Orthopaedics & Traumatology: Surgery & Research (2009) **95**, 284—292

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ORIGINAL ARTICLE

Surgical management of pelvic primary bone tumors involving the sacroiliac joint

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Accepted: 28 April 2009

KEYWORDS
Pelvic neoplasms;
Bone neoplasms;
Orthopaedic procedures;
Limb salvage;
Hemipelvectomy;
Sacroiliac joint

Summary
Introduction: Pelvic primary malignant bone tumours, especially when involving the sacroiliac joint are difficult to treat. Abdominoperineal amputations are today used, only in life-threatening situations.
Hypothesis: A precisely planed surgical technique can save the affected extremity without compromising the resection quality and subsequent patient survival.
Objective: To assess the procedures used for resection and reconstruction of bone tumours invading the sacroiliac joint as well as their effects on cancer outcome and functional results.
Materials and methods: This is a continuous and retrospective analysis of 24 patients treated between 1986 and 2003. Six tumours affected the sacral body and 18 tumours involved the wing of the ilium. The joint articular surface was invaded in only six cases. Seventeen patients received neoadjuvant chemotherapy. The procedure was performed through an enlarged iliac crest incision, giving access to two sections of the pelvic ring. Six cases required neurological sacrifice. Initial tumour grading was based on the Enneking classification, and the functional results, on the Musculoskeletal Tumour Society (MSTS) scoring system.
Results: The average operation lasted 5.27 hours. Reconstruction was performed with bone autograft and instrumentation. Resection was large with adequate margins 11 times, marginal 12 times, and contaminated once. Average follow-up was 4.77 years. The 5-year survival rate was 50%. Twelve patients either died from their disease or were in the metastatic stage at final follow-up. Survival was linked to the quality of resection and initial tumour staging. Hemisacrectomy did not affect patient survival. Local recurrences had a poor prognosis with eight cases of secondary metastases out of 11. Bone healing occurred in 13 patients, 10 of whom survived. Of the 12 patients who survived and were in complete remission at final follow-up, the average MSTS score was 61%. The score was at 38.6% in cases involving neurological sacrifice, and at 77.1% for the rest of the group. It was at 64% in healed cases and 13% in nonunion cases.

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1877-0568/$ – see front matter
doi:10.1016/j.otsr.2009.04.008

Discussion: The survival of patients presenting with a sacroiliac joint tumour is substantially related to both tumour histology and resection quality. Local recurrences carry a poor prognosis with a high rate of secondary metastatic dissemination. In situations where disease control can be achieved, the proposed method of reconstruction allows, satisfactory bone healing and fair functional recovery, provided no major neurological sacrifice has taken place.

Level of evidence: level IV: Retrospective Therapeutic Study.

Introduction

Malignant tumours of the pelvic ring often have a poor prognosis because of late diagnosis and difficult treatment. Generally affecting young and physically active subjects, the treatment should meet a double objective: first and foremost, cancer management, but also functional maintenance. External hemipelvectomies (inter-ilio-abdominal disarticulation) are justified, by most authors, only in cases of an unresectable tumour due to its size or the invasion of visceral, vascular or nerve structures [1,2]. Tumour location imposes technical constraints on surgical technique, particularly its position with respect to the acetabulum. The most widely used classification for defining this type of tumour resection is that of Enneking and Dunham [3].

Tumours invading the sacroiliac joint do not pose coxofemoral reconstruction problems, but they require extensive dissection of the two sections of the pelvic ring, which explains the significant number of complications involving scar tissue formation found in the literature [4—7]. Numerous reconstruction procedures have been proposed: nonvascularised or vascularised autografts [8], allografts [9] or modular implants [10]. Some, however, regard any type of reconstruction as pointless [11].

We present a surgical technique that we use for resection-reconstruction of the sacroiliac joint, as well as the long-term oncological and functional results based on a study of 24 patients.

