Computer-Assisted Sacral Tumor Resection. A Case Report

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Computer-Assisted Sacral Tumor Resection

A Case Report

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Resection of sacral tumors is one of the most difficult operations in orthopaedic oncology because complex anatomy and important internal organs in the pelvic area make it difficult to achieve wide surgical margins[1]. Wide resection of sacral tumors may lead to serious functional impairments due to injury to important internal organs and/or the lumbosacral nerve roots or through the disruption of load-bearing through the sacroiliac joint.

Recent advances in diagnostic modalities facilitate better surgical planning and can help in the performance of surgeries as planned. Computer-assisted surgery has been used in orthopaedic operations such as cruciate ligament reconstruction, hip and knee arthroplasty, and pedicle screw placement. The main advantage of computer-assisted navigation over other imaging modalities is that intraoperative identification can increase the accuracy of surgical resection. We report a case of sacral chondrosarcoma in which computer-assisted surgery provided intraoperative real-time imaging, thereby allowing us to achieve adequate surgical margins while preserving the sacral nerve roots. Additionally, the tumor resection was carried out through a posterior approach only. The patient was informed that data concerning the case would be submitted for publication, and he consented.

Case Report

A fifty-two-year-old man was referred to us with a longer than five-month history of a dull pain in the lower back. There was no evidence of a neurologic deficit in the lumbo-

Fig. 1

A T2-weighted spin-echo coronal magnetic resonance image showing a lobulated lesion with a high signal intensity confined to the right sacral ala.

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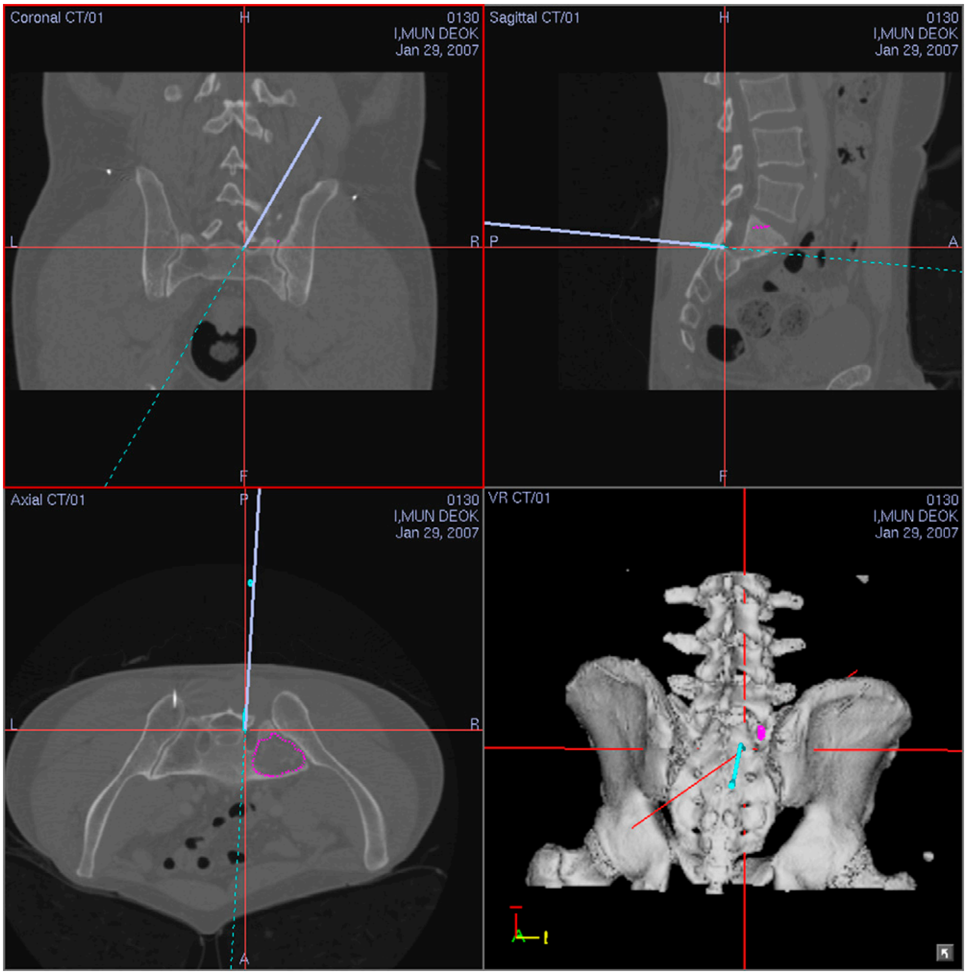

