A review and update of vertebral fractures due to metastatic tumors of various sites to the spine: Percutaneous vertebroplasty

MOHAMAD MANSOORINASAB, HESAM ABDOLHOSEINPOUR

1Department of Neurosurgery, AJA University of Medical Science, Tehran, Iran
2Department of Neurosurgery, Bou Ali Hospital, Tehran Medical Sciences Branch, Islamic Azad University, Tehran, Iran
*Corresponding author: Hesam Abdolhoseinpour; Department of Neurosurgery, Bou Ali Hospital, Tehran Medical Sciences Branch, Islamic Azad University, Tehran 1711734365, Iran; Phone: +98 91 2630 6851; Fax: +98 91 3311 734365; E-mail: Abdolhoseinpour@yahoo.com

(Received: October 10, 2017; Revised manuscript received: December 24, 2017; Accepted: January 12, 2018)

Abstract: Background: Vertebral fractures (VFs) are the most usual convolution of metastatic tumors and the vertebral column is the third most ordinary site for painful bone metastases and remains a chief factor of morbidity in cancer patients. Methods: In this paper, we investigated the previous literature on the status of clinical and prospects for the use of percutaneous vertebroplasty (PVP) with polymethylmethacrylate as a remedial alternative for the therapy of refractory pain resulting from malignant vertebral compression and pathologic fractures associated with metastatic tumors of various sites in numerous studies. The scientific document for this remedy, containing safety, immediate and long-term efficacy, and outcome measures, and also the risks of complications, was analyzed in detail. Results: PVP is a safe, feasible, reliable, effective, and useful procedure, a minimally invasive treatment, and a significant tool for reduction of pain and the relief of pain symptoms. Conclusions: This method can be employed as a further or narcotic remedy in elected patients. The techniques of PVP present a novel alternative therapy for diverse metastases with potentially large application.

Keywords: vertebroplasty, tumor, treatment, fracture, spine

Introduction

Based on published articles in scientific literature, the vertebral column is the third most ordinary site for painful bone metastases and remains a chief factor of morbidity in cancer patients, with a prevalence of 30%–70% of metastatic tumors [1–4]. These metastases occur in 65%–75% of patients with various tumors of the breast and prostate, 30%–65% of patients with pulmonary cancer, 47% of patients with advanced thyroid cancer, and 30% of patients with renal cell carcinoma of kidney as well as studies have showed that 9%–29% of patients with metastases will have a pathological fracture and 90% of fractures need surgery. Furthermore, in non-small cell lung cancer patients, approximately 70% of patients with bone metastases have bone pain [5–8]. Based on those descriptions, Jensen in his study has found the high outbreak of skeletal metastasis due to breast cancer of Denmark’s population and it occurred in 47.6% of patients with breast neoplasms. Cancer lesions still more generally happen in the thoracic or lumbar regions [9].

The remedy procedures of the vertebral column metastasis are obscure, complex, and challenging, and need to be systemic and local treatments with a multidisciplinary or integrated care approach; moreover, these treatment strategies include surgery methods, radiotherapy, and sedative therapy [10–15].

To dominate the issues, a minimally invasive method, only a little research shows the long-term consequence of PVP in the treatment of metastatic damages of different tumors in the spine, and it has been expanded as an interventional technique to treat spinal osteolytic destruction, multiple myeloma, and painful vertebral compression fractures of vertebral bodies due to malignancy of different tumors, such as breast, prostate, etc. or osteoporosis. Although it has confined
anticancer effect, PVP is considered as an impressive method for achieving fast pain control and preventing most spinal cord compression and vertebral collapse in patients with vertebral metastasis and also, PVP with polymethylmethacrylate (PMMA) (Fig. 1) is the administration of a vertebral body with bone cement [14, 16–30].

The aim of this article review is an update on new methods to determine the influence and the long-term consequence of PVP in the treatment of painful vertebral fractures (VFs) in metastatic patients of multifarious cancer of various sites on spine.

Methods

We performed search results using PubMed, Scopus, Google Scholar, Medline, EMBASE, and certain specialty databases, and we examined the recent literature on the clinical status and prospects for the use of PVP with PMMA as a therapeutic alternative for the remedy of refractory pain resulting from malignant vertebral compression and pathologic fractures associated with metastatic tumors of various sites in numerous studies.

