Internal Hemipelvectomy for Pelvic Sarcomas Using a T-incision Surgical Approach

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Abstract Internal hemipelvectomy is performed for pelvic sarcomas when the tumor can be safely resected without sacrificing the entire extremity. Wide exposure and awareness of major neurovascular structures are crucial to the success of this surgery. Various modifications on the standard utilitarian approach have been used to best achieve these goals. We reviewed our experience using the T-incision technique for 30 pelvic sarcoma resections. The minimum followup was 3.6 months (mean, 55 months; range, 3.6–185.4 months). Postoperative complications included minor complications (requiring no surgery or a simple incision and drainage with primary closure) in 27% of patients and major complications (involving a deep infection or more extensive surgical treatment) in 17%. Ninety-two percent of wound complications healed uneventfully with antibiotics and incision and drainage.

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Each author certifies that his or her institution has approved or waived approval for the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research.
This work was performed at Pennsylvania Hospital at the University of Pennsylvania.

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The 2-, 5-, and 10-year patient survival rates were 67%, 59%, and 53%. The 2-, 5-, and 10-year disease-free survival rates were 68%, 42%, and 42%. The mean Musculoskeletal Tumor Society and Toronto Extremity Salvage Scores were 69% and 86%, respectively. We believe the T-incision technique for internal hemipelvectomy is an effective surgical approach for pelvic sarcomas when limb salvage is possible.

Level of Evidence: Level IV, therapeutic study. See the Guidelines for Authors for a complete description of levels of evidence.

Introduction

Internal hemipelvectomy involves local resection of a lesion including all or part of the hemipelvis while preserving the ipsilateral lower extremity. Enneking and Dunham [10] described a classification system for pelvic resection of sarcomas based on the section or sections of bone removed (iliac, periacetabular, or pubic) and the degree of resection (wide or radical). The traditional external hemipelvectomy (hindquarter amputation), in contrast, involves resection of the innominate bone and the entire lower extremity. Both types of hemipelvectomy are performed for primary bone and soft tissue sarcomas and occasional metastatic lesions involving the pelvis [5, 18, 24], with primary bone malignancies being the most common indication [4]. Internal hemipelvectomy is performed when the tumor does not involve the major neurovascular structures of the lower extremity, so that a functional limb can be preserved without compromising the wide resection needed to minimize the risk of tumor recurrence [1, 14, 15, 19]. In cases that would have a high likelihood of resulting in a paralyzed or insensate limb after

wide or radical resection of the tumor, an external hemipelvectomy may be more appropriate. External hemipelvectomy also is favored in palliative cases for which a prolonged recovery period is undesirable [10].

The incision described by Enneking and Dunham [10] is regarded as the standard approach for internal hemipelvectomy [5]. The incision begins at the posterior-inferior iliac spine, runs along the iliac crest and inguinal ligament, turns distally at the femoral vessels, and curves laterally around the thigh to end just posterior to the femoral shaft at the junction of the proximal and middle thirds of the thigh [10]. The incision also can be extended the remaining distance of the inguinal ligament to provide exposure to the pubic symphysis [10]. Since this approach was described in 1978, various modifications have been described [5, 18, 23, 27]. These modifications attempt to improve surgical exposure and minimize risk to major neurovascular structures, two goals crucial to the success of the surgery [5]. In the T-incision modification, the “T” is located much more laterally than the turning point of the universal incision, and the vertical limb runs straight down the lateral thigh rather than turning posteriorly (Fig. 1). The T-incision represents a different anatomic approach and is more extensile anterior to posterior in light of the resulting open-book exposure. Despite this, only Karakousis et al. [20], described a similar approach and its use for pelvic sarcomas [1, 2, 17, 18, 20]. In our experience, the T-incision technique for internal hemipelvectomy achieves the goals stated above and leads to reasonable patient outcomes.

Our aims therefore were to characterize (1) the incidence of postoperative complications; (2) rates of recurrence,

disease-free survival, and overall survival; and (3) functional scores associated with the T-incision internal hemipelvectomy in patients with pelvic sarcomas.

