



Flexible Nail Capable of Bone Cement Injection for Minimally Invasive Surgery of Metastatic Bone Cancer

Hyun-Guy Kang^{1*}, Yong-Il Kim², June Hyuk Kim¹, Jong Woong Park¹, Patrick P Lin⁴ and Han Soo Kim³

¹Department of Orthopaedic Oncology Clinic, National Cancer Center, Gyeonggi-do 10408, Korea

²Department of Nuclear Medicine, CHA Bundang Medical Center, CHA University, Seongnam, Korea

³Department of Orthopaedic Oncology, The University of Texas MD Anderson Cancer Center, Houston, TX, USA

⁴Department of Orthopaedic Surgery, Seoul National University College of Medicine, Seoul 04750, Korea

Abstract

Purpose: Surgical treatment for metastatic bone cancer is often performed using a minimally invasive technique considering the patient's general health condition. Intramedullary nailing has been widely used for long bone metastases in limbs. However, intramedullary nailing may progress to bone destruction postoperatively due to intramedullary spreading of the tumor during the surgery.

Methods: We developed a titanium hollow flexible nail with multiple side holes in the tip to prevent this situation. This new implant is capable of injecting drug or bone cement while inserting a percutaneous nail. When the nail tip is located in the metastatic cancer lesion, the bone cement injection is started and continued until the nail is seating completely.

Results: The mean operative time from skin incision to closure was 42 min (range, 36 min to 52 min). The mean length of the injection nail was 23.0 cm (range, 18.0 cm to 33.0 cm), and mean volume of cement used was 28.0 ml (range, 14.0 ml to 40.0 ml). Marked pain palliation was verified 1 week postoperatively and had improved after 6 weeks ($P=0.001$). The mean MSTS functional score improved significantly from 12.5 (41.7%) at 6 weeks preoperatively to 24.9 (83.0%) postoperatively. No thromboembolism or cement embolism was encountered. No multi-holed injection nails breakage and no further intramedullary osteolysis of operative bone was observed.

Conclusions: This minimally invasive surgical method with a multi-holed injection nail could be useful for earlier stabilization of long bone metastases in patients with advanced cancer.

Keywords: Multi-holed injection nail; Bone cement; Minimally invasive surgery; Bone metastasis

Abbreviations

MIN: Multihole Injection Nail; MSTS: Musculoskeletal Tumor Society; PMMA: Poly(Methyl Methacrylate); VAS: Visual Analogue Scale

Introduction

Patients with multiple bone metastases suffer from severe pain and low quality of life. Various methods, such as analgesics, chemotherapy, radiation therapy, radiopharmaceutical agents, and surgery, have been developed for palliative pain improvement [1,2]. These patients generally require structurally augmenting surgery of the vertebra, pelvis, femoral neck, or long bones of the limbs. Surgical techniques for bone metastasis include curettage and internal fixation, open or close interlocking intramedullary nailing, and prosthesis or allograft reconstruction [3]. Up to now, intramedullary nailing has been the most accepted fixation method for femoral and tibial bone metastasis because of ease of insertion and load-sharing properties [4].

Fixation of a bone metastasis remains controversial, particularly in patients with multiple organ failure and short life expectancy due to advanced cancer. Minimally invasive surgery with advantages of a small incisional scar, minimal blood loss, and short operative time has become available for high risk patients. Other palliative surgical techniques that do not involve tissue dissection include cementoplasty, ethanol injection, cryoablation, and radiofrequency ablation [5]. Among them, percutaneous poly(methyl methacrylate) (PMMA) cementoplasty produces favorable

OPEN ACCESS

*Correspondence:

Hyun-Guy Kang, Department of Orthopaedic Oncology Clinic, National Cancer Center, 323 Ilsan-ro, Ilsandong-gu, Goyang-si, Gyeonggi-do 10408, Korea, Tel: +82-31-920-1665; Fax: +82-31-929-2798;

E-mail: ostumor@ncc.re.kr

Received Date: 04 May 2016

Accepted Date: 13 Oct 2017

Published Date: 20 Oct 2017

Citation:

Kang H-G, Kim Y-I, Kim JH, Park JW, Lin PP, Kim HS. Flexible Nail Capable of Bone Cement Injection for Minimally Invasive Surgery of Metastatic Bone Cancer. *Surg Oncol Clin Pract J*. 2017; 2(1): 1006.