Fig. 2-A

Navigation images on screen provided an intraoperative three-dimensional orientation during the sacral osteotomy through the first sacral foramen (Fig. 2-A) and during the iliac osteotomy (Fig. 2-B).

sacral nerve roots. Systemic symptoms, such as fever or weight loss, were absent. Plain radiographs of the pelvis showed an osteolytic lesion at the right sacral ala. Magnetic resonance imaging revealed that the tumor was located in the right sacral ala, between the sacroiliac joint and the first and second sacral foramina (Fig. 1). Computed tomography revealed cortical destruction of the sacral side of the sacroiliac joint, but there was no evidence of involvement of the ilium. Further evaluation, including computed tomography of the chest and technetium-99m diphosphonate bone scan, excluded distant metastasis. An incisional biopsy was performed, and histologic evaluation of the biopsy tissue was consistent with the diagnosis of grade-2 chondrosarcoma[2].

Preoperative Preparation

The tumor extended superiorly to the right superior articular process of the sacrum, inferiorly to the level of the second anterior sacral foramen, medially to the first and second sacral foramina, and laterally to the right sacroiliac joint. The goals of surgery were to resect the tumor with a wide margin while preserving the first and second sacral nerve roots. Because the first and second sacral nerve roots were isolated from the medial margin of the tumor by the cortical walls of the sacral foramina, we thought that they could be preserved if a precise dissection and osteotomy could be carried out with the help of intraoperative computer-assisted navigation. The sacroiliac joint, including the posterior third of the ilium, was also included in the resection because the sacroiliac joint was considered to have been invaded by the tumor.

One day before surgery, with the patient under local anesthesia in the operating room, four Kirschner wires—one in each of the two iliac crests and one in each of the two posterosuperior iliac spines—were placed as fiducial markers for registration. In addition, a multidetector-row computed tomography scan (LightSpeed Pro16; GE Medical Systems, Waukesha, Wisconsin) was acquired with use of the following protocol: 120 kV, effective 20 mA with 0.5-second rotation time, 20-mm scan collimation, 27.5-mm table feed per rotation, and 1.3-mm

