

Percutaneous Palliative Surgery for Femoral Neck Metastasis Using Hollow Perforated Screw Fixation and Bone Cement

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Background: We introduced a new surgical method of percutaneous hollow perforated screw (HPS) fixation with concomitant bone-cement injection for the treatment of femoral neck metastasis and evaluated its efficacy for the palliative treatment of patients with advanced cancer.

Methods: The study included 87 patients (39 men and 48 women; mean age [and standard deviation], 64.2 ± 10.2 years; mean body mass index, 24.3 ± 3.2 kg/m²) who underwent percutaneous HPS fixation and cementoplasty (mean cement amount, 19.8 ± 8.3 mL) for the treatment of unilateral or bilateral femoral neck metastasis (total, 95 sites). Anesthesia type, operative time, operative blood loss, pain score changes (according to a visual analog scale [VAS]), walking status, and complications were assessed. The mean duration of follow-up was 10.1 ± 10.8 months (range, 2 to 43 months).

Results: The majority of procedures were performed with local (3 patients) or spinal (72 patients) anesthesia (total, 75 patients; 86.2%). The mean operative time was 35.9 minutes, and the mean operative blood loss was 97.0 mL. The VAS score for pain improved significantly, from 6.8 ± 2.8 preoperatively to 2.8 ± 2.3 and 2.9 ± 2.8 at 1 and 6 weeks postoperatively ($p < 0.001$). At 6 weeks postoperatively, 63 (80.8%) of 78 patients were able to walk (with either normal or limping gait, a cane or crutch, or a walker). The prevalence of major local complications (cement leakage into the hip joint, fixation failure) was 10.5% (10 of 95), but major systemic complications (distant cement embolism) were not found.

Conclusions: Percutaneous HPS fixation and cementoplasty for the treatment of femoral neck metastasis is a minimally invasive technique that provides effective pain relief and early stabilization. This technique seems to be useful for patients with advanced cancer for whom open surgery would be hazardous.

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

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Bone metastasis is the most common malignant condition treated by orthopaedic surgeons¹. Patients with bone metastasis suffer from severe pain, and their quality of life and life expectancy are limited. Pathological fractures occur in 10% of patients with bone metastasis. The 1-year survival of patients who undergo surgery for the treatment of long-bone metastasis is 15% to 20%². Early surgical treatment is preferred for patients with long-bone metastasis associated with impending or pathological fracture as it can restore skeletal

stability and provide pain relief³. Nevertheless, many patients with bone metastasis are in too poor conditions generally—as a result of multiple advanced metastases, medical comorbidities, previous radiation therapy, and/or chemotherapy—to undergo open surgery.

The femoral neck is one of most common long-bone areas of metastasis and is vulnerable to both pathological fracture and fracture due to osteoporosis. Conservative treatment of femoral neck metastasis is difficult because of the

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Fig. 1
Figs. 1-A, 1-B, and 1-C Photographs illustrating the instruments and procedures used for percutaneous HPS fixation and cementoplasty.
Fig. 1-A Photograph of HPSs, which have many side holes for bone-cement injection. **Fig. 1-B** Photograph illustrating the HPS insertion procedure.
Fig. 1-C Intraoperative photograph made during bone-cement injection.

