Background: Reconstruction of bone after the resection of a pelvic tumor is challenging. The purpose of the present study was to evaluate the use of the ipsilateral femur as the graft material for reconstruction.

Methods: We performed a retrospective review of thirteen patients with a malignant pelvic lesion who underwent resection followed by reconstruction with an ipsilateral femoral autograft and insertion of a total hip replacement. The study group included nine men and four women with a median age of fifty-one years at the time of the reconstruction. The diagnosis was chondrosarcoma in eight patients, metastasis in three, and myeloma and radiation-induced malignant disease in one each. The surviving patients were assessed functionally and radiographically; the cumulative probability of revision was estimated while taking into account competing risks.

Results: The median duration of follow-up was forty-nine months. At the time of the latest follow-up, seven patients were alive and disease-free and six had died from metastatic disease. Four patients had had revision of the reconstruction, two for the treatment of mechanical complications and two for the treatment of infection. Three other patients had mechanical complications but had not had a revision. The cumulative probability of revision of the reconstruction for mechanical failure was 8% (95% confidence interval, 0% to 23%), 8% (95% confidence interval, 0% to 23%), and 16% (95% confidence interval, 0% to 39%) at one, two, and four years, respectively.

Conclusions: Although it has attendant complications consistent with pelvic tumor surgery, an ipsilateral femoral autograft reconstruction may be an option for reconstruction of pelvic discontinuity in a subgroup of patients following tumor resection. This innovative procedure requires longer-term follow-up studies.

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

Demographic Data

From 1994 to 2005, thirteen patients with a malignant pelvic lesion underwent resection followed by reconstruction with use of an ipsilateral femoral autograft. The study group included nine men and four women with a median age of fifty-one years (range, twenty-two to seventy-two years), a median body weight of 73 kg (interquartile range, 60 to 84 kg), and a median height of 176 cm (interquartile range, 168 to 185 cm) at the time of the index reconstruction. The right limb was affected in seven patients. One patient presented with a pathologic fracture of the acetabulum.

The diagnosis was chondrosarcoma in eight patients, metastasis (from the lung, kidney, and an unknown origin) in three, and myeloma and radiation-induced malignant disease in one each. At the time of reconstruction, metastases were detectable in three patients and contamination of the joint with tumor was suspected in one. Perioperative chemotherapy was used for four patients, perioperative radiation therapy was used for three, and immunotherapy was used for one. The preoperative data for each patient are reported in a table in the Appendix.

The functional result was assessed with the scoring system of Merle d’Aubigné and Postel, a clinician-rated measure of hip function. The score has a possible range from 3 to 18 points, with 18 being the best score; 6 points are attributed to hip range of movement, 6 points are attributed to pain, and 6 points are attributed to walking ability. The highest score that was reached after the operation was considered for patients who had a recurrence, and the score at the time of the latest follow-up was considered for patients who were alive and disease-free. Heterotopic ossification was graded according to the system of Brooker et al. by an independent radiologist (F.T.). The three pelvic regions were determined, according to the system of Enneking and Dunham, as zone I (the iliac wing), zone II (the periacetabular region), and zone III (the pubic region). Plain anteroposterior, lateral, and oblique radiographs (including ala and obturator foramen views) were used to assess union at the proximal and distal host bone-autograft junctions.

Surgical Technique

The surgical technique involved resection of the tumor (Fig. 1-A), reconstruction of the pelvic defect with an ipsilateral...
femoral autograft (Fig. 1-B), and insertion of a conventional total hip replacement (Fig. 1-C) by means of a combined anterior and posterior surgical approach. Resection of the tumor was not specific and conformed to principles for the treatment of malignant bone tumors.

After tumor resection, the iliopsoas tendon was detached from the lesser trochanter and then the bone that was to be used as the femoral autograft was harvested from the femur. The greater trochanteric region was left on the femur with the insertion of the gluteus medius and vastus lateralis muscle tendons.

