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How Often Do Acetabular Erosions Occur After Bipolar Hip Endoprostheses in Patients With Malignant Tumors and Are Erosions Associated With Outcomes Scores?

Matthew T. Houdek MD, Peter S. Rose MD, Peter C. Ferguson MD, Franklin H. Sim MD, Anthony M. Griffin MSc, Mario Hevesi MD, Jay S. Wunder MD

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Abstract

Background Bipolar endoprosthetic replacement is an option for reconstruction of the proximal femur to restore a functional extremity and salvage the limb. However, because these patients are young, there is a theoretical risk for long-term degenerative changes of the acetabulum. Currently, there is a paucity of data concerning the proportion of patients who experience degenerative acetabulum changes after reconstruction and whether these changes are associated with Musculoskeletal Tumor Society (MSTS) scores.

Questions/purposes (1) What proportion of patients develop acetabular cartilage degeneration after bipolar hemiarthroplasty for malignant tumor-related reconstructions? (2) What is the survivorship free from revision for acetabular wear, erosions, or progressive arthritis? (3) Is there an association between the presence of acetabular erosions and lower MSTS scores?

Methods Between 2000 and 2015, 148 patients underwent endoprosthetic reconstruction of the proximal femur with a bipolar hemiarthroplasty for a malignant tumor and were potentially eligible for this retrospective study. Minimum followup was 1 year except for those who died or were revised earlier; of the 148, no patients were lost to followup before that time who were not known to have died; mean followup on the remainder was 79 months (range, 12-220 months), and the mean time to death after surgery for those who died was 28 months (range, 0-196 months). Over the course of the study, 93 (63%) patients died. The mean (± SD) patient age was 57 ± 17 years, and 55% (81 of 148) of the patients were men. We used magnification-corrected supine AP plain radiographs of the hip to evaluate degenerative acetabulum changes, and we used the 1993 MSTS score to assess function through chart review and a longitudinally maintained institutional database. We used a competing-risks survivorship estimator rather than Kaplan-Meier because of the high proportion of patients who had died during the surveillance period.

M. T. Houdek, P. S. Rose, F. H. Sim, M. Hevesi, Department of Orthopedic Surgery, Mayo Clinic, Rochester, MN, USA

P. C. Ferguson, A. M. Griffin, J. S. Wunder, University Musculoskeletal Oncology Unit, Department of Orthopedic Surgery, Mount Sinai Hospital, University of Toronto, Toronto, Canada

M. T. Houdek ✉, Department of Orthopedic Surgery, Mayo Clinic, 200 First Street SW, Rochester, MN 55901, USA, email: Houdek.matthew@mayo.edu

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Results Nineteen patients (13%) developed cartilage erosion > 2 mm in the acetabulum, with two also developing protrusio after proximal femoral replacement with a bipolar endoprosthesis. Three additional patients also developed signs of protrusio. The mean acetabular wear after bipolar replacement was 1.2 mm. Patients with longer followup (p = 0.001) were at higher risk for developing acetabular wear. Six patients underwent conversion to THA to treat hip pain. At 10 years the cumulative incidence for conversion to THA for acetabular wear is 5% (95% confidence interval [CI], 0%-11%), whereas the cumulative incidence of death was 70% (95% CI, 61%-79%). There was no difference in mean MSTS scores between patients who developed > 2 mm of acetabular erosion (65% ± 25%) and those who did not (67% ± 20%; p = 0.77).
Conclusions Wear was uncommon among patients with malignant hip tumors treated with bipolar endoprostheses, but the followup here was short, and some patients indeed developed wear and underwent wear-related revisions to THA. Patients expected to survive more than a few years should have periodic radiographic surveillance and should be followed for a longer period to get a better sense for whether the problem worsens with time, as we expect it may, among patients who survive for longer periods.
Level of Evidence Level III, therapeutic study.