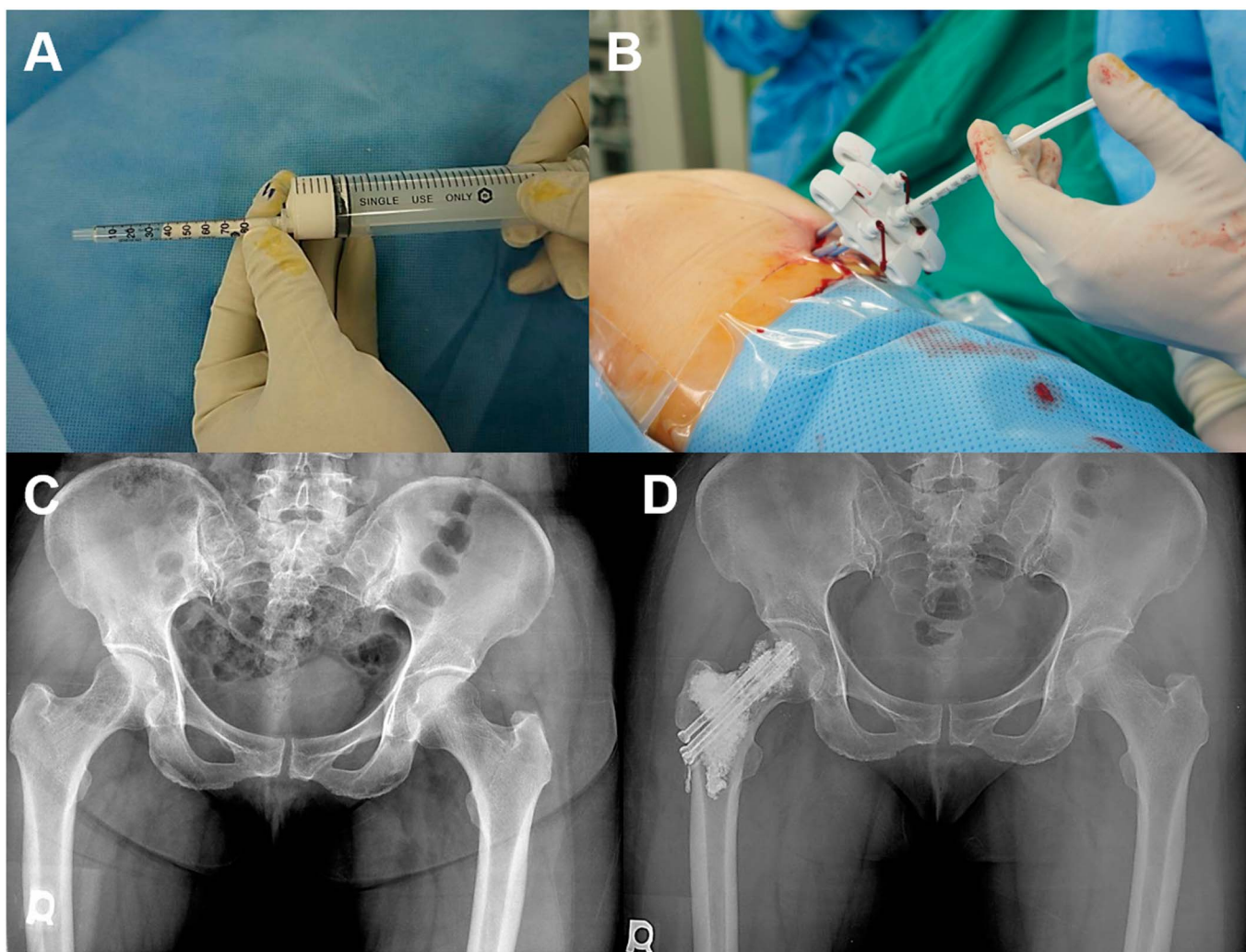


Fig. 2
Figs. 2-A through 2-D A 58-year-old woman was managed with percutaneous HPS fixation and cementoplasty for the treatment of femoral neck metastasis.
Fig. 2-A The low-viscosity radiopaque PMMA was mixed for 2 minutes and was transferred to a 30 or 50-mL syringe. **Fig. 2-B** The PMMA then was transferred again into 1-mL syringes and was injected into the head and neck of the femur, 3 to 4 minutes after mixing. **Fig. 2-C** Preoperative radiograph demonstrating an osteolytic lesion involving the right femoral neck. **Fig. 2-D** Postoperative radiograph showing secure augmentation of femoral neck with HPS fixation and bone cement.