The femoral head was fitted against the ilium, and the femoral diaphysis was fitted against one of the pubic rami or the pubic symphysis, with the remaining trochanteric process facing downward. The graft was fixed to the pelvis with one or more osteosynthesis plates. A new acetabulum was prepared in the remaining trochanteric process in the usual manner described for all-polyethylene cups. More recently, we have used an acetabular metallic reinforcement ring (Stryker Benoist Girard, Herouville Saint Clair, France) to provide better mechanical stability.

Finally, a long cemented stem was inserted in the femur, as is done for conventional total hip replacement. Limb length was adjusted on the basis of measurements that had been made before the resection. The defect along the medial part of the femur was treated with an allograft (either two halves of a femoral head or a proximal femoral allograft) that was fixed with two wires.

The median duration of the operation was 290 minutes (interquartile range, 280 to 350 minutes), the median number of intraoperative red blood cell units transfused was four (interquartile range, three to eight), the median stem length was 200 cm (range, 200 to 250 cm), and the median cup diameter was 40 mm (range, 40 to 48 mm). Contamination of the joint with tumor was found in three patients (including one patient in whom the contamination was suspected on the basis of
preoperative images that demonstrated a pathologic fracture of the acetabulum), and contaminated surgical margins were found in one patient.

Postoperative care included pain management, operative site care, and anticoagulation until weight-bearing was resumed. To allow for healing of the soft tissues and to minimize the risk of dislocation, a coaptation-suspension was installed for two weeks, followed by a spica cast for six weeks; for coaptation, as opposed to traction, the lines are directed in such a way that the forces push the femoral head into the acetabulum. Weight-bearing resumed after two months.

Statistical Analysis
The cumulative probability of reconstruction failure was estimated with revision of the reconstruction (graft, femur, or acetabulum) for any reason and revision of the reconstruction for mechanical failure as the end points. Survival was estimated with the cumulative incidence function because it has been shown to be more adequate than the Kaplan-Meier estimator in the context of limb salvage surgery\(^1\). Failure of the reconstruction because of infection was considered as a competing event when estimating revision of the reconstruction for mechanical failure, and death of the patient was considered as a competing event to both end points. For quantitative variables (continuous variables), we report the median and first and third quartile values (or range when appropriate). Categorical variables are reported as counts.

Source of Funding
There was no source of outside funding for this study.

Results
Follow-up
The median duration of follow-up was forty-nine months (range, twelve to 107 months). At the time of the latest follow-up, seven patients were alive and disease-free and six had died from metastatic disease. Five patients had postoperative complications, which included one case of wound necrosis requiring surgical débridement, one superficial wound infection requiring débridement and lavage, one deep-vein thrombosis, one postoperative dislocation during immobilization in the spica cast, and one transient sciatic nerve palsy. The median length of hospital stay was twenty-seven days (interquartile range, fifteen to thirty days). No postoperative deaths were related to the procedure. Figures 2-A, 2-B, and 2-C illustrate the results of one patient (Case 4; see Appendix) at 107 months of follow-up. The median Merle d’Aubigné and Postel score was 15 points (interquartile range, 13.8 to 17.0
seven patients used one or two canes to walk. Two patients had a 2-cm limb-length discrepancy, and the others had <1 cm of discrepancy. Heterotopic ossification was classified as grade 0 in six patients, grade 1 in two, grade 2 in one, grade 3 in three, and grade 4 in one. Six patients showed no or little evidence of bone incorporation (<25% on two orthogonal views) at the allograft-femoral host bone junction, and five allografts showed signs of resorption.
Mechanical Complications of the Reconstruction