Materials and Methods

We retrospectively reviewed the medical records of all 49 patients who underwent internal hemipelvectomy performed between 1989 and 2006. Inclusion criteria were (1) wide resection internal hemipelvectomy performed using the T-incision technique; (2) biopsy-confirmed diagnosis of sarcoma; (3) complete clinical, radiographic, and pathologic records (ie, patients with missing data were not included in the study); and (4) minimum followup of 2 years or until death of the patient. Thirty of 49 patients (14 males, 16 females) met all inclusion criteria. The mean age of the patients at the time of surgery was 41 years (range, 13–76 years). Diagnoses included 12 osteosarcomas (40%), nine chondrosarcomas (30%), four Ewing’s sarcomas (13%), three primary leiomyosarcomas of bone (10%), one recurrent liposarcoma (3%), and one soft tissue sarcoma not otherwise specified (3%). The two soft tissue sarcomas directly involved the bony pelvis necessitating internal hemipelvectomy to obtain wide margins. Twenty-four sarcomas were high grade (80%), three were intermediate grade (10%), and three were low grade (10%). Followup was calculated from the date of the internal hemipelvectomy to the date of the most recent patient encounter or death. The minimum followup was 3.6 months (mean, 55 months; range, 3.6–185.4 months). No patients were seen in followup specifically for this study. We obtained prior IRB approval.

Preoperative workup consisted of history and clinical examination, routine laboratory tests, imaging studies of the pelvis, including plain radiography and computed tomography or MRI, and biopsy. The use of adjuvant chemotherapy was based on sarcoma type and individual patient characteristics. Twenty-one patients received preoperative and/or postoperative chemotherapy, and nine patients did not receive chemotherapy. Before surgery, films were reviewed carefully to plan osteotomy sites and soft tissue resection planes to obtain appropriately wide gross margins.

All surgery was performed by the senior surgeon (RDL). At the time of surgery, the patient was placed in the supine position for induction of general endotracheal anesthesia and for placement of ureteral stents by a urologist. Ureteral stents were placed in all patients (unilateral or bilateral as indicated). The presence of the stent facilitates intraoperative identification of the ureter and as such is a valuable addition to the procedure. In addition, in our experience, there has been no morbidity associated with placement of

Fig. 1 This illustration depicts the T-shaped incision used in this series of internal hemipelvectomies.

ureteral stents. The patient then was moved to a loose lateral decubitus position (ie, positioned to allow some rotation of the trunk and pelvis) and stabilized with a bean bag. The abdomen, hip, pelvis, and leg on the affected side were prepped and draped in the standard fashion.

The first incision began at the pubic symphysis, continued over the inguinal ligament, and ran posteriorly along the superior margin of the iliac crest to end over the sacroiliac joint. The incision was carried down sharply through the skin and subcutaneous tissue using electrocautery for hemostasis. The intrapelvic dissection then was performed, usually by a general surgeon, to isolate the major neurovascular structures and separate any tumor present in the pelvis from surrounding viscera with grossly wide margins. Even when the pelvic viscera have not been invaded by the tumor, they must be dissected away carefully from the bony, muscular, and other soft tissue structures that will be removed with the tumor. Collaboration with a general surgeon for this part of the procedure is useful for the orthopaedic surgeon who routinely does not operate near the pelvic viscera and wants to ensure expert care for the patient throughout the surgery.

After the intrapelvic dissection was complete, a longitudinal incision was made over the proximal femur, extending superiorly over the greater trochanter and joining with the transverse incision to make a T-shaped incision (Fig. 1). This second incision was carried down through the fascia over the proximal femur and along the anterior pelvis enabling anterior and posterior flaps to be fashioned (Fig. 2). The gluteus maximus was separated from the gluteus medius and minimus by dissecting from distal to proximal, which facilitates this process. The inferior

Fig. 2 This shows the deep dissection and exposure for this approach.