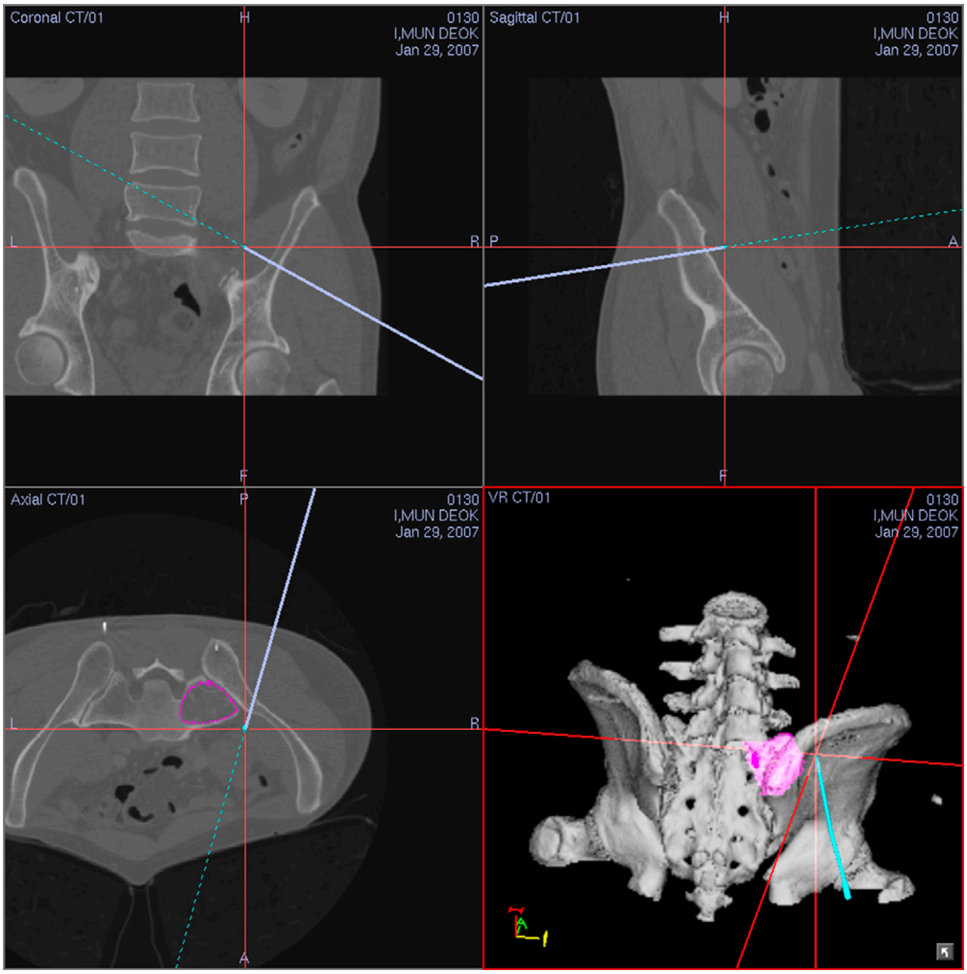

Fig. 2-B

reconstruction increment. The image data were transferred to the navigation system (System II; Stryker, Kalamazoo, Michigan).

Operative Procedure

The patient was placed in the prone position. An inverted Y-shaped skin incision centered on the S1 spinous process was created to expose the posterior part of the sacrum and the posterior third of the ilium. After soft-tissue dissection, a dynamic reference-base was fixed to the spinous process of L5. Patient-to-image registration was performed with two methods to increase accuracy. First, paired-point registration was performed with use of the four Kirschner wires (one wire in each of the two iliac crests and one in each of the two posterosuperior iliac spines) that had been placed as fiducial markers. Second, we performed surface-fit registration with use of the posterior surface of the sacrum. The registration error was <1 mm. After right L5-S1 facetectomy and right S1 and S2 hemilaminectomy were performed, an osteotomy was carried out along the S1 and S2 anterior sacral foramina with use of a small burr (2 mm) and under navigational guidance. An iliac osteotomy was also carried out under navigational

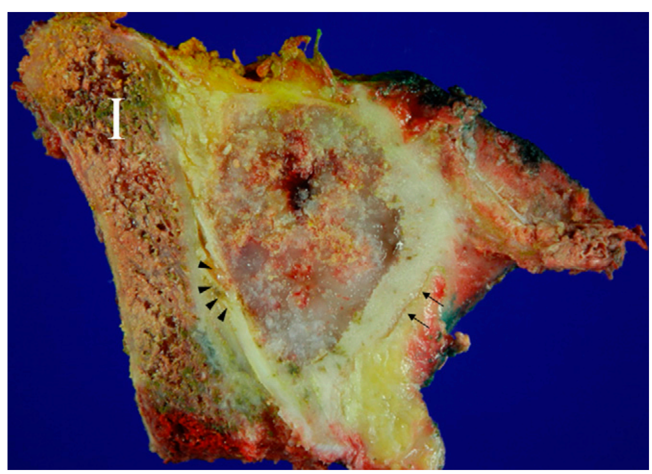

Fig. 3

The gross specimen demonstrates that the tumor was excised with a wide surgical margin as planned. The posterior portion of the ilium (I) was included in the resected specimen. The sacroiliac joint was invaded by the tumor (arrowheads). The anterior cortex (arrows) of the sacral ala was intact.