Five patients had mechanical complications, with two undergoing revision of the reconstruction. One patient (Case 5) showed radiographic evidence of acetabular loosening with cup migration and underwent revision thirty-five months after the index procedure. At the time of revision, the cup was found to be loose but there were no signs of mechanical failure of the graft. An acetabular metallic reinforcement ring was added to the reconstruction, and a 44-mm all-polyethylene cemented cup was implanted. The patient had a dislocation three and one-half months after the revision procedure. It was reduced with the patient under anesthesia, and no further episodes of dislocation occurred. Four years after the revision procedure (seven years after the index procedure), the patient had no radiographic signs of loosening of the cup and no signs of failure of the reconstruction. One patient (Case 8) had failure of the reconstruction with fracture of the graft and loosening and migration of the cup ten months postoperatively (Figs. 3-A through 3-D). During revision, the fracture was bridged with a femoral head allograft, an acetabular metallic reinforcement ring was added to the reconstruction, and an all-polyethylene 42-mm cemented cup was implanted. However, the patient had a postoperative posterior dislocation, and another revision procedure was performed one month later. The pelvic reconstruction was left intact, the cup was exchanged for an all-polyethylene 44-mm cemented constrained cup, the stem was positioned higher and was fitted with a long neck (+3 mm), and an artificial ligament (Ligastic; Orthomed, Saint Jeannet, Alpes Maritimes, France) was added to the reconstruction to limit internal rotation. This ligament was placed posterior to the hip joint, from the acetabulum to the greater trochanter, and was stretched at neutral hip rotation. At the time of the latest follow-up, six years after the index reconstruction, the patient had not had another hip dislocation and only breakage of the reinforcement ring at the level of the hook could be seen radiographically (Fig. 3-D). Another patient (Case 10) had fracture of the graft with slow migration of the cup. At fifty-two months, the patient complained of moderate pain and walked with two canes but had not opted for a revision procedure. Two other patients (Cases 9 and 12) had delayed union at the autograft-host bone junction. For both patients, stabilization of the reconstruction eventually occurred with bone union.

Revision of the Reconstruction

Four patients had revision of the reconstruction. Two patients (Cases 5 and 8) underwent revision to treat mechanical complications (as described above), and two underwent revision to treat infection. One patient (Case 7) had development of an infection and underwent débridement, lavage, and antibiotic therapy five months after the reconstruction. However,
Plain radiographs showing a grade-2 chondrosarcoma of the pelvis (zone II) in a fifty-year-old man (Case 8; see Appendix). Figs. 3-B and 3-C Immediate postoperative (Fig. 3-B) and ten-month postoperative (Fig. 3-C) plain radiographs demonstrating cup loosening with tilting and migration of the acetabular component. The reconstruction was revised with a new cemented cup and a reinforcement ring (Fig. 3-C).
Fig. 3-D Seventy months after the index reconstruction, the autograft has united to the pelvis and there are no signs of loosening.
the infection could not be eradicated and a resection arthroplasty was done nine months later. The patient died from multiple metastases three and one-half years after the resection arthroplasty. Another patient (Case 11) had recurrent hip dislocations, and a constrained cup was implanted. Subsequently, the patient had development of an infection, which could not be eradicated with lavage and débridement. The patient underwent a resection arthroplasty twelve months after the index reconstruction. The patient died from disease with multiple metastases at twenty-one months of follow-up.

**Cumulative Probability of Revision, Local Recurrence, and Reoperations**

The cumulative probability of revision of the reconstruction for any reason was 15% (95% confidence interval, 0% to 36%), 23% (95% confidence interval, 0% to 47%), and 32% (95% confidence interval, 4% to 59%) at one, two, and four years, respectively. The cumulative probability of revision of the reconstruction for mechanical failure was 8% (95% confidence interval, 0% to 23%), 8% (95% confidence interval, 0% to 23%), and 16% (95% confidence interval, 0% to 39%) at the same follow-up times. Four patients had local tumor recurrence (three with clinical signs and one on imaging studies). Three of these patients had development of multiple metastases at the same time and died from the disease. The fourth patient had local recurrence that was diagnosed during surgical exploration for the evaluation of increasing pain at the reconstruction level; he died from multiple metastases shortly thereafter. Other reoperations included the treatment of a foreign-body reaction created by a subcutaneous suture (one patient) and an exploration for local recurrence, with a negative result (one patient). Two patients had a single dislocation each; both dislocations were reduced without further recurrence.