gluteal vessels were protected while the superior gluteal vessels were sacrificed. The superior gluteal vessels were sacrificed because the muscles they serve, the gluteus medius and minimus, were resected with the tumor as the lateral margin. Occasionally, the gluteus medius was saved along with its blood supply via the superior gluteal artery when considered safe for complete tumor resection. The leg then was rotated internally and the short external rotators were incised and retracted. The sciatic nerve was exposed along its course and protected. Next, the leg was rotated externally and, with general surgery assistance, the dissection was carried along the anterior border of the pelvis. In doing so, the anterior muscles were removed extraperiosteally from the surface of the ilium. This included extraperiosteal incision of the origins of the sartorius, rectus femoris, and pectineus. The tensor muscle was reflected with the anterior flap. The femoral neurovascular bundle was protected throughout the dissection. One of the advantages of this approach is that it preserves anterior blood supply via the femoral vessels and posterior blood supply via the inferior gluteal vessels.

Pelvic resections were classified according to the Enneking and Dunham system [10] as follows: seven Type I resections (23%), zero Type II resections (0%), three Type III resections (10%), four Type I/II resections (13%), seven Type I/II/III resections (23%), and nine Type II/III resections (30%). All resections were designed to provide wide surgical margins while preserving as much healthy anatomy and function as possible. For all except Type I and Type III resections, which did not involve the hip, the hip capsule then was incised circumferentially and the ligamentum teres cut to allow temporary dislocation of the femoral head. The innominate bone was exposed fully as needed and the soft tissues protected at the planned osteotomy sites. Then, an oscillating saw was used to perform the pelvic osteotomies as indicated. Once the osteotomies were complete, the specimen was rotated gently out of the field with incision of any remaining soft tissue attachments. The specimen was oriented and sent to pathology for diagnosis and margin evaluation. The wound then was irrigated copiously with normal saline. Bone wax was placed over the bleeding bone surfaces if necessary, and electrocautery used to ensure hemostasis of the wound bed.

Twenty-three of the 30 (76%) patients had no reconstruction (Fig. 3). Five patients (17%) had an iliofemoral arthrodesis (Fig. 4), one (3%) had a pubofemoral arthrodesis, and one (3%) had a pelvic allograft reconstruction. When the remaining bone and tissues provided sufficient structure to support a flail hip, the incision was closed without reconstruction. If sufficient iliac bone stock remained to create a pseudarthrosis with the femoral head, Dacron (Mersilene®) tapes (Ethicon, Inc, Somerville, NJ) were placed between drill holes in the femoral head and the

Fig. 3 This 30-month postoperative radiograph shows a Type II/III resection that did not require pelvic reconstruction.

Fig. 4 This postoperative radiograph shows a Type II/III resection and iliofemoral arthrodesis.

remaining pelvis to provide temporary stabilization of the femoral head under the cut surface of the ilium. When further stabilization was needed, fixation of the femoral head to the remaining ilium (iliofemoral arthrodesis) or pubis (pubofemoral arthrodesis) was performed using screws or a plate. Finally, Jackson-Pratt drains were placed to prevent postoperative hematoma, and the wound was closed in layers in the usual fashion. We used no free or rotational flaps for closure. The mean estimated blood loss

was 1513 mL (range, 300–5000 mL). The mean surgical time was 290 minutes (range, 170–560 minutes).

Postoperatively, patients were instructed to remain nonweightbearing on the affected leg for a minimum of 6 weeks, after which physical therapy was initiated. The typical hospital stay was 1 to 2 weeks, with outpatient postoperative followup scheduled at 3 weeks, 6 weeks, 3 months, and then per usual tumor followup protocol. At followups, patients were monitored for local recurrence and metastasis using history, physical examination, and radiographic studies.

We recorded data regarding tumor history, operative time, surgical blood loss, postoperative complications, disease-free survival, overall survival, postoperative back pain and osteoarthritis, and postoperative shoe lift height. Complications were classified as major or minor. Superficial infections and wound dehiscences that resolved with no surgery or a single incision and drainage (I&D) were considered minor complications. Deep infections, reconstruction failures, and wound problems requiring more extensive surgical treatment were considered major complications. Patients alive at the time of data collection were contacted for functional evaluation using the Musculoskeletal Tumor Society (MSTS) 1993 rating scale [11] and the Toronto Extremity Salvage Score (TESS) [7]. The MSTS scale is a surgeon-assessed system that equally weighs six parameters on a scale of 0 to 5, with a total score of 30 representing highest function. The TESS is a patient-assessed score that rates the difficulty of activities of daily living on a scale of 1 to 5, with a total score of 100% representing highest function. As with most series of patients with pelvic sarcomas, many of our patients died before reaching intermediate- to long-term followup, and followup in the context of progressive disease would not have been relevant. As such, these patients were not available for functional outcome measurements.