TABLE 1 Baseline Characteristics

Parameter	Value
No. of patients	87
Age* (yr)	64.2 ± 10.2 (range, 42 to 89)
Male:female ratio (no. of patients)	39:48
Body mass index* (kg/m ²)	24.3 ± 3.2 (range, 13.8 to 32.8)
Operative side (R:L:bilateral) (no. of patients)	37:42:8
Combined radiation therapy (preop. and/or postop.) (no. of patients)	65 (74.7%)
Combined chemotherapy (preop. and/or postop.) (no. of patients)	74 (85.1%)

*The values are given as the mean and the standard deviation, with the range in parentheses.

frequency of intractable pain and the presence of either a pathological fracture or an impending fracture. Therefore, symptomatic femoral neck metastasis usually requires bipolar hemiarthroplasty or intramedullary nailing, regardless of the patient's general condition⁴. Minimally invasive approaches for the treatment of femoral neck metastasis⁵, including percutaneous ethanol therapy, radiofrequency ablation, cryoablation, and cementoplasty, have been developed^{6,7}. Another treatment, percutaneous cementoplasty, involves the injection of polymethylmethacrylate (PMMA) into metastatic osseous lesions and is known to reduce metastatic bone pain and to improve mechanical stability in the spine, pelvis, and long bones^{8,9}. Cementoplasty in combination with radiofrequency ablation¹⁰ and cryoablation¹¹ also have been investigated; however, these palliative methods have not been shown to substantially improve femoral neck stability. Therefore, the addition of metal fixation may be advantageous.

The advent of the new surgical technique involving the use of hollow perforated screws (HPSs) and bone-cement injection⁵ for the treatment of femoral neck metastasis has demonstrated achievable fixation with flexibility through the injection of materials in areas of weak bone area via multiple side holes. A previous pilot study⁵ demonstrated that the technique was simple to perform and provided effective pain relief and reliable stability; however, the data were somewhat limited as the study included only 11 patients. In the present study, as an expansion of the previously published study, we evaluated the efficacy, complications, and contraindications of this technique for the palliative treatment of femoral neck metastases in a larger population of patients with advanced cancer. We hypothesized that percutaneous HPS fixation and cementoplasty might be a palliative method to prevent pathological fracture and to preserve the hip joint in patients with femoral neck metastasis.

Materials and Methods

Patients

The present study included 87 patients who underwent percutaneous HPS fixation and cementoplasty for the treatment of femoral neck metastasis between May 2008 and Dec 2015 at our institution. These patients were diagnosed with advanced cancer in the bone and/or visceral organs. All patients met the criteria of a Mirels score of >9 for femoral neck metastasis¹², and all required local pain control and mechanical stability. All patients had been evaluated at the surgical conference by means of a multidisciplinary team approach and had been deemed not to be candidates for open surgery because of a poor general condition, with multiple bone metastases or difficulty in stopping chemotherapy. The primary malignant lesions involved the lung (n = 38), breast (n = 20), liver (n = 6), prostate (n = 4), intestine and colon (n = 4), bone marrow (n = 3), kidney (n = 3), brain (n = 2), skeleton (n = 2), gallbladder (n = 2), lymphatic system (n = 1), esophagus (n = 1), and thyroid (n = 1). The present study was approved by the institutional review board of our institution, and informed consent was obtained from the patients.

Percutaneous HPS Fixation and Cementoplasty

HPS 6.5-mm cannulated screws (Multihole Injection Screw; Solco) with multiple side holes for the injection of bone cement (Fig. 1-A) were used for percutaneous HPS fixation and cementoplasty. The procedure was performed as previously described⁵. Briefly, the patient was placed in the lateral decubitus position. After sterilization and draping of the affected lower limb, lines were drawn on the skin overlying the femoral shaft and neck under fluoroscopy. Two or three 2.2-mm guide-pins were inserted into the femoral neck. The length of the inserted guide-pin was measured, and a small skin incision was made for cannulated drilling. After cannulated drilling, 2 or 3 multihole injection screws were introduced over the guide-pins. The location of all screws was checked fluoroscopically, and then a percutaneous cementoplasty needle (10 or 11-gauge; length, 11 cm) (Kyungwon Medical) was inserted into each HPS through the guidewire (Figs. 1-B and 1-C).