**Discussion**

Mechanical failure has been commonly reported following partial pelvic resection, regardless of the reconstruction that has been chosen. In the present series, mechanical failure necessitating additional surgery occurred in two of thirteen patients. The mechanical complications in our series may be attributed in part to technical flaws and the so-called learning curve and possibly could be avoided with improvement in the surgical technique. Inadequate fixation of the autograft to the pelvic bone or insufficient support of the acetabular component likely played a role in the mechanical failures seen in these patients. Fixation of the autograft is currently achieved with use of a single long plate securing a minimum of four cortices at each end, and we systematically use a reinforcement ring in the reconstruction to decrease the risk of cup loosening. In some cases, the ipsilateral femoral autograft reconstruction may not always be adequate. First, this procedure is adapted for reconstruction of Enneking zone-II defects and combined zone-II and III defects owing to the natural curvature of the proximal part of the femur that fits adequately into the defect. However, when the resection extends into zone I (above the level of the inferior part of the sacroiliac joint), the stability created by the construct is likely to be insufficient and abductor function is often compromised by soft-tissue resection. Therefore, if the tumor extends into zone I, an ischiofemoral or iliofemoral arthrodesis is probably more appropriate. Second, the limited size of the trochanteric area does not allow for a large cup, and all cup failures in the present series were seen in association with the smallest-diameter cups (40 mm). The anteroposterior size of the proximal part of the femur should be checked before the procedure is attempted so as to avoid cementation of too small a cup. If necessary, the reconstruction can be supplemented with allograft bone.

Infection and local recurrence are major concerns after the operative treatment of malignant tumors of the pelvis. In the present series, three patients had development of an infection, with two of them having a deep infection and requiring resection of the reconstruction to eradicate it. Reported infection rates after massive pelvic allograft reconstruction have ranged from 12% to 15% in series ranging in size from thirteen to twenty-four patients and from 12% to 18% in series of seventeen patients following the implantation of a saddle prosthesis. Abudu et al. reported a 26% infection rate in a series of thirty-five patients undergoing endoprosthetic reconstruction. Four of the thirteen patients in our series had local tumor recurrence, which is similar to the results found in the literature, with rates ranging from 18% to 29% in series ranging in size from thirteen to thirty-five patients. One patient who had a local recurrence was noted to have had contamination of the joint with tumor at the time of resection. Preoperative magnetic resonance imaging can be helpful for determining whether joint contamination is present.

There is no ideal option for the reconstruction of a major defect after the resection of a bone tumor from the pelvis. Massive allografts are very attractive as they provide anatomical reconstruction and an osteoarticular allograft. However, fractures, transmission of infectious diseases, and the absence of incorporation in the long term have hindered their use. Pelvic endoprostheses provide an immediate reconstruction and have limited mechanical complications in the short term. However, they are expensive, are associated with a high risk for infection, and are nonbiologic. In a review of fifty patients who were managed operatively for a pelvic tumor, Zeifang et al. reported that endoprosthetic reconstruction was associated with comparatively lower implant-related complication rates as compared with biologic reconstructions. Hillmann et al., in a retrospective review of 110 patients who were managed operatively for a pelvic tumor, reported that infection was more frequent after endoprosthetic reconstruction (38%) and massive allograft reconstruction (38%) as compared with autograft reconstruction (8%). However, comparisons should be made with caution because, in both of those studies, there were differences among the groups with regard to tumor size, resection type, and adjuvant treatment, and the sizes of the series were limited.
In summary, we believe that the ipsilateral femoral autograft reconstruction is an attractive option for a zone-II and/or a combined zone-II and III pelvic defect and should be added to the armamentarium of tumor surgeons. However, the technique should be rigorously performed to minimize the risk of complications. Preoperative magnetic resonance imaging and intraoperative frozen-section analysis should be done to ensure that there is no joint contamination. The autograft should be stabilized with a plate and screws, with four cortices fixed at each extremity in the host bone, and a reinforcement acetabular ring should always be used.

Appendix

A table presenting clinical details is available with the electronic version of this article, on our web site at jbjs.org (go to the article citation and click on Supplementary Material) and on our quarterly CD/DVD (call our subscription department, at 781-449-9780, to order the CD or DVD).

References