Disease-free survival was calculated from the date of resection of all disease (date of internal hemipelvectomy or metastasectomy) to the date of local recurrence or metastasis. Overall survival was calculated from the date of internal hemipelvectomy to the date of the last patient encounter or death. Survival data were analyzed with a Kaplan-Meier product limit estimator (SPSS® v15.0; SPSS Inc, Chicago, IL) using the Kaplan-Meier method [16].

Results

Twenty-two patients (73%) had an uncomplicated postoperative course with normal wound healing (Fig. 5). Eight patients (27%) experienced a minor postoperative complication that required no surgery or a single incision and drainage with primary closure. Two of these minor

Fig. 5 This photograph shows a fully healed scar at 2 years after internal hemipelvectomy.

Fig. 6 This photograph shows the wound healing defect at the “T” of the incision.

complications were superficial infections and six were minor wound dehiscences, which involved a small defect and drainage at the “T” intersection (Fig. 6). Five patients (17%) experienced a major complication. Four patients had a deep infection and one patient had a reconstruction failure. Three of the deep infections were treated with one I&D whereas only one underwent hardware removal and multiple I&Ds for resolution of the infection. The reconstruction failure involved fracture of the iliofemoral fixation plate after 6 years, requiring conversion to a saddle prosthesis.

Continuous disease-free survival rates were 68%, 42%, and 42% at 2, 5, and 10 years, respectively. Surgical margins were positive in two patients (7%). Eight patients (27%) had local recurrence at a mean of 26 months. Five of these patients underwent further surgery (four amputations, one resection), and three of them were still alive at last followup. Five patients had metastatic disease before surgery. Four of these patients had resection of the metastases, but only one patient was alive at last followup. Five patients (17%) had metastases develop during postoperative followup at a mean of 25 months. Four of these patients died; one patient had lung metastasectomy and was alive with no evidence of disease at last followup. Thirteen patients (43%) had died of disease at last followup. The 2-, 5-, and 10-year overall survival rates were 67%, 59%, and 53%, respectively.

The mean MSTS score for 14 of the 17 living patients was 20.7 of 30 (69%, range, 17%–90%). The mean TESS score was 86% (range, 59%–99%). Ten percent of patients reported back pain and no patients had osteoarthritis of the contralateral hip or knee. The mean shoe lift height was 5.8 cm (range, 3.8–8.9 cm).

Discussion

Steel [27] and Eilber et al. [9] were among the first to attempt internal hemipelvectomy for sarcomas of the innominate bone. They established the technical feasibility of removing the hemipelvis while leaving the unaffected, functionally intact limb and reported local disease control comparable to that of external hemipelvectomy at that time [9, 27]. In a retrospective study directly comparing internal and external hemipelvectomy outcomes, Fuchs et al. [12] confirmed survival and recurrence rates were no worse for internal hemipelvectomy than for external hemipelvectomy. Since these noteworthy studies, surgeons have used various technical modifications to minimize complications and recurrence risk and maximize postoperative function. In this study, we tested the ability of the T-incision internal hemipelvectomy to achieve these goals. Specifically, we characterized (1) the incidence of postoperative complications; (2) rates of recurrence, disease-free survival, and overall survival; and (3) functional scores associated with the T-incision internal hemipelvectomy in patients with pelvic sarcomas.