Results and Discussion

Evaluation of the safety and efficacy of the therapy and complications

In a study on assessment of PVP method by Lim et al. [14], the 185 vertebral bodies of 102 patients during 6 years, which were composed of 81% patients with metastatic spine tumors and 19% with multiple myeloma, reported that VP could be a safe or secure and efficient method as a sedative treatment of the spinal tumor patients and pathological VFs due to these cancers. In parallel, in agreement with this finding, several series of the studies have found this as an effective and safety procedure in providing pain palliation [31–41]. In the literature of most studies, it has been revealed that there is a decrease in pain after VP, with the progress in pain ranging from 20% to 79% in 1 month [18, 19, 42, 43].

Another study with a period of over a 1-year follow-up by Blasco et al. [44] suggested that VP is associated with a remarkable improvement in pain and quality of life in patients with painful osteoporotic VFs and it could be achieved to a quicker pain alleviation at the 2-month follow-up, but it was associated with a higher prevalence...
in vertebral defects. In contrast with these findings, some studies raised concern about the possible effect of VP on increasing the risk of new VFs after the procedure, particularly in the vertebrae located adjacent to the cemented vertebral body [45–48]. In addition, Hao and Hu [49] performed VP on 72 patients for vertebral hemangiomas, there was one major complication of vertebroplasty that involved bone cement leakage into the spinal canal and intervertebral foramen, compressing the left nerve root and causing leg numbness. The indications and limitations of the different forms of remedy have been addressed in multifarious researches. Moreover, the reported complication rate in PVP ranged from 0% to 10% depends on the initial indications of PVP: 2%–5% in patients with vertebral angiomas; 1%–3% with osteoporotic lesions; and 10% with spinal malignant tumors [50–53]. Minor complications commonly associated with local trauma. The approximately usual complication being pain away the infusion location, which generally subsides after 48–72 h; this may be composed with hemorrhage from the puncture place, which is further usual if several vertebral levels are being targeted or if many vascular lesions are being acted such as metastases from thyroid or renal cell carcinoma. Other complications associated with local trauma contain rib fractures and fracture of the posterior vertebral elements, which occur in <1% of cases and remaining cases are infection and allergic reaction to the cement, which can cause cardiovascular instability [50]. Permeation into the epidural space and neural foramina with resultant cord compression and radicular pain is the most feared complication associated with PVP augmentation of cement extravasation.

Wang et al. [54] have conducted a study on a large group of patients with metastatic lung cancer to spinal, the majority of treated lesions with VP method were located in the thoracic with 134 lesions or lumbar with 119 lesion areas and their results showed a pain intensity reduction of at least 50%, as well as Botton et al. [55] conducted a similar research on 42 patients and they also defined treatment efficacy as good (57%, 24/42). Furthermore, Qian et al. [56] reported that the first administration of PVP will allow continuous pain relief and spine stabilization and prevent further compression fracture due to metastasis. Another study by Zuo Zhang et al. [57] revealed that pain was relieved after PVP. A number of researches have shown the influence of VP in adjusting pathological spinal fractures [14, 58–60]. On the other hand, Cho et al. [61] suggested that VP could be served for short-term rein of localized pain; however, the number of patients was very little to acknowledge the inference. It is hard to assess the superiority of the therapy modalities; hence, a usual guideline for the recognition and remedy of metastatic pathological fractures of the spine is needed. Multiple studies found that VP provides prompt strengthening of the anterior column, which may limit painful VF [62–65]. Seo et al. [66] at a report on a 51-year-old woman with breast cancer for compression fracture in the C7 vertebra suggested PVP procedure as an anterolateral approach for treating metastatic osteolytic vertebral lesions in the cervical spine for alleviating intractable axial neck pain.