Low-viscosity radiopaque PMMA (DePuy International) was mixed for 2 minutes and was transferred to a 30 or 50-mL syringe, depending on the number of cement packs (20 g per pack). Then, PMMA was transferred again into 18 to 20 1-mL syringes per pack. According to the Pascal law (which states that the change in pressure applied at any given point of the fluid is transmitted undiminished throughout the fluid), we moved PMMA from the 30 or 50-mL syringe to a 1-mL syringe to increase the transmission of power. After guidewire removal, PMMA was injected into the head and neck of the femur with use of 1-mL syringes 3 to 4 minutes after mixing (Figs. 2-A and 2-B).

Two or 3 percutaneous cementoplasty needles were used to reduce intraosseous pressure at the time of bone-cement injection. The bone cement was injected through a single needle until bloody fluids and injected bone cement regurgitated through the other needles. An empty syringe was used to aspirate unnecessary fluids, and then bone cement was injected through all needles. The initial PMMA injection was done slowly while the surgical team monitored regional short venous cement drainage by means of fluoroscopy and evaluated blood pressure in order to ensure avoidance of hypotension. With frequent checks to avoid extraosseous or intra-articular leakage, the bone cement was injected as liberally as was achievable. The percutaneous cementoplasty needle was removed before complete cement solidification, which was roughly 10 to 12 minutes after mixing. When osteolytic metastasis was found on the same side of pelvis, percutaneous cementoplasty was also done with direct insertion of ≥2 additional percutaneous cementoplasty needles at the dome of acetabulum.

Postoperative Care and Evaluation

Anesthesia type, operative time, blood loss, and local and systemic complications were determined on the basis of a review of medical records. In addition, each patient was asked to quantify regional resting pain with use of a visual analog scale (VAS) score with values ranging from 0 (absence of pain) to 10 (strongest pain ever experienced) 1 day preoperatively and 1 and 6 weeks