The fact that sarcomas involving the innominate bone are rare means it is difficult to gather a study group large enough to investigate long-term outcomes, such as disease-free survival, overall survival, and preservation of hip function, for this surgical technique as compared with other techniques used for internal hemipelvectomy. This is further complicated by the variations in treatment of pelvic

sarcomas with time. As all subjects were obtained from one referral center, this bias allowed for standardization in surgical technique because all procedures were performed by the same surgeon. Other limitations in this study include a patient group that was heterogeneous in terms of sarcoma type and stage, adjuvant treatment, extent of bony resection, and reconstruction technique. Thus, these results are intended to describe trends that can help guide clinical practice rather than define explicit treatment algorithms. Additionally, this study serves to raise issues deserving further investigation, such as how to prevent the more common complications.

The crucial aspects of this surgery include preoperative planning of bone and soft tissue margins, wide exposure, and protection of the femoral neurovascular bundle, sciatic nerve, and gluteal vessels. Careful review of preoperative radiographs and MR images is important for determining where the osteotomies will be made and what soft tissue structures are involved. This evaluation reveals whether internal hemipelvectomy is appropriate by characterizing the involvement of critical neurovascular structures and the presence of metastatic disease, which could make survival well beyond the recovery period unlikely [14, 26]. Internal hemipelvectomy using the T-incision approach is indicated when the tumor is restricted to one hemipelvis and does not invade or directly contact the major neurovascular structures of the pelvis and lower extremity, and when the expected recovery period does not approach or surpass the expected survival for the patient. We often use preoperative chemotherapy for chemosensitive tumors to reduce the extent of viable tumor [18] and treat any observed or potential metastatic disease.

For the surgery, the lateral T-incision approach we have described provides an extremely extensile view, allowing surgical access to all pelvic anatomy while avoiding the major neurovascular structures and preserving flap vascularity. Because pelvic sarcomas frequently grow to a large size before presentation, wide exposure is needed to extract the entire tumor and avoid contaminating the surrounding tissues. This approach also optimizes observation and maneuverability for the meticulous dissection this surgery demands [5, 18]. Despite this, only one group of authors reported on a clinical series of internal hemipelvectomy using a similar approach [20]. Karakousis et al. [18, 20] stated the exposure should be large enough to permit access to the sacroiliac joint, pubic symphysis, and ischial tuberosity, and they achieved this with a similar technique, described as the “reverse Y” approach. The T-incision and reverse Y approaches provide more of an open-book view of the hemipelvis compared with the universal incision. Extending the vertical limb distally increases observation as needed by allowing for greater reflection of the skin and subcutaneous tissue. The T-incision also keeps the femoral

neurovascular bundle away from the center of the operative field by placing the vertical limb more laterally.

Among our patients, the mean estimated blood loss was approximately 1500 mL, and the mean surgical time was just less than 5 hours. Earlier studies report mean blood loss of 2700 to 3800 mL and a mean surgical time of approximately 4.5 to 7.5 hours for internal hemipelvectomy [1, 4, 9, 20]. The extensive exposure afforded by the T-incision approach may contribute to the low surgical time and blood loss. For comparison, a large series of external hemipelvectomy reported an average blood requirement of three units and an average operative time of 1 to 3 hours [24].

Although postoperative complications were common in our series (43%), most were minor and healed well with antibiotics and one I & D. Our major complications were not life-threatening and most required only I & D. Other studies report postoperative complication rates of 31% to 60% [3, 8, 28] for internal hemipelvectomy, with the highest incidences being infection (7%–50%) [1, 4, 8, 10, 22] and wound healing problems (13%–29%) [1, 4, 8, 10, 28]. Our infection rate was 20% and our wound complication rate also was 20%. Factors that may contribute to these high complication rates include the large size of the surgical wound and the need to sacrifice vessels to remove the entire tumor [1, 4, 12, 28]. Two-thirds of our patients who had infections or wound complications had preoperative chemotherapy, but this proportion was similar to the proportion of the entire group who received preoperative chemotherapy. Medical history also may play a large role in such a major surgery. For instance, two of our patients who had deep infections had Type II diabetes mellitus. The intersection of the two incisions seems especially prone to healing problems, potentially owing to inadequate blood flow and opposing skin tension at this location of the incision. Although some authors have proposed the use of a muscle flap to help with bony coverage and filling of dead space in external hemipelvectomy [25], we have not found the use of a muscle flap is warranted primarily in these procedures for the amount of resection and degree of complications we encountered with internal hemipelvectomy.