Cortet et al. [67] conducted VP in 37 patients, 29 with osteolytic metastases, and 8 with several myelomas and indicated in 97% of their 37 patients with cancers above a reduction of pain within 48 h of VP and complete absence of pain was in 13.5%, significantly decreased in 55%, and moderately decreased in 30%. Useful impacts were found in 3 months with 89% and next 6 months with 75%. Their complication rate was 2%–3%. In addition, Fournel et al. [18] reported a complete pain palliation of 65 patients undergoing VP on the treatment of cancer lesions. Cotten et al. [20] utilized PVP for metastases and reported that pain relief can occur despite insufficient lesion filling. Barr et al. [51] documented that the PVP involved noteworthy pain relief on osteoporotic fractures with great percentage of patients. In addition, Farrokhi et al. [60] proposed that VP seems to be significantly effective in pain sedation in metastatic spinal tumors. Cheung et al. [58] reported that PVP in metastatic fractures are notable. Weil et al. [68] with study on 37 patients who underwent 52 VP procedures for spinal metastases have demonstrated that VP as a minimally invasive procedure can provide immediate and long-term pain relief of metastases, contribute to spinal stabilization, and reduced many patients’ back pain, and altogether, they achieved a final result that showed 73% of 33 patients have pain relief and according to this finding, VP was a safe procedure with no serious complications. Sun et al. [69] found that PMMA was leakage in 64% treated vertebrae as well as another study by Anselmetti et al. [70] indicated that employment of high PMMA during routine PVP is safe and practical and can remarkably reduce venous cement leakage without any substantial modifications in the VP technique. Saliou et al. [71] reported that PVP can relieve pain related to movement of weighted vertebrae and all complications associated with it by VP method are inactive, such as acute phase of infection, hemorrhagic diathesis, and severe cardiac disease. In a recent literature, PVP indicated complete or partial pain relief in 73%–100% on spinal metastases-treated patients [18, 20, 21, 68, 72–75].

A report on osteoblastic and mixed spinal metastases by Calmes et al. [21] concluded rate of 92% at 6 months VP as an analgesic efficacy and a complication rate of 12% in a series of 52 patients, and also Gu et al. [76] reported 88.6% pain relief or pain progress during follow-up with spinal metastatic tumor and/or malignant vertebral compression fractures. A study on 31 patients with metastatic spinal tumors and malignant vertebral compression fractures by Gu et al. [77] proposed that VP is safe, effective, and minimally invasive palliative therapies for reducing
pain and improving function in patients and in summary, they expressed that pain is reduced in six cases and unimproved in two cases, yielding a pain relief rate of 94%, and in study else on malignant vertebral compression fractures by Su et al. [78] reported that PVP is a safe and effective procedure, capable of providing significantly greater pain relief and vertebral stability in patients, and they achieved notable pain relief in 94% of their patients after treatment with PVP, which is at the higher end of the range of 73%-100% reported with other treatment modalities [1, 68, 73, 79].

This study had no any limitations.

Conclusions

In summary, our results suggest that PVP is a safe, feasible, reliable, effective, and useful procedure, a minimally invasive treatment, and a significant tool for reduction of pain and the relief of pain symptoms. This method can be used as an additional or palliative therapy in selected patients. The techniques of PVP present a novel alternative remedy for various metastases with potentially wide application.

Funding sources: The authors state that there were no external financing sources.

Authors’ contribution: MM and HA participated in conceiving and designing the study, and participated in drafting the manuscript, statistical analyses, administrative, technical, and material support. All authors read and approved the final manuscript.

Conflict of interest: None.

References

1. Shimony JS, Gilula LA, Zeller AJ, Brown DB: Percutaneous vertebroplasty for malignant compression fractures with epidural involvement. Radiology 232, 846–853 (2004)

2. Bates T: A review of local radiotherapy in the treatment of bone metastases and cord compression. Int J Radiat Oncol Biol Phys 23, 217–221 (1992)

3. Schachar NS: An update on the nonoperative treatment of patients with metastatic bone disease. Clin Orthop Relat Res 382, 75–81 (2001)

4. Jandaghi SH, Abdolhoseinpour H, Ghofraniha A, Tofighirad N, Doghmehchi E, Goodarznejad H: A limb-saving procedure for treatment of arterial cement embolism during lumbar percutaneous vertebroplasty: A case report. J Tehran Heart Cent 8, 61–64 (2013)

5. Coleman RE: Metastatic bone disease: Clinical features, pathophysiology and treatment strategies. Cancer Treat Rev 27, 165–176 (2001)

6. Kosteva J, Langer C (2003): Skeletal metastases of non-small cell lung cancer: Advances in diagnosis and treatment. In: Lung Cancer Principles and Practices, ed Carbone D, Lippincott Williams & Williams, Philadelphia, PA, pp. 1–14