Materials and methods

Inclusion criteria

This retrospective, monocentric, continuous study was conducted between 1986 and 2003 on 24 patients treated for primary malignant pelvic bone tumours involving the sacroiliac joint in Surgical Orthopaedics Department B of Cochin Hospital. We excluded patients presenting with a tumour invading the acetabulum to maintain homogeneity of the surgical technique. Intrasacral tumours requiring total sacrectomy were not included. All histological types were included. The inclusion and exclusion criteria are summarized in Table 1. This study includes only operated cases.

Surgical technique

This major surgery is associated with heavy blood loss and requires good collaboration with the anaesthesiology team. It is useful to insert a double-J ureteral catheter before the procedure to facilitate intraoperative visualization of the ureter. The patient is placed in the lateral decubitus position. Support placed under the thorax makes it possible to put the patient's pelvic area into a three-quarter anterior and posterior pelvic tilt during the intervention.

The incision is started along the contours of the iliac crest in a curvilinear manner and ends in the back with a vertical portion on the sacroiliac joint. Ideally, biopsy is performed first along this trajectory and its scar is removed with the tumour resection.

The wing of the ilium and the sacrum are exposed, allowing for safety margins around the tumour, which may extend into the soft tissue. The iliac muscle is sectioned or detached from the endopelvic side of the ilium. The iliac vessels, ureter, lumbosacral trunk, sacral roots and sciatic nerve are located and protected. On the exopelvic side, the gluteus muscles are moved as a unit with their fascia and skin, creating a lower myocutaneous flap. During dissection, it is necessary to preserve, whenever possible, the superior gluteal artery, which provides the primary vasculature to this flap, and also the accompanying superior gluteal nerve. The ischial notch is finally exposed and examined on both sides of the pelvic ring.

At the level of the sacrum, the posterior cortex is exposed and the sacroiliac ligaments are sectioned. If the tumour is contained within the sacral ala, access via the sacral canal is not necessary. The cut is made from back to front outside the sacral foramina. In the event of tumour expansion into the sacral body, hemisacrectomy is performed. After completely exposing the anterior section of the sacrum and after hemostasis of the presacral venous plexus, spatulas are placed in the anterior sacral foramina, from S1, S2 and

Table 1 Inclusion and exclusion criteria.

Inclusion	Exclusion
Primary tumour	Secondary tumour of metastatic origin
Affects the iliac bone or sacrum	Affects the acetabulum or the obturator area
Invades the sacroiliac joint or adjacent area	Unresectable tumour
Conservative surgical treatment	Healthy margins cannot be foreseen
Resection interrupts continuity of the pelvic ring	

Figure 1 An example of reconstruction with tibial autografts.

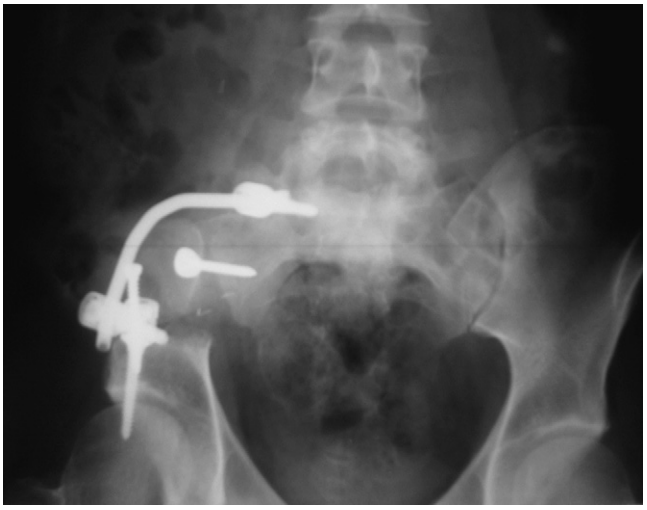

Figure 2 An example of reconstruction with iliac autografts.

S3, making it possible to locate them later. Sacral laminectomy is performed and the nerve roots are identified, ligated and sectioned as required, based on tumour invasion. After excising disk L5/S1, vertebral body osteotomy is undertaken with chilled scissors from back to front and then front to back. The level of the cut on the sagittal plane is determined by the location of the tumour.