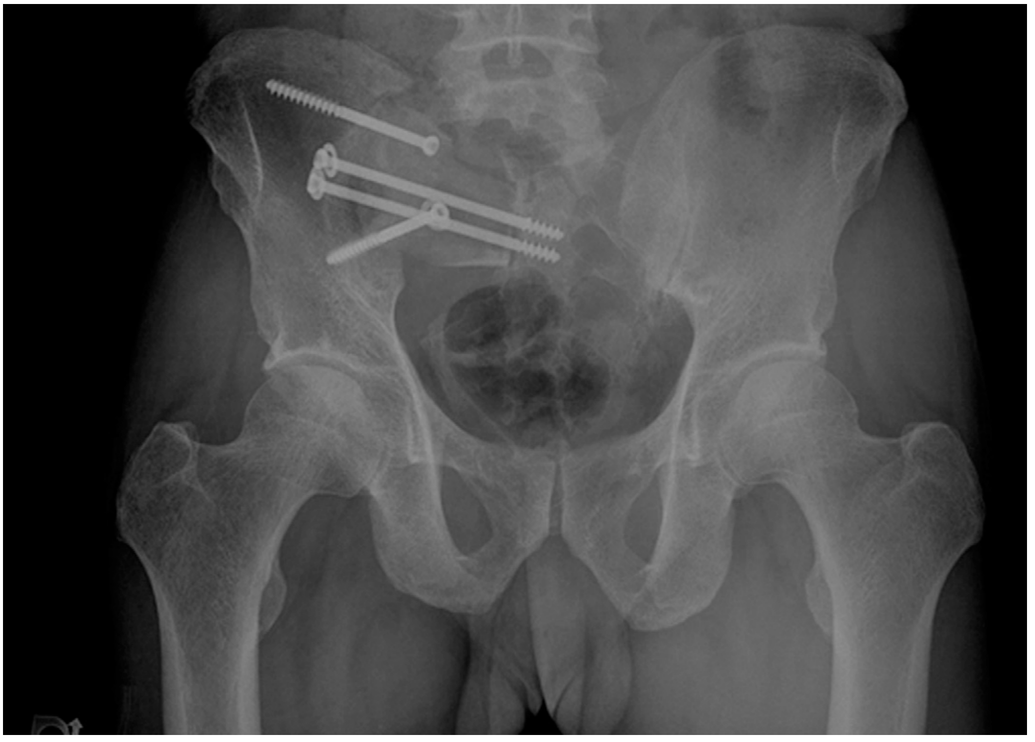

Fig. 4
A distal femoral allograft was placed in the defect and fixed with four screws to restore sacroiliac continuity.

guidance. The location of the burr in spatial relationship to the tumor was checked three-dimensionally with use of the navigation system. Before proceeding with the osteotomy of the pelvic ring, we first marked all of the osteotomy sites with the help of computer-assisted navigation, as an osteotomy of the pelvic ring could potentially disrupt the previously set spatial relationship between the registration points and the reference frame. An osteotomy through the sacrum was performed first because we regarded this step to be the most technically demanding for achieving an adequate surgical margin (Figs. 2-A and 2-B). With use of the navigational system, resection of the sacral tumor was performed through a posterior approach, avoiding the need for combined anterior and posterior dissection. The dissection of the anterior surface of the sacrum was achieved through the iliac osteotomy site. Blunt dissection was performed along the plane between the anterior surface of the sacrum and the piriformis muscle. The tumor was excised with a wide surgical margin as planned (Fig. 3), and all of the sacral nerve roots as well as the L5 nerve root were preserved. To restore sacroiliac continuity, a deep-frozen distal femoral allograft strut was placed in the defect and fixed with four screws. Two of the four screws were inserted into the residual ilium, and the other two were inserted into the sacral promontory (Fig. 4). The total surgical time from the patient's entrance into the operating room to his exit was 480 minutes. It took sixty-five minutes for preoperative preparation, including patient positioning, draping, and navigation set-up, 295 minutes for the tumor resection, and 120 minutes for the reconstruction. The estimated blood loss was 2100 mL.