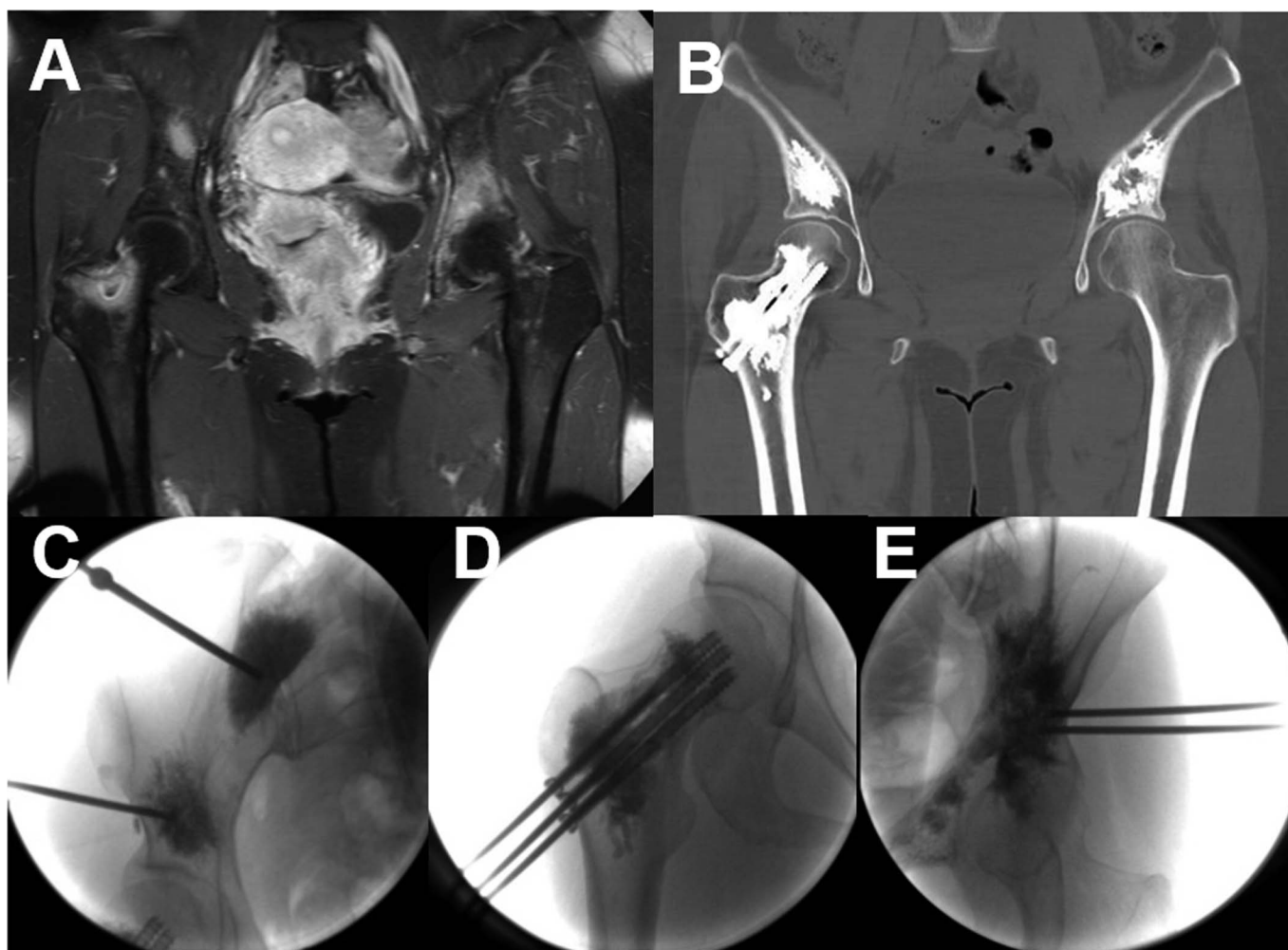


Fig. 3

Figs. 3-A through 3-E A 37-year-old woman with breast cancer and femoral neck metastasis underwent simultaneous percutaneous HPS fixation and cementoplasty and pelvic bone cementoplasty. **Fig. 3-A** Preoperative T2-weighted coronal magnetic resonance imaging (MRI) scan showing right femoral neck and bilateral pelvic bone metastases. **Fig. 3-B** Postoperative CT scan showing augmentation of the femoral neck with HPS fixation and bone cement and bilateral pelvic augmentation with bone cement. **Figs. 3-C, 3-D, and 3-E** Intraoperative fluoroscopic images showing bone-cement injection into the pelvic bone metastases.

postoperatively¹³. Walking status was also evaluated preoperatively and 6 weeks postoperatively. For most patients, low-molecular-weight heparin was administered 12 hours before surgery and was continued for 2 to 5 days after surgery to prevent pulmonary thromboembolism. A pneumatic compression pump or anti-embolic stockings were also used as mechanical prophylaxis against deep-vein thrombosis (DVT). Postoperatively, patient-controlled analgesia (PCA) was provided for a duration of 2 days for operative and metastatic pain control. Clexane (enoxaparin sodium) was routinely used for 3 days for prophylaxis against DVT. On the first postoperative day, patients were encouraged to walk with either a cane or crutch according to their preoperative walking status. A determination regarding additional radiation therapy and/or chemotherapy routinely was made by the hematologist-oncologist within 5 days¹⁴.

Statistical Analysis

Change in the VAS score was validated by means of a 1-way analysis-of-variance (ANOVA) test. Preoperative and postoperative walking status was evaluated by means of a chi-square test (normal or limping gait, cane or crutch, and walker versus wheelchair and bedridden). The level of significance was set at $p < 0.05$.