Copyright © 2017 Hyun-Guy Kang.

This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

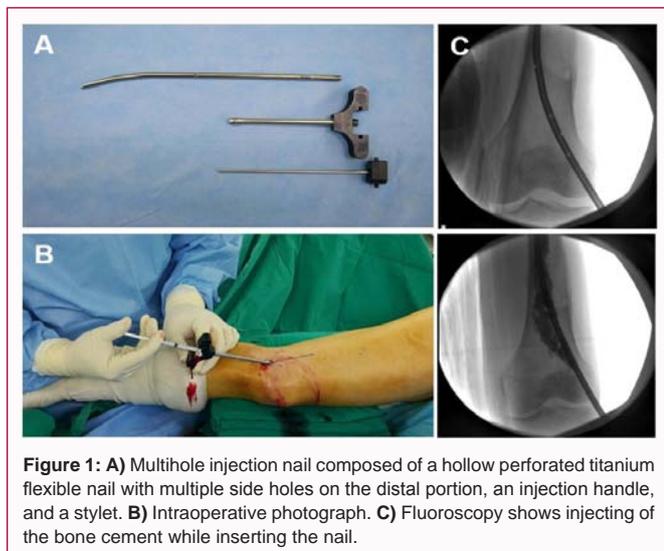


Figure 1: A) Multihole injection nail composed of a hollow perforated titanium flexible nail with multiple side holes on the distal portion, an injection handle, and a stylet. B) Intraoperative photograph. C) Fluoroscopy shows injecting of the bone cement while inserting the nail.

outcomes for patients with spinal tumors and those in flat bone locations, such as the pelvis, scapula, and sternum [6,7]. However, the risk of a pathological fracture remains high when percutaneous cementoplasty is performed in a long bone without metal fixation [8,9]. The hollow-perforated screw is a new device for a femoral neck metastasis to achieve fixation, followed by injecting PMMA into the weak bone area simultaneously through multiple side holes [10].

Percutaneous flexible Ender nail fixation and intramedullary PMMA injection was introduced for diaphyseal metastasis of the humerus, femur, and tibia [11]. In this method, the cement injection needles are placed into the intramedullary area through new portals in the skin and bone [12]. The new implant is a titanium flexible nail that has hollow perforations and multiple side holes on the distal portion (multi-hole injection system (screw & nail), Solco Biomedical, Seoul, Korea). This implant can be used to inject bone cement through the nail during the course of percutaneous fixation without making additional side skin and bony holes for cement needles. Here we report the preliminary results of this surgical technique.

Materials and Methods

Patient characteristics

Nine patients (three men and six women; mean age, 57.9 years; range, 46.0 to 72.0 years; mean body mass index (BMI), 22.1 kg/m²; range, 17.0 kg/m² to 28.1 kg/m²; Mirels' grade, 8-11; grade 8=1, grade 10=2, and grade 11=6 patients) underwent multi-hole injection nail (MIN) fixation with simultaneous bone cement injection when their advanced cancer had progressed. The primary cancers were lung in five patients and breast in four patients. All patients had multiple bone and organ metastases. The locations of the surgery with the MIN were diaphyseal osteolytic lesions of the humerus (n=4), femur (n=4), and tibia (n=1). Combined radiation therapy was done in 66.7% (6/9) of patients and combined chemotherapy was performed in 100.0% (9/9) of patients. The severity of regional pain was measured by a visual analogue scale (VAS) ranging from 0 (no pain) to 10 (worst pain). Pain was measured on the day before surgery and 1 and 6 weeks postoperatively. The functional outcomes were objectively assessed through the Musculoskeletal Tumor Society (MSTS) for upper and lower limbs preoperatively and 6-weeks postoperatively [13]. Ambulation status was evaluated 6 weeks postoperatively. Mean follow up was 8.1 months (range, 1.0 to 22.0 months).

Multihole injection nail

The MIN was developed into a hollow titanium flexible nail containing a tip with multiple side holes. The MIN is connected to an injector handle with a stylet. Bone cement can be injected deeply during percutaneous fixation without adding bone cortex holes (Figure 1).