Introduction

The proximal femur is a common location for malignant and benign bone tumors as well as metastatic disease [26, 33]. Adjuvant treatments, improved surgical techniques, and better imaging modalities have allowed limb salvage to become the treatment of choice for malignant tumors and benign aggressive lesions of the proximal femur [6, 15, 37]. Endoprosthetic replacements have become the primary treatment for reconstructing the proximal femur after tumor resection because they allow immediate weightbearing and are relatively cost-effective, widely available, and durable [8, 10, 11, 16, 18, 21, 38].

Historically, a bipolar hip component sometimes is used to reduce the dislocation rate and to preserve the acetabulum after proximal femoral replacement [5, 11, 26, 30]. Because most patients with metastatic disease typically do not live longer than 2 years after surgery [8, 19, 28, 34], it was thought that the conversion rate to THA because of acetabular erosions would be low. However, these data come from smaller series and combine endoprosthetic replacements from multiple locations [9, 11, 17, 18, 20, 21, 23, 30, 33, 38]. Concerns that are largely unanswered include a more precise estimate of how often patients with orthopaedic tumors treated with bipolar endoprostheses develop deep acetabular erosions or progressive acetabular wear, how often these patients undergo THA to treat symptoms from acetabular cartilage wear, and to what degree those patients who have acetabular cartilage wear in this setting notice it in terms of pain or impairment.

We therefore combined data from two tertiary sarcoma centers that consistently used bipolar endoprosthetic replacements for reconstruction in the setting of malignant disease in the proximal femur to answer the following questions: (1) What proportion of patients develop acetabular cartilage degeneration after bipolar hemiarthroplasty for malignant tumor-related reconstructions? (2) What is the survivorship free from revision for acetabular wear, erosions, or progressive arthritis? (3) Did patients with acetabular erosions > 2 mm deep have lower Musculoskeletal Tumor Society (MSTS) scores than those patients without such acetabular erosions?

Patients and Methods

After obtaining approval from our institutional review boards for this retrospective study, we reviewed our institutions' total joint and tumor databases to obtain the records of all patients who underwent modular endoprosthetic reconstruction of the proximal femur with a bipolar hemiarthroplasty after en bloc resection of a malignant tumor between 2000 and 2015 because electronic radiographs were available for these patients. The study was chosen to provide a convenience sample of patients for whom electronic radiographs were available.

We identified 148 patients who met these criteria and were potentially eligible for this retrospective study. Minimum followup was 1 year except for those who died or were revised earlier; of the 148, no patients were lost to followup before that time and not known to have died; mean followup on the remainder was 79 months (range, 12-220 months), and the mean time to death after surgery for those who died was 28 months (range, 0-196 months). Of the surviving patients, four had not been seen in the clinic for the past 5 years and are not known to have died. The mean followup for this cohort was 59 months (range, 37-91 months). Of these patients, two had evidence of metastatic disease at their most recent followup.

This cohort consisted of 67 females (45%) and 81 males (55%) with a mean age at the time of surgery of 57 years (range, 11–88 years). Three patients were < 18 years of age at the time of surgery. No expandable tumor endoprostheses and no unipolar hemiarthroplasties were used in any of the study patients. Mean body mass index was 28 kg/m^2 (range, 14–45 kg/m^2). More patients had primary bone sarcomas (74 patients [50%]) than metastatic disease (65 patients [44%]) or hematologic malignancies (nine patients [6%]; Table 1). The mean resection length of the femur was

Table 1. Diagnosis at the time of proximal femoral replacement

Diagnosis	Number
Primary sarcomas	n = 74
Chondrosarcoma	28
Osteosarcoma	15
Ewing sarcoma	8
Pleomorphic sarcoma	6
Leiomyosarcoma	5
Fibrosarcoma	4
Undifferentiated sarcoma	3
Synovial sarcoma	2
Liposarcoma	2
Alveolar soft part sarcoma	1
Hematologic malignancies	n = 9
Multiple myeloma	7
Lymphoma	2
Metastatic disease	n = 63
Renal	27
Lung	11
Breast	7
Colon	3
Uterine	3
Prostate	2
Melanoma	2
Salivary gland	2
Ovarian	1
Adrenal	1
Neuroendocrine	1
Adenocarcinoma of unknown primary	1
Squamous cell carcinoma of unknown primary	1
Germ cell tumor	1

19 cm (range, 5–47 cm). Forty-eight patients (32%) received radiation therapy (19 postoperative, 28 preoperative, and three pre- and postoperative), and 74 patients (50%) were treated with chemotherapy.