Statistical analyses were performed with use of the SPSS software package (version 18.0; IBM).

Results

Demographics and Clinical Characteristics

A total of 87 patients were included in the study (mean age [and standard deviation], 64.2 ± 10.2 years; range, 42 to 89 years) (Table I). The majority of the patients were female ($n = 48$), and the mean body mass index (BMI) was 24.3 ± 3.2 kg/m² (range, 13.8 to 32.8 kg/m²). More unilateral procedures were performed on the left side than on the right side (42 compared with 37), and the procedure was performed bilaterally in 8 patients (total, 95 sites). Combined radiation therapy for the treatment of femoral neck metastases was performed in sixty-five patients (74.7%), and combined chemotherapy was done for 74 patients (85.1%). The procedure did not interfere with treatment plans for postoperative radiation and/or

TABLE II Results of Percutaneous HPS Fixation and Cementoplasty	
Parameter	Value
Injected cement amount* (mL)	19.8 ± 8.3 (range, 8.0 to 45.0)
Anesthesia (local: spinal: general) (no. of patients)	3:72:12
Operative time* (min)	35.9 ± 30.2 (range, 25.4 to 87.0)
Operative blood loss* (mL)	97.0 ± 83.7
Postop. walking ability (including with a cane, crutch, walker) (no. of patients)	63 (80.8%) of 78

*The values are given as the mean and the standard deviation, with the range in parentheses.

TABLE III Changes in Walking Ability		
Walking Ability	Preop.	6 Weeks Postop.
No. of patients evaluated	87	78
Normal or limping gait	27 (31.0%)	36 (46.2%)
Cane or crutch	18 (20.7%)	19 (24.4%)
Walker	8 (9.2%)	8 (10.3%)
Wheelchair	27 (31.0%)	7 (9.0%)
Bedridden	7 (8.0%)	8 (10.3%)

chemotherapy. The mean duration of follow-up was 10.1 ± 10.8 months (range, 2 to 43 months). At the time of writing, 74 patients (85.1%) had died and 13 patients (14.9%) were alive. The mean duration of survival was 9.2 ± 11.4 months (range,

0 to 43 months). Twenty patients (23.0%) lived for >12 months after the procedure. For 9 patients (including 2 who had died, 4 who had been lost to follow-up, and 3 who had insufficient medical records because of transfer), the VAS pain score and walking status could not be assessed at 6 weeks. The causes of the 2 deaths were organ failure and pneumonia.

Outcomes of Percutaneous HPS Fixation and Cementoplasty

Percutaneous HPS fixation and cementoplasty was performed without major complications in most cases (Figs. 2-C and 2-D). The mean amount of cement injected at each site was 19.8 ± 8.3 mL (range, 8.0 to 45.0 mL), and most patients (75 patients; 86.2%) were managed with local (3 patients) or spinal (72 patients) anesthesia. Local anesthesia was used for patients who could not undergo spinal anesthesia because of extensive lumbar spine metastases. Concomitant percutaneous cementoplasty for the acetabulum or pelvis was performed in 18 patients (27 sites) (Fig. 3). The mean operative time was 35.9 ± 30.2 minutes (range, 25.4 to 87.0 minutes). The mean blood loss was 97.0 ± 83.7 mL (range, 0 to 300.0 mL), and perioperative blood transfusion (mean, 2.6 ± 1.4 units of packed red blood cells) was performed for 20 patients (23.0%), usually because of bone-marrow suppression caused by multiple skeletal radiation treatments and/or ongoing chemotherapy (Table II). The VAS score for pain improved significantly, from 6.8 ± 2.8 preoperatively to 2.8 ± 2.3 and 2.9 ± 2.8 at 1 and 6 weeks postoperatively (p < 0.001). At 6 weeks postoperatively, 63 (80.8%) of 78 patients were able to walk with either normal or limping gait (n = 36), a cane or crutch (n = 19), or a walker (n = 8) (Table III). Compared with the preoperative status, significant improvement of walking was achieved (p = 0.009).