The position of the distal cut also depends on tumour extension. The cut is performed with an oscillating bone saw and bone scissors and completed with a Gigli saw at the ischial notch. The resected section, oriented and landmarked, is sent to anatomical pathology in a fresh state; fixation is performed in the laboratory.

For reconstruction, we use an ilium autograft whenever possible. If the ilium is entirely resected, it is possible to remove the fibula or the ipsilateral tibial shaft. An allograft is rarely needed, but can be useful in the event of a major defect. Stability of the reconstruction is ensured by spinal osteosynthesis hardware of the screw-rod type that allows modularity in three dimensions as well as graft compression.

Generally, a screw is implanted in the anterolateral side of the sacral body via an endopelvic approach. Another is positioned in the anterior column of the acetabulum through the bony section (Figs. 1 and 2). In the event of hemisacrectomy, the assembly is extended to L5 with a intrapedicular screw fixation, and the set-up completed with a contralateral L5-S1 arthrodesis.

Epidemiological data

We studied 24 patients (14 women and 10 men) who met the inclusion criteria (Table 2). Their average age was 33.5 years. The majority of patients were classified as ASA 1 (16 cases) or ASA 2 (eight cases).

The two most commonly found tumours were Ewing's sarcoma (eight cases) and chondrosarcoma (eight cases). Three malignant fibrous histiocytomas (MFH), two osteosarcomas (including one chondroblastic), one malignant schwannoma, one hemangiopericytoma and one leiomyosarcoma were also found (Fig. 3). According to the classification of Enneking et al. [12], there were four Ia stages, six IIa stages, 12 IIb stages, and two IIIb stages (resectable lung metastases). Tumour extension affected the ilium in 18 cases and the sacral body in six cases. The sacroiliac joint itself was invaded in only six cases. A sacral tumour of the malignant schwannoma type was initially intramedullary. There was significant invasion in the soft tissue of the endo- or exopelvic areas in half of the cases.

Four patients who were initially treated elsewhere were admitted because of tumour recurrence. Patient #1 had intramedullary Ewing's sarcoma affecting S1, and initially underwent laminectomy and intralesional curettage of the tumour, followed by radiotherapy and chemotherapy, after definitive anatomicopathological results. He was admitted to the service with a recurrence, 4 years after the initial surgery. Patient #2 had presented 7 years earlier with intrasacral Ewing's sarcoma, treated with a combination of chemotherapy and radiotherapy. He presented with a local recurrence 7 years after the initial treatment. Patient #8 presented with a tumour of the buttock, initially considered a benign schwannoma, and treated with resective biopsy. Definitive anatomicopathology found a malignant schwannoma and postoperative radiochemotherapy was administered. The recurrence took place 2 years later, invading the ilium and spreading to the sacroiliac joint. A cutaneous ulcer was also linked to tumour recurrence. Finally, patient #21 initially had a surface chondrosarcoma

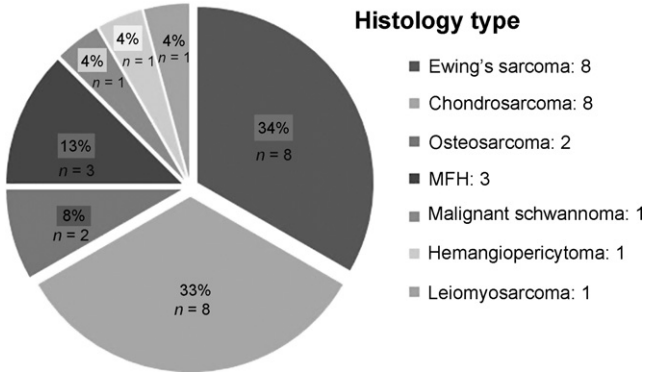

Figure 3 Division of patients by histological type.

Table 2 Summary of cases.