With thorough preoperative planning and an emphasis on optimizing surgical exposure, we obtained 2-, 5-, and 10-year overall survival rates of 67%, 59%, and 53%, respectively. The incidences of local recurrence (27%) and metastasis (17%) were still relatively high despite a low rate of positive margins and the judicious use of adjuvant chemotherapy. Of the two patients with positive margins, one had local recurrence treated with amputation and was disease-free at last followup; the second patient died of combined local and metastatic disease spread at 11 months. Comparable rates of local recurrence (15%–36%) [1, 3, 8, 10, 12] and death (23%–33% at 2 years and 28%–49% at

5 years) [1, 3, 12] are reported in other studies of internal hemipelvectomy for pelvic sarcomas, reflecting the inherently aggressive behavior of these tumors. It has been suggested recurrence and mortality in these patients are more closely related to presurgical disease state than to the type or extent of resection [6, 21]. Kawai et al. [21] found tumor size, histologic grade, and sacral involvement have a major effect on prognosis for bone sarcomas treated with internal or external hemipelvectomy [21].

Considering the magnitude of the anatomic resection, the functional outcomes of these patients are quite remarkable. On average, our patients rated their ability to participate in daily activities as 86% of normal (TESS). Functional assessment by the physician (MSTS) was lower than the patient's assessment but still averaged 69% of normal. Perhaps most notable is the majority of these patients had no pelvic reconstruction. Flail hips allow for reasonable function without incurring the additional risks of hardware failure that can occur with reconstructed hips in general, regardless of the type of surgical approach used. Leg-length discrepancy [3, 9] and substantially reduced hip motion should be expected [13, 18], but they do not preclude the ability to walk, drive, and return to work for most patients [9, 27]. Shoe lifts can be used to compensate for leg-length discrepancies [3] and may help avoid consequences of abnormal gait, such as back pain or stress on the contralateral leg. Young patients tend to have the best results, whereas older patients may need to use crutches or a walker for assistance [1, 18]. All patients showed improved gait with the use of a cane on the contralateral side.

We present data for a group of 30 patients who underwent internal hemipelvectomy using the T-incision approach. The T-incision approach is an effective surgical technique for performing wide resection internal hemipelvectomy for pelvic sarcomas. The greatest benefit of this modified approach is improved exposure of the tumor and surrounding critical structures, allowing for a cautious yet potentially faster surgery. Wound complications tend to be minor and are easily managed, and the encouraging functional outcomes justify the complexity of the procedure. Because local recurrence and metastasis are not uncommon, careful patient selection and vigilant followup are essential.