Of the 74 patients with primary bone sarcoma, five (7%) had metastases at diagnosis so oncologic outcome was analyzed in the remaining 69 patients. Chondrosarcoma (28 patients) and osteosarcoma (15 patients) were the most common primary tumor pathologies. The mean tumor size was 11 cm (range, 3–34 cm) and the mean tumor volume was 513 cm^3 (range, 17–3691 cm^3). Forty-four of the primary tumors (59%) were considered high grade. A negative surgical margin (R0) was obtained in 73 patients (99%). One patient with dedifferentiated chondrosarcoma had a microscopically positive surgical margin and received postoperative chemotherapy but still developed a local recurrence. Thirty-five patients (47%) with bone sarcomas underwent chemotherapy within 3 months of their arthroplasty. Five patients received neoadjuvant radiation, one patient received adjuvant radiation, and two patients received combined neoadjuvant and adjuvant radiation. The mean proximal femoral resection length was 21 cm (range, 6–47 cm).

Patients were followed at regular intervals during the study using the total joint and tumor registries at their respective institutions to evaluate for death, implant revision and reoperation, complications, tumor recurrence, or amputation. Patients were followed for tumor recurrence every 3 months for the first 2 years postoperatively with a physical examination and plain radiographs of the pelvis, hip, and femur along with chest CT scans or chest radiographs, depending on the tumor histology. The patients were then seen in the clinic at 6-month intervals for postoperative years 2 to 5 and annually until 10 years after tumor resection.

Surgical Procedures

Limb salvage was performed when preoperative imaging suggested that it was possible to achieve a negative surgical margin and provide the patient with a functional extremity.

All surgical procedures were performed by orthopaedic oncology subspecialty surgeons. Of the reconstructions, 110 (74%) were cemented. If the hip capsule remained after tumor resection and endoprosthetic reconstruction, the surgeon repaired it using a pursestring suture around the neck of the prosthesis. Alternatively, if the capsule was deficient and could not be repaired, as was the case for 29 patients (20%), it was augmented with synthetic mesh (Marlex; BARD Davol, Minneapolis, MN, USA) as previously described [25]. In addition, based on the amount of remaining hip abductor and quadriceps musculature, the muscles were repaired to the proximal portion of the prosthesis or to the iliotibial band with either Ethibond (Ethicon, Somerville, NJ, USA) or FiberWire® (Arthrex, Naples, FL, USA) sutures as previously described [35]. Greater trochanter fragments were included in the abductor repair if present. All hip reconstructions during the study period at the participating institutions were performed using bipolar endoprostheses. No unipolar hemiarthroplasties or THAs were performed during this period.

Assessment of Study Outcomes

We defined revision as any surgery resulting in removal and/or replacement of the hip components because of acetabular wear. We defined reoperation as any surgical procedure performed on the hip where the arthroplasty

components were retained. Data were drawn from institutional databases and chart review (by MTH and AMG).

We defined acetabular erosion as the change in acetabular cartilage thickness based on the magnification-corrected supine radiographs using templating software (Merge OrthoCase™, IBM Watson Health Imaging, Chicago, IL, USA; and OrthoView, Carestream Health Inc, Rochester, NY, USA) postoperative and most recent AP hip radiographs as previously described [24] before review of the patient's status (MTH, OSD); protrusio was defined as medial migration of the acetabulum > 3 mm in males and > 6 mm in females past the ilioischial line [1, 24]. Kappa value was not assessed.

The MSTS scores were collected through a combination of chart review and a review of a longitudinally maintained institutional database (MTH, AMG). A comparison of the MSTS score was made between patients with an erosion > 2 mm and those without erosion.