7. Kanis JA: Bone and cancer: Pathophysiology and treatment of metastases. Bone 17, 1015–1055 (1995)

8. Varadhanachary GR, Abbruzzese JL, Lenzi R: Diagnostic strategies for unknown primary cancer. Cancer 100, 1776–1785 (2004)

9. Jensen A: Incidence of bone metastases and skeletal-related events in breast cancer patients: A population based cohort study in Denmark. BMC Cancer 11, 29 (2011)

10. Savage P, Sharkey R, Kaa T: Malignant spinal cord compression: NICE guidance, improvements and challenges. QJM 107, 277–282 (2014)

11. L’esperance S, Vincent F, Gaudreault M: Treatment of metastatic spinal cord compression: Cepo review and clinical recommendations. Curr Oncol 19, e478–e490 (2012)

12. Ha KY, Min CK, Seo JY: Bone cements augmentation procedures for spinal pathologic fractures by multiple myeloma. J Korean Med Sci 30, 88–94 (2015)

13. Schuster JM, Grady MS: Medical management and adjuvant therapies in metastatic spinal disease. Neurosurg Focus 11, e3 (2001)

14. Lim BS, Chang UK, Youn SM: Clinical outcomes after percutaneous vertebroplasty for pathologic compression fractures in osteolytic metastatic spinal disease. J Korean Neurosurg Soc 45, 369–374 (2009)

15. Chong S, Shin SH, Yoo H: Single-stage posterior decompression and stabilization for metastasis of the thoracic spine: Prognostic factors for functional outcome and patients’ survival. Spine J 12, 1083–1092 (2012)

16. Burton AW, Mendel E: Vertebroplasty and kyphoplasty. Pain Physician 6, 335–343 (2003)

17. Burton AW, Reddy SK, Shah HN, Tremont-Lukas I, Mendel E: Percutaneous vertebroplasty, a technique to treat refractory spinal pain in the setting of advanced metastatic cancer: A case series. J Pain Symptom Manage 30, 87–95 (2005)

18. Fourney DR, Schomer DF, Nader R, Chlan-Fourney J, Suki D, Ahraz K, Rhines LD, Gokaslan ZL: Percutaneous vertebroplasty and kyphoplasty for painful vertebral body fractures in cancer patients. J Neurosurg 98, 21–30 (2003)

19. Masala S, Anselmetti GC, Marcia S, Massari F, Manca A, Simonetti G: Percutaneous vertebroplasty in multiple myeloma vertebral involvement. J Spinal Disord Tech 21, 344–348 (2008)

20. Cotten A, Dewatre F, Cortet B, Assaker R, Leblond D, Duquesnoy B, Chastanet P, Clarisse J: Percutaneous vertebroplasty for osteolytic metastases and myeloma: Effects of the percentage of lesion filling and the leakage of methylmethacrylate at clinical follow-up. Radiology 200, 525–530 (1996)

21. Caltells M, Valléc JN, Rose M, Chiras J: Osteoblastic and mixed spinal metastases: Evaluation of the analgesic efficacy of percutaneous vertebroplasty. AJNR Am J Neuroradiol 28, 570–574 (2007)

22. Barragán-Campos HM, Vallée JN, Lo D, Cormier E, Jean B, Rose M, Astagneau P, Chiras J: Percutaneous vertebroplasty for spinal metastases: Complications. Radiology 238, 354–362 (2006)

23. Bhatt AD, Schuler JC, Beakye M, Woo SY: Current and emerging concepts in non-invasive and minimally invasive management of spine metastasis. Cancer Treat Rev 39, 142–152 (2013)

24. Dalbayrak S, Onen MR, Yilmaz M, Naderi S: Clinical and radiographic results of balloon kyphoplasty for treatment of vertebral body metastases and multiple myelomas. J Clin Neurosci 17, 219–224 (2010)

25. Wu F, Jamali M, Hatami N, Sonni I, Baratto L, Guo HH: 99mTc-MDP scintigraphy vs. 18F-NaF PET/CT for detection of skeletal metastases. J Nucl Med 57, 599 (2016)

26. Chi JH, Gokaslan ZL: Vertebroplasty and kyphoplasty for spinal pathologic fractures by multiple myeloma. J Korean Med Sci 29, 880–853 (2014)