Surgical method

The patient was positioned in the lateral decubitus or supine positions according to the nail insertion site. We selected the appropriate length MIN and confirmed length under fluoroscopy. The MIN was tightened with the injector handle and shaped manually into the curvature of the bone with a press bender. A 2.2 mm Steinmann pin fixation was placed at the entrance point and a small skin incision was made for cannulated drilling. After cannulated drilling of the cortex, the MIN was inserted into the bony entrance hole. The MIN was advanced into the medullary canal manually and with hammering. If the predicted path of the nail was inappropriate for advancement, the MIN was pulled out and re-bent. The MIN was full seated in the entrance bone. We checked precise nail length and curvature through fluoroscopy before fully inserting the nail. The nail tip and side holes were repositioned at the osteolytic lesion, and the PMMA bone cement was prepared.

The low-viscosity radiopaque PMMA was mixed and transferred to a 30 ml or 50 ml syringe, depending on the number of cement packs needed (20 g/pack). Then, PMMA was transferred into several 1 ml syringes. We aspirated the unnecessary fluid in the hollow nail with an empty syringe before injecting the bone cement. The bone cement was injected under fluoroscopic guidance. If the injection became difficult, a handle stylet was used to push the PMMA. The injection was usually started 3 min to 4 min after mixing the cement. Leakage to the surrounding soft tissue must be carefully observed at the initial stage. After sufficient PMMA was injected into the osteolytic area, we further advanced the nail by hammering the handle and continued to inject the bone cement. The MIN was completely buried in the bone. The viscosity of the cement increases after 8 min so the injection was completed within 10 min. The injector handle was detached by rotating it counter clockwise and removed within 12 min before the cement hardened completely. The anesthesiologist monitored temporary changes in blood pressure, pulse rate, and respiration due to toxicity or the volatile smell of the PMMA.

Statistical analysis

Changes in the VAS for pain were validated by one-way analysis of variance. A P-value <0.05 was considered significant. Statistical analyses were performed using SPSS 18.0 software (IBM Corp., Chicago, IL, USA).

Results

Operative results

Spinal anesthesia was used in five patients for lower extremity surgery and the interscalene regional block was used in four patients undergoing surgery on the humerus. The mean operative time from skin incision to closure was 42 min (range, 36.0 to 52.0 min). The mean length of the injection nail was 23.0 cm (range, 18.0 cm to 33.0 cm), and mean volume of cement used was 28.0 ml (range, 14.0 ml to 40.0 ml) (Figure 2 and 3). Perioperative red blood cell transfusions were performed in three patients (two patients preoperatively and one patient postoperatively) (Table 1).

Table 1: Surgical results.

No.	Age/Sex	Primary cancer	Operative site	Mirels' grade	Operative time (min)	Length of nail (cm)	Amount of cement injection (ml)	ChemoTx(c) RadioTx(r) (preop/postop)	MSTS functional score (preop/postop)	Follow up (months)	Status
1	65/F	Lung	Femur left	11	43	24	37	c/c.r	13/26	22	AWD
2	46/F	Breast	Humerus left	11	36	18	19	c/r	10/25	6	DOD
3	55/F	Breast	Humerus left	8	38	21	14	c/r	18/27	19	AWD
4	54/F	Breast	Femur right	11	45	33	32	c/c.r	12/26	12	AWD
5	55/M	Lung	Humerus right	10	37	24	14	c.r/c	10/25	2	DOD
6	54/F	Breast	Humerus right	10	41	21	30	c/-	18/27	4	DOD
7	72/M	Lung	Femur left	11	48	24	40	c.r/r	5/-	1	DOD
8	60/F	Lung	Tibia right	11	38	24	34	c.r/r	18/25	4	AWD
9	60/M	Lung	Femur left	11	52	18	32	c.r/r	9/18	3	AWD

MSTS: Musculoskeletal Tumor Society; AWD: Alive with Disease; DOD: Died of Disease