Postoperative Period

Histologic examination of the final biopsy specimen revealed a grade-2 chondrosarcoma, which was an identical result to that obtained from examination of the incisional biopsy, and showed that all resection margins were free of tumor. The postoperative course was uneventful. The patient walked on crutches with partial weight-bearing for three months. Six months after surgery, he had no difficulty with urination, defecation, or sexual function; a computed tomography scan of the pelvis showed no evidence of recurrent disease, and a computed tomography scan of the chest revealed no evidence of metastatic disease. The patient was able to walk without any assistance.

Discussion

Even with improvements in treatment modalities, patients with malignant neoplasms of the pelvic girdle are still at a higher risk of having treatment failure than are patients with a similar tumor located in an extremity. The reason for this higher risk of treatment failure is related to the inadequacy of the surgical margin obtained. Tumors with sacral involvement have a higher prevalence of inadequate surgical margins than tumors without sacral involvement[3]. Accordingly, an even sectioning of the sacral nerve roots and/or a radical sacrectomy may be necessary in order to obtain negative margins for tumors that involve the sacrum[4]. Another problem associated with tumors with sacral involvement is that the extensive surgical procedures often affect neural function, especially innervation of the bowel and bladder.

The concept of limb-salvage surgery is to maximize preservation of function by minimizing unnecessary resection yet have satisfactory oncologic results. Recent diagnostic modalities, such as magnetic resonance imaging and computed tomography scanning, are valuable for locating tumors and planning surgical resection, but they have some limitations with regard to intraoperative identification and guidance, especially in the flat bones such as the pelvis and sacrum[5]. Therefore, to minimize unnecessary resection, extremely accurate intraoperative identification is necessary. The usefulness and accuracy of intraoperative navigational guidance have been evaluated under clinical conditions in orthopaedic operations, such as spinal pedicle screw placement and total joint arthroplasty[6,7]. We applied the advantages of computer-assisted surgery to the malignant sacral tumor in our patient. The accuracy of intraoperative identification by navigation made it possible to preserve all of the sacral nerve roots as well as ensure excision of the tumor with an adequate margin. To preserve the sacral nerve roots, a sacral osteotomy was performed along the sacral foramina. If the sacral osteotomy had been done medial to the sacral foramina, we could not have preserved the nerve roots, although the nerve roots could have been visualized after laminectomy. If the sacral osteotomy had been performed along the foramina without navigation, there would have been a great risk of contamination of the resection margin.

The prerequisite to ensure the accuracy of computer-assisted surgery is precise patient-to-image registration. In the case of our patient, four Kirschner wires—one in each of the two iliac crests and one in each of the two posterosuperior iliac spines—were placed as fiducial markers in order to keep the registration error to <1 mm before computed tomography scanning for paired-point registration. Paired-point registration is a method that correlates an anatomical landmark on the real body with a corresponding point on the image, point by point. However, the precise correlation of a point on the body with a corresponding point on the computer is not easy. Moreover, some prominent osseous points that may be included in the resection area should be excluded from the landmarks for registration in tumor surgery. Therefore, preoperative placement of a Kirschner-wire as a fiducial marker for paired-point registration, which can be performed under local anesthesia, seems to be helpful in tumor surgery, especially in the area about the pelvis and sacrum. There are still some disadvantages of using the navigation system in oncologic surgery. Use of the system requires additional costs and time. In our case, it took about thirty minutes for navigation setup and registration. In addition to intraoperative setup time, placement of the fiducial markers and preoperative planning took several hours. Another disadvantage is the exposure of the patient to radiation from the preoperative computed tomography scan. Even though the data acquired with magnetic resonance imaging may be used as the navigation data by means of computed tomography-magnetic resonance imaging fusion, computed tomography scanning is required for precise registration in oncologic surgery.