27. Chen KY, Ma HI, Chiang YH: Percutaneous vertebral compression fractures by multiple myeloma. J Nucl Med 57, 181 (2016)
30. Sonni I, Minamimoto R, Loening A, Jamali M, Hatami N, Baratto L, Wu F: Imaging patients with breast and prostate cancers using combined 18F NaF/18F FDG and TOF simultaneous PET/MRI. J Nucl Med 57, 1410 (2016)

31. Ansemet CC, Corrao G, Monica PD, Tartaglia V, Manca A, Eminenfidec H, Russo F, Tosseti I, Regge D: Pain relief following percutaneous vertebroplasty: Results of a series of 283 consecutive patients treated in a single institution. Cardiovasc Intervent Radiol 30, 441–447 (2007)

32. Evans AJ, Jensen ME, Kip KE, DeNardo AJ, Lawler GJ, Negin GA, Remley KB, Boutin SM, Dunngan SA: Vertebral compression fractures: Pain reduction and improvement in functional mobility after percutaneous polymethylmethacrylate vertebroplasty retrospective report of 245 cases. Radiology 226, 366–372 (2003)

33. Alvarez I, Alcaraz M, Pérez-Higuera A, Granizo JJ, de Miguel I, Pérez-Higueras A, Alvarez L, Rossi RE, Quiñones D: Percutaneous vertebroplasty: Functional improvement in patients with osteoporotic compression fractures. Spine (Phila Pa 1976) 31, 1113–1118 (2006)

34. Pérez-Higuera A, Alvarez I, Rossi RE, Quinones D, Al-Assir I: Percutaneous vertebroplasty: Long-term clinical and radiological outcome. Neuroradiology 44, 950–954 (2002)

35. Eck JC, Nachtrigall D, Humphreys SC, Hodges SD: Comparison of vertebroplasty and balloon kyphoplasty for treatment of vertebral compression fractures: A meta-analysis of the literature. Spine J 8, 488–497 (2008)

36. Hulme PA, Krebs J, Ferguson SJ, Berlemann U: Vertebroplasty and kyphoplasty: A systematic review of 69 clinical studies. Spine (Phila Pa 1976) 31, 1983–2001 (2006)

37. Zoański GH, Snow P, Olan WJ, Stallmeyer MJ, Dick BW, Hebel JR, De Deyne M: Percutaneous vertebroplasty for osteoporotic compression fractures: Quantitative prospective evaluation of long-term outcomes. J Vasc Interv Radiol 13, 139–148 (2002)

38. McGraw JK, Lippert JA, Minkus KD, Rami PM, Davis TM, Budzik RF: Prospective evaluation of pain relief in 100 patients undergoing percutaneous vertebroplasty: Results and follow-up. J Vasc Interv Radiol 13, 883–886 (2002)

39. Legroux-Gerot I, Lormeau C, Boutry N, Cotten A, Duquesnoy B, Cortet B: Long-term follow-up of vertebral osteoporotic fractures treated by percutaneous vertebroplasty. Clin Rheumatol 23, 310–317 (2004)

40. Voormolen MH, Lohle PN, Lammann LE, van den Wildenberg W, Juttman JR, Dirkerhof CH, de Waal Malefijt J: Prospective clinical follow-up after percutaneous vertebroplasty in patients with painful osteoporotic vertebral compression fractures. J Vasc Interv Radiol 17, 1313–1320 (2006)

41. Diamond TH, Bryant C, Browne L, Clark WA: Clinical outcomes after acute osteoporotic vertebral fractures: A 2-year non-randomised trial comparing percutaneous vertebroplasty with conservative therapy. Med J Aust 184, 113–117 (2006)

42. Pflugmacher R, Beth P, Schroeder RJ, Schaser KD, Melcher I: Balloon kyphoplasty for the treatment of pathological fractures in the thoracic and lumbar spine caused by metastasis: One-year follow-up. Acta Radiol 48, 89–95 (2007)

43. Kose KC, Cicebesoy O, Akcan B, Altinel L, Dincer D, Yazar T: Functional results of vertebral augmentation techniques in pathological vertebral fractures of myelomatous patients. J Natl Med Assoc 98, 1654–1658 (2006)