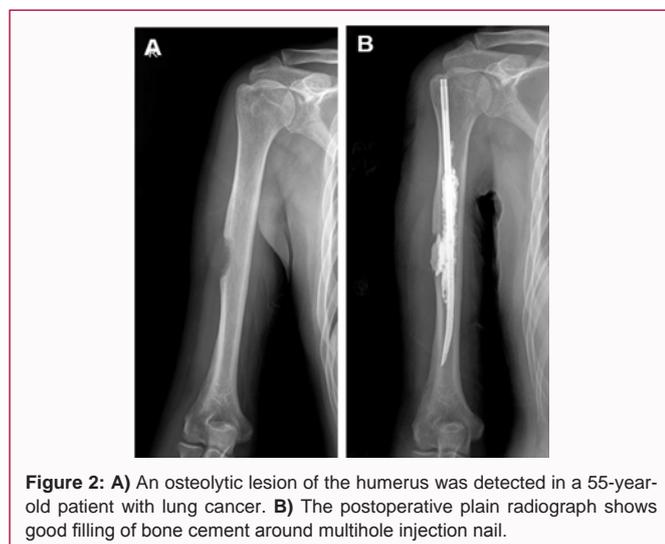


Figure 2: A) An osteolytic lesion of the humerus was detected in a 55-year-old patient with lung cancer. B) The postoperative plain radiograph shows good filling of bone cement around multihole injection nail.

Surgical outcomes

Marked pain palliation was verified 1 week postoperatively and had improved after 6 weeks (P=0.001). The mean VAS pain score in eight patients on the day before the operation was 8.1 (range, 6-10). The VAS pain scores 1 and 6 weeks after the operation were 3.5 (range, 2-5) and 1.9 (range, 0-3), respectively. One patient with lung cancer was not score on the VAS because of early death by aspiration pneumonia 1 month after the operation. Five patients were alive and four patients died during the follow up (Table 1). The mean MSTS functional score improved significantly from 12.5 (41.7%) at 6 weeks preoperatively to 24.9 (83.0%) postoperatively. All of the patients who performed F-18-FDG positron emission tomography/computed tomography (PET/CT) (n=4) showed decreased FDG uptake after the surgery (Figure 4). No thromboembolism or cement embolism was encountered. No MIN breakage, and no further intramedullary osteolysis of operative bone was observed.

Discussion

The MIN provides immediate mechanical stabilization using injected bone cement, resulting in early pain relief, less blood loss, shorter recovery time, and less delay of scheduled chemotherapy or radiation therapy. This concomitant bone cement injection technique and inserting of the nail may prevent the spread of intramedullary tumors.



Figure 3: 54-year-old female had multiple surgical treatments due to bone metastases from breast cancer. A) The right femur shows a symptomatic osteolytic lesion. B) Earlier surgical management before massive bony destruction is a good indication for the multi-hole injection nail technique.

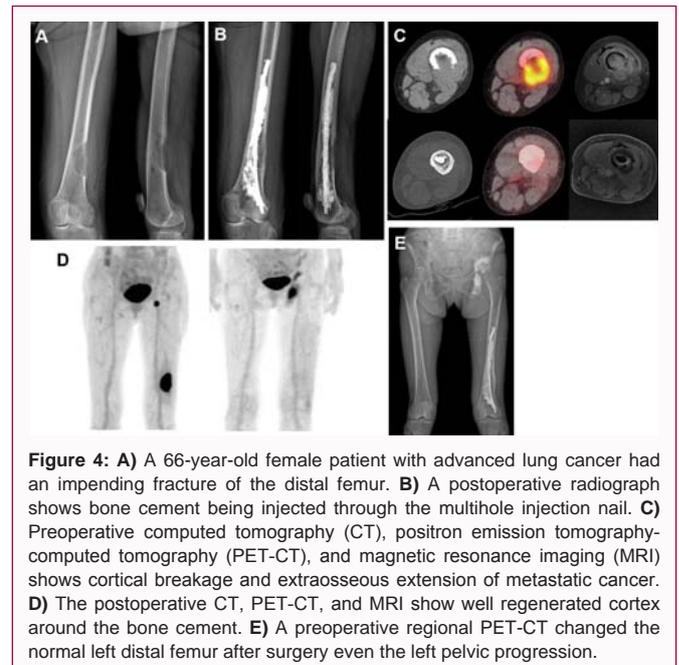


Figure 4: A) A 66-year-old female patient with advanced lung cancer had an impending fracture of the distal femur. B) A postoperative radiograph shows bone cement being injected through the multi-hole injection nail. C) Preoperative computed tomography (CT), positron emission tomography-computed tomography (PET-CT), and magnetic resonance imaging (MRI) shows cortical breakage and extraosseous extension of metastatic cancer. D) The postoperative CT, PET-CT, and MRI show well regenerated cortex around the bone cement. E) A preoperative regional PET-CT changed the normal left distal femur after surgery even the left pelvic progression.