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References

1. Apffelstaedt JP, Driscoll DL, Karakousis CP. Partial and complete internal hemipelvectomy: complications and long-term follow-up. *J Am Coll Surg*. 1995;181:43-48.
2. Apffelstaedt JP, Zhang PJ, Driscoll DL, Karakousis CP. Various types of hemipelvectomy for soft tissue sarcomas: complications, survival and prognostic factors. *Surg Oncol*. 1995;4:217-222.
3. Asavamongkolkul A, Pimolsanti R, Waikakul S, Kiatsevee P. Periacetabular limb salvage for malignant bone tumours. *J Orthop Surg (Hong Kong)*. 2005;13:273-279.
4. Baliski CR, Schachar NS, McKinnon JG, Stuart GC, Temple WJ. Hemipelvectomy: a changing perspective for a rare procedure. *Can J Surg*. 2004;47:99-103.
5. Bickels J, Malawer M. Pelvic resections (internal hemipelvectomy). In: Malawer M, Sugarbaker P, eds. *Musculoskeletal Cancer Surgery: Treatment of Sarcomas and Allied Diseases*. Boston, MA: Kluwer Academic Publishers; 2001:405-414.
6. Bruns J, Luessenhop SL, Dahmen G Sr. Internal hemipelvectomy and endoprosthesis pelvic replacement: long-term follow-up results. *Arch Orthop Trauma Surg*. 1997;116:27-31.
7. Davis AM, Wright JG, Williams JI, Bombardier C, Griffin A, Bell RS. Development of a measure of physical function for patients with bone and soft tissue sarcoma. *Qual Life Res*. 1996;5:508-516.
8. Donati D, Giacomini S, Gozzi E, Ferrari S, Sangiorgi L, Tienghi A, DeGroot H, Bertoni F, Bacchini P, Bacci G, Mercuri M. Osteosarcoma of the pelvis. *Eur J Surg Oncol*. 2004;30:332-340.
9. Eilber FR, Grant TT, Sakai D, Morton DL. Internal hemipelvectomy—excision of the hemipelvis with limb preservation: an alternative to hemipelvectomy. *Cancer*. 1979;43:806-809.
10. Enneking WF, Dunham WK. Resection and reconstruction for primary neoplasms involving the innominate bone. *J Bone Joint Surg Am*. 1978;60:731-746.
11. 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;286:241-246.
12. Fuchs B, Yaszemski MJ, Sim FH. Combined posterior pelvis and lumbar spine resection for sarcoma. *Clin Orthop Relat Res*. 2002;397:12-18.
13. Ham SJ, Schraffordt Koops H, Veth RP, van Horn JR, Molenaar WM, Hoekstra HJ. Limb salvage surgery for primary bone sarcoma of the lower extremities: long-term consequences of endoprosthesis reconstructions. *Ann Surg Oncol*. 1998;5:423-436.
14. Hosalkar HS, Dormans JP. Surgical management of pelvic sarcoma in children. *J Am Acad Orthop Surg*. 2007;15:408-424.
15. Hugate R Jr, Sim FH. Pelvic reconstruction techniques. *Orthop Clin North Am*. 2006;37:85-97.
16. Kaplan EL, Meier P. Nonparametric estimation from incomplete observations. *J Am Stat Assoc*. 1958;53:457-481.
17. Karakousis CP. Internal hemipelvectomy. *Surg Gynecol Obstet*. 1984;158:279-282.
18. Karakousis CP. Internal hemipelvectomy. In: Sugarbaker P, Malawer M, eds. *Musculoskeletal Surgery for Cancer: Principles and Techniques*. New York, NY: Theime Medical Publishers, Inc; 1992:150-163.
19. Karakousis CP. Abdominoinguinal incision and other incisions in the resection of pelvic tumors. *Surg Oncol*. 2000;9:83-90.
20. Karakousis CP, Emrich LJ, Driscoll DL. Variants of hemipelvectomy and their complications. *Am J Surg*. 1989;158:404-408.
21. Kawai A, Healey JH, Boland PJ, Lin PP, Huvos AG, Meyers PA. Prognostic factors for patients with sarcomas of the pelvic bones. *Cancer*. 1998;82:851-859.
22. Kollender Y, Shabat S, Bickels J, Flusser G, Isakov J, Neuman Y, Cohen I, Weyl-Ben-Arush M, Ramo N, Meller I. Internal hemipelvectomy for bone sarcomas in children and young adults: surgical considerations. *Eur J Surg Oncol*. 2000;26:398-404.
23. Mankin HJ, Hornicek FJ. Internal hemipelvectomy for the management of pelvic sarcomas. *Surg Oncol Clin N Am*. 2005;14:381-396.

24. Miller TR. Hemipelvectomy in lower extremity tumors. *Orthop Clin North Am.* 1977;8:903–919.
25. Ross DA, Lohman RF, Kroll SS, Yasko AW, Robb GL, Evans GR, Miller MJ. Soft tissue reconstruction following hemipelvectomy. *Am J Surg.* 1998;176:25–29.
26. Somville J, Van Bouwel S. Surgery for primary bone sarcomas of the pelvis. *Acta Orthop Belg.* 2001;67:442–447.
27. Steel HH. Partial or complete resection of the hemipelvis: an alternative to hindquarter amputation for periacetabular chondrosarcoma of the pelvis. *J Bone Joint Surg Am.* 1978;60:719–730.
28. Wirbel RJ, Schulte M, Mutschler WE. Surgical treatment of pelvic sarcomas: oncologic and functional outcome. *Clin Orthop Relat Res.* 2001;390:190–205.