44. Blasco J, Martinez-Ferrer A, Macho J, San Roman L, Pomés J, Carrasco J, Monegal A, Guiañabens N, Peris P: Effect of vertebroplasty on pain relief, quality of life, and the incidence of new vertebral fractures: A 12-month randomized follow-up, controlled trial. J Bone Miner Res 27, 1159–1166 (2012)

45. Kim SH, Kang HS, Choi JA, Ahn JM: Risk factors of new compression fractures in adjacent vertebrae after percutaneous vertebroplasty. Acta Radiol 45, 440–445 (2004)

46. Uppin AA, Hirsch JA, Centenera LV, Pfeifer BA, Pazianos AG, Chois IS: Occurrence of new vertebral body fracture after percutaneous vertebroplasty in patients with osteoporosis. Radiology 226, 119–124 (2003)

47. Lin EP, Ehkolm S, Hiwatashi A, Westerlind PL: Vertebroplasty: Cement leakage into the disc increases the risk of new fracture of adjacent vertebral body. AJNR Am J Neuroradiol 25, 175–180 (2004)

48. Lin WC, Cheng TT, Lee YC, Wang TN, Cheng YF, Liu CC, Yu CY: New vertebral osteoporotic compression fractures after percutaneous vertebroplasty: Retrospective analysis of risk factors. J Vasc Interv Radiol 19, 225–231 (2008)

49. Hao J, Hu Z: Percutaneous cement vertebroplasty in the treatment of symptomatic vertebral hemangiomas. Pain Physician 15, 43–49 (2012)

50. Deramond H, Depriester C, Galibert P, Le-Gars D: Percutaneous vertebroplasty with polymethylmethacrylate. Technique, indications, and results. Radiol Clin North Am 36, 533–546 (1998)

51. Barr JD, Barr MS, Lemley TJ, McCann RM: Percutaneous vertebroplasty for pain relief and spinal stabilization. Spine (Phila Pa 1976) 25, 923–928 (2000)

52. Barragan-Campos HM, Vallerie JN, Lo D, Cormier E, Jean B, Rose M, Astagneau P, Chiras J: Percutaneous vertebroplasty for spinal metastases: Complications. Radiology 238, 354–362 (2002)

53. Martin J, Jean B, Sugiu K, San Millán Ruiz D, Proin T, Murphy K, Rüfenacht B, Muster M, Rüfenacht DA: Vertebroplasty: Clinical experience and follow-up results. Bone 25, 115–155 (1999)

54. Wang Z, Zhen Y, Wu C, Li H, Yang Y, Shen Z: CT fluoroscopy-guided percutaneous osteoplasty for the treatment of osteolytic lung cancer bone metastases to the spine and pelvis. J Vasc Interv Radiol 23, 1135–1142 (2012)

55. Bottone E, Edelene J, Rolland Y, Vauleon E, Le Roux C, Mesbah H: Cementoplasty for painful bone metastases: A series of 42 cases. Med Oncol 29, 1378–1383 (2012)

56. Qian Z, Sun Z, Yang H, Gu Y, Chen K, Wu G: Kyphoplasty for the treatment of malignant vertebral compression fractures caused by metastases. J Clin Neurosci 18, 763–767 (2011)

57. Xu Zhiyang Z, Lin X, Honggu S, Yunichao H, Xiang M, Tao Y, Jinke Z, RuiLan Z: A patient with lung cancer metastatic to the fifth thoracic vertebra and spinal cord compression treated with percutaneous vertebroplasty and 1-125 seed implantation. Diagn Interv Radiol 17, 384–387 (2011)

58. Cheung G, Chow E, Holden L, Vidmar M, Danjoux C, Yee AJ, Connolly R, Finkelstein J: Percutaneous vertebroplasty in patients with intractable pain from osteoporotic or metastatic fractures: A prospective study using quality-of-life assessment. Can Assoc Radiol J 57, 13–21 (2006)

59. McDonald RJ, Trout AT, Gray LA, Dispensieri A, Thielan KR, Kalimms DF: Vertebroplasty in multiple myeloma: Outcomes in a large patient series. AJNR Am J Neuroradiol 29, 642–648 (2008)

60. Farrokhz H, Nouraei H, Kian A: The efficacy of percutaneous vertebroplasty in pain relief in patients with pathological vertebral fractures due to metastatic spinal tumors. Iran Red Crescent Med J 14, 523–530 (2012)