It is most important to relieve pain and prevent pathological fractures when treating patients with metastatic bone cancer. Closed

intramedullary nailing is the most useful method for metastatic cancer of the long bone in the limbs [14]. It is usually combined with radiation therapy and provides reliable stability and pain relief. However, intramedullary nailing in the long bone does not remove tumor tissue and runs the risk of progressing bone destruction postoperatively by causing intramedullary spreading of the tumor during intramedullary reaming or when inserting the nail.

A new method called “closed intramedullary nailing with percutaneous cement augmentation for long bone metastases” has been introduced [15]. This method adds to percutaneous cementoplasty during the conventional closed intramedullary nail fixation method. It provides immediate postoperative stability and pain relief, less intra and postoperative blood loss, and early ambulation. Additionally, it restricted intramedullary spread of tumors due to the PMMA and reduced the frequency of postoperative reoperations due to progressive osteolysis, as the decreased FDG uptake means tumor suppression [16,17]. Combined cancer treatment is now being performed, including chemo, target gene, hormone, and immune therapies. In particular, bisphosphonate is effective in many types of cancer, particularly breast cancer [18]. Osteolytic bone shows sclerotic changes in response to treatment; thus, we often experienced intramedullary narrowing due to a calcified lesion, which required medullary reaming to fix the rigid intramedullary nail. If we tried intramedullary fixation earlier and blocked further local tumor spread using bone cement, a low profile flexible nail may be sufficient to achieve mechanical stability for ambulation or palliative care.

The humerus is a more applicable area to use MIN fixation and simultaneous cementing because it is a non-weight bearing site. The femur and tibia may need to be considered more carefully due to the higher ambulation load, including size and nature of the bone destruction, range of cortical breakage, primary cancer type, response to treatment, and patient parameters such as BMI, bone density, activity level, and remaining life expectancy.

Concomitant bone cement injection and internal fixation of a metastatic bony lesion is a proven effective technique [10-12,15]. The important point is to select a fixation method between rigid IM nailing and flexible nailing, such as MIN. Although all of our patients had advanced cancer and had a higher hazard during surgical management, this MIN technique may prevent an earlier pathological fracture of the long bone. This unique minimally invasive surgical method does not require skin or bony holes for cement needles, as with the previously introduced flexible nail (Ender nail) fixation and percutaneous cementing technique [11,12].

The most worrisome complications during the bone cement injection are a cement embolism [19-21] or extraosseous cement leakage [22,23]. In our study, no bone cement embolism was encountered but the risk always existed due to the large amount of bone cement injected. No extramedullary cement leakage was detected, even in the cortical cookie bite lesions of two patients with lung cancer.

Many other injectable materials, including tumor suppressive agents or bone healing materials besides PMMA bone cement may be used with the MIN but this needs further study. Because the present series was small we could not verify the indications or complications of this surgical method, so more cases will be collected for additional study. In addition, comparison study with other conventional methods should be performed to identify the value of this minimally

invasive surgical method.

The newly devised MIN may provide another option for palliative surgical management of long bone metastasis in some patients with advanced cancer.

Compliance with Ethical Standards

Conflict of interest

The authors declare that they have no conflict of interest.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent

This study was approved by National Cancer Center Institutional Review Board (IRB), and informed consent about surgical procedure was obtained from all individual participants included in the study following our IRB policy.