Statistical Analysis

We used unpaired Student's t-tests to assess continuous variables and compared categorical variables with Fisher's exact test and odds ratios (ORs). We used competing risk analysis in which death was considered as a competing risk to implant revision for acetabular wear, erosions, or progressive arthritis to analyze revision over time. Cumulative incidence functions and Gray's test were used for comparing competing risks by age group. MSTS scores [12] were calculated for patients at their last clinical followup. All tests were two-sided. Probability values < 0.05 were considered statistically significant. Analyses were performed using R 3.4.3 (R Core Team, Vienna, Austria).

Results

Proportion of Patients Developing Acetabular Erosions

Overall, postoperative radiographic evaluation of 148 patients revealed acetabular erosion (Fig. 1A-B) in 52 patients (35%). The mean change in acetabular cartilage thickness was 1.2 mm (range, 0–49 mm). However, 21 patients (14%) had > 2 mm of acetabular cartilage erosion. Of these patients, two also demonstrated acetabular protrusio. In addition, three patients developed protrusio without acetabular erosion > 2 mm. There was no difference in the proportion of patients with acetabular migration > 2 mm based on age at the time of surgery (55 ± 15 years versus 56 ± 18 years, p = 0.89) or treatment with preoperative (four of 21 [19%] versus 26 of 127 [20%]; OR, 0.91; 95% confidence interval [CI], 0.28-2.94; p = 1.0) or postoperative (four of 21 [19%] versus 18 of 127 [14%]; OR, 1.42; 95% CI, 0.43-4.72; p = 0.74) radiotherapy or chemotherapy (10 of 21 [48%] versus 64 of 127 [50%];