61. Cho JH, Ha JK, Hwang CJ, Lee DH, Lee CS: Patterns of treatment for metastatic pathological fractures of the spine: The efficacy of each treatment modality. Clin Orthop Surg 7, 476–482 (2015)

62. Gilbert HA, Kagan AR, Nussbaum H, Rao AR, Satzman J, Chan P: Evaluation of radiation therapy for bone metastases: Pain relief and quality of life. AJR Am J Roentgenol 129, 1095–1096 (1977)

63. Janjan NA: Radiation for bone metastases: Conventional techniques and the role of systemic radiopharmaceuticals. Cancer 80, 1628–1645 (1997)

64. Pilitsis JG, Rengachary SS: The role of vertebroplasty in metastatic spinal disease. Neurosurget Focus 11, e9 (2001)
65. Shepherd S: Radiotherapy and the management of metastatic bone pain. Clin Radiol 39, 547–550 (1988)
66. Seo SS, Lee DH, Kim HJ, Yoon JW, Kwon OS, Kim KH: Percutaneous vertebroplasty at C7 for the treatment of painful metastases – A case report. Korean J Anesthesiol 64, 276–279 (2013)
67. Cortet B, Cotten A, Boutry N: Percutaneous vertebroplasty in patients with osteolytic metastases or multiple myeloma. Rev Rhum Engl Ed 64, 177–183 (1997)
68. Weill A, Chiras J, Simon JM: Spinal metastases: Indications for and results of percutaneous injection of acrylic surgical cement. Radiology 199, 241–247 (1996)
69. Sun G, Jin P, Li M, Lu Y, Liu X, Li F, Xie Z, Ding J, Peng Z: Percutaneous vertebroplasty for pain management in spinal metastasis with epidural involvement. Technol Cancer Res Treat 10, 267–274 (2011)
70. Anselmetti GC, Zoarski G, Manca A, Masala S, Eminefendic H, Russo F, Regge D: Percutaneous vertebroplasty and bone cement leakage: Clinical experience with a new high-viscosity bone cement and delivery system for vertebral augmentation in benign and malignant compression fractures. Cardiovasc Intervent Radiol 31, 937–947 (2008)
71. Saliou G, Kochieda el M, Lehmann P: Percutaneous vertebroplasty for pain management in malignant fractures of the spine with epidural involvement. Radiology 254, 882–890 (2010)
72. Chen KY, Ma HI, Chiang YH: Percutaneous transpedicular vertebroplasty with polymethyl methacrylate for pathological fracture of the spine. J Clin Neurosci 16, 1300–1304 (2009)
73. Martin JB, Wetzel SG, Scium Y: Percutaneous vertebroplasty in metastatic disease: Transpedicular access and treatment of lyed pedicles – Initial experience. Radiology 229, 593–597 (2003)
74. Shimony JS, Gilula LA, Zeller AJ, Brown DB: Percutaneous vertebroplasty for malignant compression fractures with epidural involvement. Radiology 232, 846–853 (2004)
75. Alvarez L, Alcaraz M, Pérez-Higuera A: Percutaneous vertebroplasty: Functional improvement in patients with osteoporotic compression fractures. Spine (Phila Pa 1976) 31, 1113–1118 (2006)
76. Gu YF, Tian QH, Li YD, Wu CG, Su Y, Song HM: Percutaneous vertebroplasty and interventional tumor removal for malignant vertebral compression fractures and/or spinal metastatic tumor with epidural involvement: A prospective pilot study. J Pain Res 10, 211–218 (2017)
77. Gu YF, Li YD, Wu CG, Sun ZK, He CJ: Safety and efficacy of percutaneous vertebroplasty and interventional tumor removal for metastatic spinal tumors and malignant vertebral compression fractures. AJR Am J Roentgenol 202, W298–W305 (2014)
78. Su Y, Sun ZZ, Shen LX, Ding J, Xu ZY, Chai YM, Song WQ, Chen D, Wu CG: Comparison of percutaneous vertebroplasty with and without interventional tumor removal for spinal metastatic tumor without epidural involvement. J Bone Oncol 6, 1–7 (2016)
79. Tian QH, He CJ, Wu CG: Comparison of percutaneous cementoplasty with and without interventional internal fixation for impending malignant pathological fracture of the proximal femur. Cardiovasc Intervent Radiol 39, 81–89 (2016)