References

1. Mercadante S, Fulfaro F. Management of painful bone metastases. *Curr Opin Oncol.* 2007;19(4):308-14.
2. Cappuccio M, Bandiera S, Babbi L, Boriani L, Corghi A, Amendola L, et al. Management of bone metastases. *Eur Rev Med Pharmacol Sci.* 2010;14(4):407-14.
3. Aboulafia AJ, Levine AM, Schmidt D, Aboulafia D. Surgical therapy of bone metastases. *Semin Oncol.* 2007;34(3):2016-14.
4. Callstrom MR, Charboneau JW, Goetz MP, Rubin J, Atwell TD, Farrell MA, et al. Image-guided ablation of painful metastatic bone tumors: a new and effective approach to a difficult problem. *Skeletal Radiol.* 2006;35(1):1-15.
5. Kodama H, Aikata H, Uka K, Takaki S, Mori N, Waki K, et al. Efficacy of percutaneous cementoplasty for bone metastasis from hepatocellular carcinoma. *Oncology.* 2008;72(5-6):285-92.
6. Deramond H, Depriester C, Galibert P, Le Gars D. Percutaneous vertebroplasty with polymethylmethacrylate: technique, indications, and results. *Radiol Clin North Am.* 1998;36(3):533-46.
7. Tschirhart CE, Finkelstein JA, Whyne CM. Optimization of tumor volume reduction and cement augmentation in percutaneous vertebroplasty for prophylactic treatment of spinal metastases. *J Spinal Disord Tech.* 2006;19(8):584-90.
8. Deschamps F, Farouil G, Hakime A, Barah A, Guieu B, Teriitehau C, et al. Cementoplasty of metastases of the proximal femur: is it a safe palliative option? *J Vasc Interv Radiol.* 2012;23(10):1311-6.
9. Yamada K, Matsumoto Y, Kita M, Yamamoto K, Kohda W, Kobayashi T, et al. Clinical outcome of percutaneous osteoplasty for pain caused by metastatic bone tumors in the pelvis and femur. *J Anesth.* 2007;21(2):277-81.
10. Kang H, Roh Y, Kim H. The treatment of metastasis to the femoral neck using percutaneous hollow perforated screws with cement augmentation. *J Bone Joint Surg Br.* 2009;91(8):1078-82.
11. Kim YI, Kang HG, Kim TS, Kim SK, Kim JH, Kim HS. Palliative percutaneous stabilization of lower extremity for bone metastasis using flexible nails and bone cement. *Surg Oncol.* 2014;23:192-8.
12. Kim JH, Kang HG, Kim JR, Lin PP, Kim HS. 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.

13. Enneking WF, Dunham W, Gebhardt MC, Malawar M, Pritchard DJ. A system for the functional evaluation of reconstructive procedures after surgical treatment of tumors of the musculoskeletal system. *Clin Orthop Relat Res.* 1993;286:241-6.
14. Arvinius C, Parra JLC, Mateo LS, Maroto RG, Borrego AF, Stern LL-D. Benefits of early intramedullary nailing in femoral metastases. *Int Orthop.* 2014;38(1):129-32.
15. Kim Y, Kang H, Kim J, Kim S, Lin P, Kim H. Closed intramedullary nailing with percutaneous cement augmentation for long bone metastases. *Bone Joint J.* 2016;98-B(5):703-9.
16. Tateishi U, Gamez C, Dawood S, Yeung HW, Cristofanilli M, Macapinlac HA. Bone metastases in patients with metastatic breast cancer: morphologic and metabolic monitoring of response to systemic therapy with integrated PET/CT. *Radiology.* 2008;247(1):189-96.
17. Kim YI, Kang HG, Kim SK, Kim JH, Kim HS. Clinical outcome prediction of percutaneous cementoplasty for metastatic bone tumor using (18) F-FDG PET-CT. *Ann Nucl Med.* 2013;27(10):916-23.
18. Group EBCTC. Adjuvant bisphosphonate treatment in early breast cancer: meta-analyses of individual patient data from randomised trials. *Lancet.* 2015;386(10001):1353-61.
19. Wang LJ, Yang HL, Shi YX, Jiang WM, Chen L. Pulmonary cement embolism associated with percutaneous vertebroplasty or kyphoplasty: a systematic review. *Orthop Surg.* 2012;4(3):182-9.
20. Monticelli F, Meyer HJ, Tutsch-Bauer E. Fatal pulmonary cement embolism following percutaneous vertebroplasty (PVP). *Forensic Sci Int.* 2005;149(1):35-8.
21. Duran C, Sirvanci M, Aydoğan M, Ozturk E, Ozturk C, Akman C. Pulmonary cement embolism: a complication of percutaneous vertebroplasty. *Acta Radiol.* 2007;48(8):854-9.
22. Tomé-Bermejo F, Piñera AR, Duran-Álvarez C, López-San Román B, Mahillo I, Alvarez L, et al. Identification of risk factors for the occurrence of cement leakage during percutaneous vertebroplasty for painful osteoporotic or malignant vertebral fracture. *Spine (Phila Pa 1976).* 2014;39(11):E693-700.
23. Baumann C, Fuchs H, Kiwit J, Westphalen K, Hierholzer J. Complications in percutaneous vertebroplasty associated with puncture or cement leakage. *Cardiovasc Intervent Radiol.* 2007;30(2):161-8.