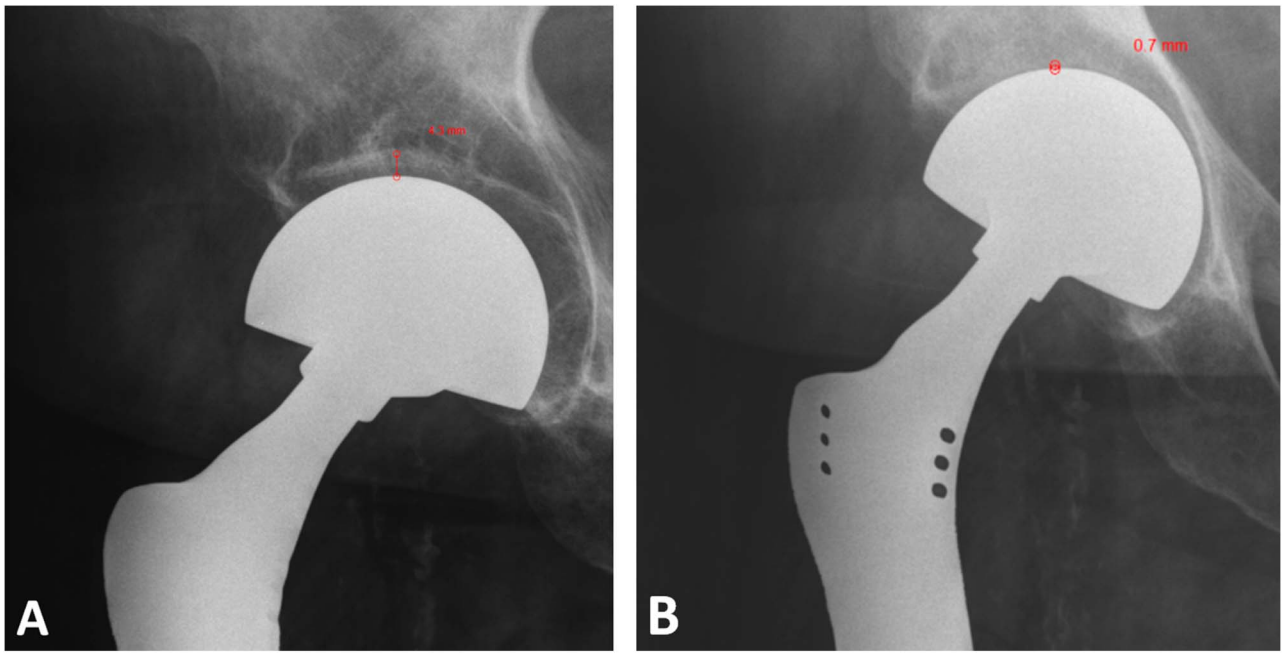

Fig. 1A-B The images show magnification-corrected AP hip radiographs from a patient (**A**) immediately after surgery and (**B**) 7 years later. Measurement of the acetabular cartilage thickness postoperatively was 4.3 mm; however, this decreased to 0.7 mm at last followup, a 3.6-mm change.

Table 2. Cumulative risk of revision to THA as a result of symptomatic hip pain

Resulting risk	2 years	5 years	10 years	15 years
Revision to THA (95% CI)	0% (0%-0%)	2 % (-1% to 4%)	5% (0%-11%)	9% (0%-19%)
Death (95% CI)	46% (37%-54%)	57 % (49%-66%)	70% (61%-79%)	70% (61%-79%)

CI = confidence interval.

OR, 0.89; 95% CI, 0.35-2.25; p = 0.99). However, we note that patients with acetabular erosion > 2 mm had a mean followup of 8 ± 5 years compared with 4 ± 3 years for those with less acetabular wear (p < 0.001).

Survivorship Analysis

The cumulative incidence of revision to THA for hip pain at the 2-, 5-, 10-, and 15-year postoperative marks was 0% (95% CI, 0%-0%), 2% (95% CI, -1% to 4%), 5% (95% CI, 0%-11%), and 9% (95% CI, 0%-19%), respectively (Table 2). During the same time period, the cumulative incidence of death at the 2-, 5-, 10- and 15-year postoperative marks was 46% (95% CI, 37%-54%), 57% (95% CI, 49%-66%), 70% (95% CI, 61%-79%), and 70% (95% CI, 61%-79%) (Fig. 2). Based on patient age (Table 3), patients < 50 years of age were at increased risk of death (p < 0.001) compared with patients ≥ 50 years of age at the time of surgery (Fig. 3). However, there was no difference (p = 0.43) in the cumulative incidence of conversion of a bipolar hemiarthroplasty to THA in patients < 50 years compared with those ≥ 50 years of age (Fig. 3). Of 148 patients, a total of six (4%) underwent revision of their endoprosthetic replacement to treat symptomatic hip pain and/or arthritis (range, 3–15 years). Six were the result of groin pain with or without arthritis. Revision was performed on three patients with a history of a primary bone sarcoma, two with metastatic disease, and one with a hematologic malignancy.

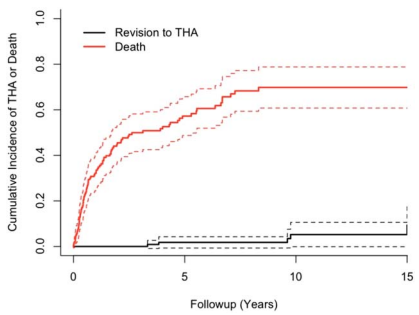

Fig. 2 The graph shows the cumulative incidence of death and revision to THA after bipolar endoprosthetic replacement of the proximal femur with a 15-year incidence of 70% and 9%, respectively.

Association Between Erosions and MSTS Scores

There was no difference in MSTS scores between patients who developed > 2 mm of acetabular erosion (65% ± 25%) and those who did not (67% ± 20%; p = 0.77). At the most recent followup, the mean MSTS score was 58% ± 26% for the study group.

Discussion

Endoprosthetic replacement has become the primary form of reconstruction after resection of a proximal femoral malignancy because it allows for early return to weight-bearing and improved functional status [4, 16, 21, 26, 30, 32, 36, 38]. This type of reconstruction is often performed using a bipolar hemiarthroplasty component to decrease the risk of instability. Although proximal femoral endoprostheses have been used for > 40 years, the long-term consequences, and particularly the rate of conversion to THA because of acetabular erosions, have not been well described. The results of this study demonstrated that the rate of conversion from bipolar hemiarthroplasty to THA was low (8%), especially when considering only acetabular erosion (5%).