Local complications occurred at 13 (13.7%) of 95 sites, and systemic complications occurred in 9 (10.3%) of 87 patients (Table IV). Local complications included cement leakage into the hip joint (n = 3), femoral head collapse (n = 2), femoral neck fracture with metal breakage (n = 2), subtrochanteric fracture (n = 3), and short venous cement drainage

TABLE IV Complications		
Complications	No. of Complications	Time of Onset
Local complications (n = 95 sites)		
Cement leakage into hip joint (major)	3 (3.2%)	Intraop.
Fixation loss (major)		
Femoral head collapse	2 (2.1%)	4, 7 mo postop.
Femoral neck fracture with metal breakage	2 (2.1%)	3, 8 mo postop.
Subtrochanteric fracture	3 (3.2%)	5, 9, 10 mo postop.
Regional short venous cement drainage	3 (3.2%)	Intraop.
Systemic complications (n = 87 patients)		
Distant cement embolism (major)	0 (0%)	—
Transient hypotension	6 (6.9%)	Intraop.
Deep venous thromboembolism	2 (2.3%)	8, 14 d postop.
Pulmonary thromboembolism	1 (1.1%)	5 d postop.



Fig. 4

Figs. 4-A, 4-B, and 4-C A 55-year-old man who had complications after percutaneous HPS fixation and cementoplasty. **Fig. 4-A** Preoperative T1-weighted coronal MRI scan showing bone metastases in the neck of the right femur and lesser trochanter of the left femur. **Fig. 4-B** Radiograph, made 3 months postoperatively, showing an avulsion fracture in the subtrochanteric area of the left femur. **Fig. 4-C** Radiograph made 3 months after reoperation with use of an intramedullary nail.

(as indicated by a vessel shadow around the lesion on fluoroscopy) ($n = 3$). Among the 7 patients with fixation failure (femoral head collapse, femoral neck fracture with metal breakage, and subtrochanteric fracture), 4 patients underwent reoperation (with use of a tumor prosthesis, long-stem bipolar prosthesis, cephalomedullary nail, or plate) (Fig. 4) and the remaining 3 patients could not undergo reoperation because of a poor general condition and died. Cement leakage into the hip joint and short venous cement drainage did not affect mortality. Systemic complications included transient hypotension ($n = 6$), deep venous thromboembolism ($n = 2$), and pulmonary thromboembolism ($n = 1$); however, there was no case of distant cement embolism (Table IV).

Discussion

Early surgical treatment may be indicated for patients with femoral neck metastasis because the femoral neck is a high-weight-bearing area and fractures are difficult to treat with conservative means. In the present study, percutaneous HPS fixation and cementoplasty was found to be safe and useful as a palliative, minimally invasive procedure for patients with advanced cancer associated with an impending femoral neck fracture. Major systemic complications were not detected. However, major local complications, such as cement leakage into the hip joint, femoral head collapse, femoral neck fracture with metal breakage, and subtrochanteric fracture, were observed after the operation.

Bipolar hemiarthroplasty is the main surgical treatment for femoral neck metastasis, but it is associated with the risk of major surgical complications, especially in patients with stage-IV cancer¹⁵. In recent years, percutaneous cementoplasty has been widely used to treat multiple bone metastases in flat bones as well as long bones and has achieved substantial pain reduction postoperatively^{16,17}. Cementoplasty can be performed in combination with screw or nail insertion for the prevention of perioperative bone bleeding, the suppression of local tumor spreading, and the achievement of immediate mechanical stability^{18,19}.