High sacral amputation, which is indicated for tumors involving the upper portion rather than the lower free portion of the sacrum, usually requires combined anterior and posterior approaches, even if the tumor is confined to the sacral ala[4,8]. In the case of our patient, an iliac osteotomy allowed for the dissection of the anterior face of the sacrum without use of an anterior approach. The plane of cleavage was between the anterior surface of the sacrum and the piriformis muscle. Because the internal iliac artery and its branches were located anterior to the piriformis muscle, dissecting along that plane avoided major bleeding in our patient.

Other possible applications of computer-assisted surgery in orthopaedic oncology are the preservation of the articular cartilage during resection of the tumor around the joint and the preservation of the growth plate in skeletally immature patients by precise identification of the extent of the tumor with use of the navigation. There have been several reports of attempts having been made to preserve the adjacent articular surface in skeletally immature patients who have a metaphyseal sarcoma[9,10]. In these patients, intraepiphyseal resection was performed with intraoperative fluoroscopic guidance because the open physis could be used as a landmark for intraepiphyseal osteotomy. The application of computer-assisted techniques may help to preserve the growth plate as well as the adjacent articular cartilage in such patients. In skeletally mature patients, navigation may facilitate safe resection of a metaphyseal tumor while preserving the adjacent joint.

In this report, we have shown that the advantages of computer-assisted surgery can be applied in the resection of malignant sacral tumors. In appropriately selected patients, this technique can be helpful in increasing the accuracy of surgical resection and reducing the functional impairment that is often seen after resection of a malignant sacral neoplasm. However, the feasibility of applying computer-assisted surgery in the treatment of malignant sacral tumors needs to be clarified in studies that have a larger number of patients and a longer duration of follow-up. ■

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References

1. Hulen CA, Temple HT, Fox WP, Sama AA, Green BA, Eismont FJ. Oncologic and functional outcome following sacrectomy for sacral chordoma. J Bone Joint Surg Am. 2006;88:1532-9.

2. Campanacci M, Enneking WF. Central chondrosarcoma. In: Campanacci M, editor. Bone and soft tissue tumors. 2nd ed. New York: Springer; 1999. p 283-318.

3. Kawai A, Healey JH, Boland PJ, Lin PP, Huvos AG, Meyers PA. Prognostic factors for patients with sarcomas of the pelvic bones. Cancer. 1998;82:851-9.

4. Stener B, Gunterberg B. High amputation of the sacrum for extirpation of tumors. Principles and technique. Spine. 1978;3:351-66. Erratum in: Rev Chir Orthop. 1987;73:following 217.

5. Kojima T, Ishiko O, Ichimura T, Nishimura S, Sumi T, Ueda J, Tsujimura T, Shimura K. The usefulness and limits of magnetic resonance imaging in the differential diagnosis of pelvic tumors. Oncol Rep. 2001;8:867-9.

6. Amiot LP, Lang K, Putzier M, Zippel H, Labelle H. Comparative results between conventional and computer-assisted pedicle screw installation in the thoracic, lumbar, and sacral spine. Spine. 2000;25:606-14.

7. Jolles BM, Genoud P, Hoffmeyer P. Computer-assisted cup placement techniques in total hip arthroplasty improve accuracy of placement. Clin Orthop Relat Res. 2004;426:174-9.

8. Simpson AH, Porter A, Davis A, Griffin A, McLeod RS, Bell RS. Cephalad sacral resection with a combined extended ilioinguinal and posterior approach. J Bone Joint Surg Am. 1995;77:405-11.

9. Muscolo DL, Ayerza MA, Aponte-Tinao LA, Ranalletta M. Partial epiphyseal preservation and intercalary allograft reconstruction in high-grade metaphyseal osteosarcoma of the knee. J Bone Joint Surg Am. 2004;86:2686-93.

10. Amitani A, Yamazaki T, Sonoda J, Tanaka M, Hirata H, Katoh K, Uchida A. Preservation of the knee joint in limb salvage of osteosarcoma in the proximal tibia. A case report. Int Orthop. 1998; 22:330-4.