without percutaneous vertebroplasty for pain relief and functional recovery in painful bone metastases. Skeletal Radiol. 2013;42(1):25–36.
20. Botton E, Edeline J, Rolland Y, et al. Cementoplasty for painful bone metastases: a series of 42 cases. Med Oncol. 2012;29(2):1378–83.
21. Wei Z, Hui W, Ji-Hong H, et al. Palliative pain relief and safety of percutaneous radiofrequency ablation combined with cement injection for bone metastasis. Jpn J Clin Oncol. 2018;48(8):753–9.
22. Hartung MP, Tutton SM, Hohenwalter EJ, et al. Safety and efficacy of minimally invasive acetabular stabilization for periacetabular metastatic disease with thermal ablation and augmented screw fixation. J Vasc Interv Radiol. 2016;27(5):682–8.
23. Kang HG, Roh YW, Kim HS. The treatment of metastasis to the femoral neck using percutaneous hollow perforated screws with cement augmentation. J Bone Jt Surg Br. 2009;91(8):1078–82.
24. Kim JH, Kang HG, Kim JR, et al. Minimally invasive surgery of humeral metastasis using flexible nails and cement in high-risk patients with advanced cancer. Surg Oncol. 2011;20(1):e32–7.
25. Cho HS, Park IH, Jeon IH, et al. Direct application of MR images to computer-assisted bone tumor surgery. J Orthop Sci. 2011;16(2):190–5.
26. Fayad LM, Jacobs MA, Wang X, et al. Musculoskeletal tumors: how to use anatomic, functional, and metabolic MR techniques. Radiology. 2012;265(2):340–56.
27. Kim YJ, Lee JW, Kim KJ, et al. Percutaneous vertebroplasty for intravertebral cleft: analysis of therapeutic effects and outcome predictors. Skeletal Radiol. 2010;39(8):757–66.
28. Burgard CA, Dinkel J, Strobl F, et al. CT fluoroscopy-guided percutaneous osteoplasty with or without radiofrequency ablation in the treatment of painful extraspinal and spinal bone metastases: technical outcome and complications in 29 patients. Diagn Interv Radiol. 2018;24:158–65.
29. Lee JH, Kim SY, Ok HG, et al. Extraspinal percutaneous osteoplasty for the treatment of painful bony metastasis. J Kor Med Sci. 2018;33:61.
30. Wallace AN, Huang AJ, Vaswani D, et al. Combination acetabular radiofrequency ablation and cementoplasty using a navigational radiofrequency ablation device and ultrahigh viscosity cement: technical note. Skelet Radiol. 2016;45(3):401–5.
31. Guzik G. Cemented reconstruction of acetabular ceiling using the vertebroplasty set in treatment of metastatic lesions. Ortop Traumatol Rehabil. 2014;16(2):129–37.
32. Kim YI, Kang HG, Kim SK, et al. Clinical outcome prediction of percutaneous cementoplasty for metastatic bone tumor using (18)F-FDG PET-CT. Ann Nucl Med. 2013;27(10):916–23.
33. Zhang J, Yang Z, Wang J, et al. Study of treatment using percutaneous acetabuloplasty and interstitial implantation of (125)I seeds for patients with metastatic periacetabular tumors. World J Surg Oncol. 2012;10(1):250.