Percutaneous HPS fixation and cementoplasty has some advantages over bipolar hemiarthroplasty, including a minimal need for general anesthesia, a reduced operative time, a reduced need for blood transfusion, and a minimal need for rehabilitation. In addition, early surgical treatment could be possible before the occurrence of pathological fracture, a known marker of poor prognosis²⁰. Moreover, HPS fixation has a mechanical stabilization effect when combined with the use of bone cement in the area of osteolytic bone destruction. In the present study, early treatment with percutaneous fixation and cementoplasty showed favorable results in terms of the improvement of



Fig. 5

Radiograph showing the HPS insertion point according to tumor involvement. The usual insertion point was on the upper side of the thick lateral cortex of the proximal part of the femur (right [R] side). However, if the tumor involved the lesser trochanteric area, screws were fixed in an X shape (left side).

walking ability, mainly from wheelchair status to normal or limping gait. A previous study demonstrated that cementoplasty without internal fixation had shortcomings in terms of mechanical stabilization when used for the treatment of femoral neck metastasis²¹. In addition, percutaneous HPS fixation and cementoplasty did not interfere with the plans for treatment with radiation therapy and/or chemotherapy. The major complication rate following HPS fixation and cementoplasty surgery (10.5%; 10 of 95) was comparable to that reported in a previous study on joint replacement surgery for the treatment of long-bone metastases (10.7%; 15 of 140)²².

The usual HPS insertion point is the upper side of the thick lateral cortex of the proximal part of the femur. If the tumor involves the lesser trochanteric area, the HPS fixation is X-shaped, with 1 screw directed toward the femoral head and the other directed toward the lesser trochanter (Fig. 5).

In the present study, femoral head collapse occurred as a result of progressive osteolysis. To prevent this complication, one would need to inject bone cement into both the femoral neck and the femoral head; as a result, severe femoral head involvement is not an indication for this procedure. To prevent femoral neck fracture with metal breakage, 1 or 2 conventional 6.5-mm cannulated screws can be used instead of 2 or 3 HPS in patients with a high risk of metal breakage. Subtrochanteric fractures were accompanied by lesser trochanteric and calcar lesions. Therefore, a femoral neck metastasis associated with medial calcar or lesser trochanteric cortical involvement is not an indication for this procedure and would be best treated with gamma nailing. Regional short venous cement drainage usually was detected at the time of initiation of bone-cement injection. The high intraosseous pressure and very low viscosity of bone cement may lead to additional extraosseous venous drainage of cement. When regional short venous drainage was seen on fluoroscopy, cement injection was stopped for about 1 minute and reinjection was started after increasing the viscosity of cement. On the basis of the complications that we observed, we suggest that arthroplasty or rigid intramedullary nail fixation is preferable for patients with osteolysis involving >2/3 of the femoral head or cortical breakage involving the lesser trochanter or subtrochanteric area.

With regard to systemic complications, transient hypotension was presumed to have been due to a hypersensitivity

reaction, reflex autonomic effects, or vasodilatation in response to the PMMA cement²³. Intravenous fluid hydration was necessary before cement injection and the use of epinephrine was recommended by the anesthesiologist if the diastolic pressure fell below 50 mm Hg. Deep venous thromboembolism was found in the popliteal vein and the superficial femoral vein. We treated deep venous thromboembolism with Fragmin (dalteparin) injection. The 1 instance of symptomatic pulmonary thromboembolism in the present study was detected on the fifth postoperative day. The patient was evaluated with Doppler ultrasound, computed tomography (CT) angiography, and venography. The density of the thrombus was low and was not consistent with that of bone cement on the CT scan of the chest, and the patient died 12 months after surgery as a result of cancer progression, not pulmonary thromboembolism.

In conclusion, percutaneous HPS fixation and cementoplasty can be a useful form of palliative surgical treatment for femoral neck metastasis that does not interfere with systemic treatment in patients with advanced cancer. ■

NOTE: The physician assistants (Sung Geun Kim, Jae Won Jang, and Sin Ae Park) and the operating room charge nurse (Young Jin Yu) helped us in collecting the surgical records. The clinical coordinator (Seong Eun Oh) assisted us in gathering the clinical records of the patients.

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