The study has certain limitations. It was a retrospective study, which limited the data we were able to collect and the statistical analysis we were able to perform. However, our longitudinally maintained arthroplasty and tumor registries reduced the study's recall and selection bias. Although the oncologic resections were based on the local extent of tumor involvement, we were unable to investigate the resultant size of the soft tissue defect and subsequent indications for prosthetic choice, and as such, we cannot comment on the influence of these variables on this study. Although this study combined patients from two large tertiary sarcoma centers, all procedures were performed by orthopaedic oncology subspecialty surgeons, so the indications and surgical techniques were likely very similar. Likewise, for a majority of the patients in the study, the followup was short because a substantial number of patients died of disease. As such, the proportion of patients who might develop erosions after this operation might be underestimated. This will not be a concern for most patients who receive these implants, because it appears that most

Table 3. Cumulative risk of revision to THA resulting from symptomatic hip pain based on age

Age (years)	Resulting risk	2 years	5 years	10 years	15 years
< 50	Revision to THA (95% CI)	0% (0%-0%)	0% (0%-0%)	5% (-5% to 15%)	17% (-8% to 43%)
	Death (95% CI)	36% (23%-50%)	46% (31%-61%)	46 % (31%-61%)	46% (31%-61%)
≥ 50	Revision to THA (95% CI)	0% (0%-0%)	3% (-1% to 7%)	5% (-1% to 11%)	5% (-1% to 11%)
	Death (95% CI)	51% (40%-61%)	63% (53%-74%)	83% (73%-93%)	83% (73%-93%)

CI = confidence interval.

will die before erosions develop; however, for those patients who survive for longer periods, it could well be a clinical concern. Another factor that might have caused us to underestimate the loss of acetabular cartilage was our use of nonweightbearing supine plain radiographs as the means of assessment; these may not be as sensitive as other modalities to detect small amounts of cartilage loss. However, radiographs are the most commonly used surveillance tool in practice, very small amounts of cartilage loss are unlikely to result in severe symptoms, and we also looked at conversion to THA and MSTS scores to ensure that we evaluated the clinical impact of acetabular erosions in these patients.

Although the incidence of protrusio was examined, the difference in the medial joint space over time was not nor was the incidence of condensation of the bony trabeculae of the acetabulum, which may herald acetabular erosion. In addition, a formal grading scale of the degenerative changes of the acetabulum was not assessed. The study examined the functional outcomes of the patients, but the impact of acetabular erosions on quality of life was not assessed. Finally, the assessment of the relationship between acetabular erosions on MSTS scores was relatively crude (it was assessed categorically, comparing patients with more than or less than 2 mm of cartilage loss); given the small patient numbers and the imprecision in measurement on plain radiographs, it did not seem reasonable to assess it using a correlation analysis. There is every reason to think that acetabular cartilage wear will, at some level, be associated with pain and functional limitations; however, for most patients in this population, this surgical approach seemed to meet the need. However, for patients who will survive for longer periods, erosions may become a larger problem. Longer term studies will need to evaluate this.

Acetabular erosion after endoprosthetic replacement of the proximal femur with a bipolar hemiarthroplasty has not been commonly reported. Drexler et al. [11] found degenerative changes occurred in 4.6% (three of 65) and protrusio acetabuli in 13.8% (nine of 65) in 65 patients after hemiarthroplasty endoprosthetic replacement with 4.6% (three of 65) patients converted to THA to treat groin pain. The revisions in the series by Drexler et al. occurred at 26, 34, and 47 months after surgery [11]. By contrast, we noted a higher proportion of patients with degenerative changes (13%) but a lower frequency of protrusion (3%) in a larger series of 148 patients; however, we observed a similar rate of conversion of the bipolar hemiarthroplasty to THA (4% [six of 148]) because of degenerative changes and groin pain. However, we noted that with longer followup, the risk of conversion of bipolar hemiarthroplasty to THA increased. In the nononcologic setting, the proportion of patients undergoing conversion to THA to treat symptoms of degenerative arthritis has been reported to be up to 18% after initial hemiarthroplasty for hip arthritis or fracture