No.	Age	Location	Histology	Stage	Margins	Complementary treatment
1	19	Sacrum + SI	Ewing's - recurrence	IIB	Marginal	Chemo + Pre-R
2	53	Sacrum + SI	Ewing's - recurrence	IIA	Marginal	Chemo
3	23	SI	Ewing's	IIB	Large	Chemo
4	22	Wing of ilium	Chondrosarcoma	IB	Large	Chemo
5	22	Wing of ilium	Hemangiopericytoma	IIB	Large	Chemo
6	29	Sacrum	Ewing's	IIA	Large	Chemo
7	34	Wing of ilium	Chondrosarcoma	IIB	Large	Chemo
8	45	Wing of ilium + SI	Recurrence of schwannoma	IIIB	Marginal	Chemo + Pre-R
9	38	Wing of ilium	Chondrosarcoma	IIB	Large	0
10	19	Wing of ilium	Chondroblastic osteosarcoma	IIA	Large	Chemo
11	18	Sacrum	Chondrosarcoma	IIB	Marginal	0
12	16	Wing of ilium	Ewing's	IIB	Large	Chemo + Post-R
13	72	Wing of ilium + SI	Leiomyosarcoma	IB	Marginal	0
14	25	Wing of ilium	Chondrosarcoma	IIA	Marginal	0
15	41	Sacrum	Chondrosarcoma	IB	Large	0
16	30	Wing of ilium	Ewing's	IIB	Marginal	Chemo
17	23	Wing of ilium	MFH recurrence	IIA	Contaminated	Chemo + Pre-R Post-R
18	67	Wing of ilium + SI	MFH	IIB	Large	Chemo
19	19	Wing of ilium	Ewing's	IIIB	Marginal	Chemo + Post-R
20	17	Wing of ilium	Osteosarcoma	IIB	Marginal	Chemo
21	43	Sacrum	Chondrosarcoma	IB	Large	0
22	60	Wing of ilium + SI	MFH	IIA	Marginal	Chemo
23	42	Wing of ilium	Chondrosarcoma	IIB	Large	0
24	27	Wing of ilium	Ewing's	IIB	Marginal	Chemo

SI: sacroiliac joint; MFH: malignant fibrous histiocytoma; Chemo: chemotherapy; R: radiotherapy; Pre: preoperative; Post: postoperative.

of the anterior side of the sacrum, which was treated by simple tumour resection, without extensive bone resection. He had a recurrence 1 year later.

A patient (#14) who developed a chondrosarcoma was a carrier of Ollier's disease. The patient presenting with a schwannoma was operated for pleural neurinoma. One of the three malignant histiocytomas (#23) was a radio-induced tumour secondary to treatment of cervical cancer.

All these patients were managed preoperatively by multidisciplinary collaboration with the oncology and pathological anatomy teams. Neoadjuvant chemotherapy was administered upon tumour diagnosis according to existing protocols in 17 chemosensitive patients (Ewing's sarcomas, osteosarcomas, malignant schwannoma, MFH and dedifferentiated chondrosarcoma). These same patients also received adjuvant chemotherapy. Intra-arterial chemotherapy was used in a case of hemangiopericytoma. Preoperative radiotherapy was administered three times in patients #1, #8 and #17, who had recurrences with poor prognosis, and postoperative radiotherapy was administered twice in patients #12, #17 and #19. Patient #17, managed during a recurrence, received pre- and postoperative radiation as treatment for malignant histiocytofibroma that developed in the posterior iliac spine at the sacroiliac joint, of which the resection margins were marginal.

The surgical technique employed was the one described above. Hemisacrectomy was performed in the six patients presenting with invasion of the sacral body or the sacral canal (patients #1, #2, #6, #11 and #21). All six required neurological sacrifice. For the 18 other patients, the proximal cut was made at the sacral ala and no neurological sacrifice was necessary. In two cases, the defect was filled by an omental flap to limit the risks of cutaneous separation and infection.

Method of results evaluation

The preoperative data gathered focused on the circumstances of tumour discovery and neurological examination, including perineal assessment. The duration of surgery, type of reconstruction performed as well as the volume and nature of the required blood transfusions were studied. We undertook postoperative evaluation of the quality of the resection margins and the neurological examination. All complications and surgical revisions were recorded.