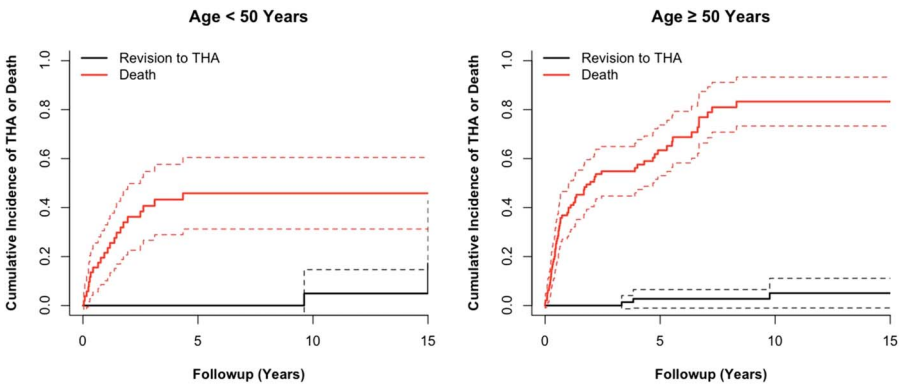

Fig. 3 The graph shows the cumulative incidence of death and revision to THA after bipolar endoprosthetic replacement of the proximal femur based on patient age (≥ or < 50 years of age). For patients < 50 years, the 15-year incidence was 17% and 46%, whereas for patients ≥ 50 years, the 15-year incidence was 5% and 83%, respectively.

[2, 29, 39]. Although we noted a higher rate of degenerative changes than has been previously reported after reconstruction with a bipolar hemiarthroplasty for a proximal femoral malignancy, at the current followup, this did not seem to result in worse functional outcomes based on MSTS scores.

Of the 148 patients in this study, conversion of a bipolar hemiarthroplasty to THA was in six patients with symptomatic hip pain and degenerative joint disease with a 10-year cumulative risk of conversion to THA to treat symptomatic acetabular erosions of 5% (95% CI, 0%-11%). This finding is similar to other reports of proximal femoral endoprostheses [11, 14, 18, 27]. In randomized controlled trials of patients with femoral neck fractures, however, the rate of conversion from bipolar hemiarthroplasty to THA for symptomatic osteoarthritis is 4% to 10%, which seems similar to the results of this study [2, 39]. Because the overall rate of conversion to THA was so low, we do not advocate for the use of primary THA after proximal femoral resection for cancer.

Endoprosthetic replacement of the proximal femur is a functionally successful procedure for most patients [13, 14, 18, 26, 30, 40] and in the current series, radiographic changes in acetabular erosion were not indicative of the patients' functional outcome based on the MSTS score. After hemiarthroplasty, functional improvement based on the Harris hip score has been found to peak 1 to 2 years after the index procedure [2, 7, 22, 31]. In prospective randomized studies comparing a bipolar hemiarthroplasty with a THA for patients with displaced femoral neck fractures, it has been found that erosion can be a problem, necessitating revision to THA [2, 3]. Likewise, Pellegrini et al. [29] noted that although radiographic evidence of cephalad or medial migration of a bipolar hemiarthroplasty occurred, it did not correspond with pain, satisfaction, or clinical outcome measures, similar to the outcome of the current series.

Overall, the rates of acetabular erosion and conversion to THA were low after endoprosthetic reconstruction of the proximal femur using bipolar hemiarthroplasty. Although some patients may demonstrate radiographic evidence of acetabular cartilage wear, with the current followup, it does not typically affect their functional outcome. Studies with longer clinical followup are needed to determine if the expected increased incidence of continued acetabular erosion translates into clinical impairment.

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