An assessment of the final follow-up of patients in complete remission involved a new neurological examination and a functional evaluation according to the Musculoskeletal Tumour Society (MSTS) score [13].

Given the difficulty in confirming bone healing in this region, patients presenting with major and persistent pain as well as displacement or ruptures of osteosynthesis material, were considered and analyzed as pseudoarthroses.

It was not possible to perform statistical analyses in this study as the total number of patients was too small.

Results

The initial symptoms were most often aspecific, falsely reassuring and leading to a delayed diagnosis. The most common clinical signs were isolated pain, limiting walking distance in

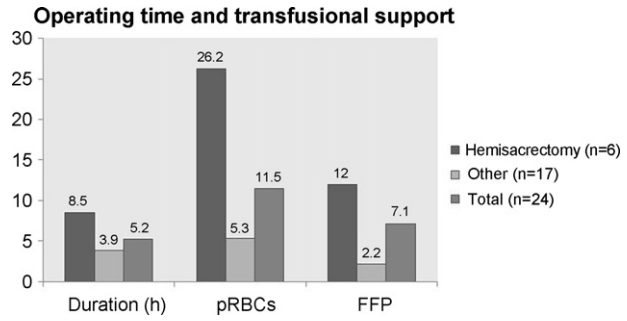

Figure 4 Operative data based on type of resection (pRBCs: packed red blood cells; FFP: fresh frozen plasma).

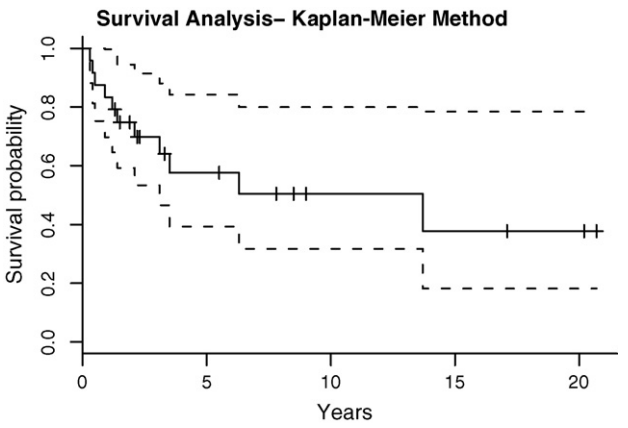

Figure 5 Survival analysis by the Kaplan-Meier method, with 95% confidence interval.

only five cases (pains in the buttocks, truncated sciatica, low back pain). A pathological fracture of the ilium and a sphincter deficit were also found. Three patients managed in the recurrence stage were discovered following pain (two cases) or a sphincter deficit (one case). It should be noted that no patient presented with a motor neurological deficit in the lower limbs. The average delay between the diagnosis and resective surgery was 4½ months, due to the preoperative treatments administered to 17 patients.

The surgical procedure lasted on average 5.27 hours (2.5—12). An average of 11.5 (1—43) units of packed red blood cells (pRBCs) and 7.1 (0—34) units of fresh frozen plasma (FFP) were administered. In the case of hemisacrectomy ($n = 6$), average operation duration was 8.5 hours (transfusion of 26.2 units of pRBCs and 12 units of FFP). For simple resections of the ilium and sacral ala, surgery was shorter and less hemorrhagic (3.9 hours, 5.3 units of pRBCs and 2.2 units of FFP) (Fig. 4).

Reconstruction was performed by order of occurrence: 12 single iliac crests, seven nonvascularised autologous fibulas and one autologous tibial shaft. A massive allograft was required only in four cases, using two femurs, a tibia and a femur head. Since 1993, only spinal hardware has always been used. The seven earlier patients underwent reconstruction by screw fixation of massive bone grafts. We ended up performing lumbosacral pelvic arthrodesis seven times (including the six hemisacrectomies).

Postoperative care in 15 cases consisted of immobilization in a hemibermuda cast. The walking period without weight bearing was on average 69 days (45—150).

Anatomicopathology results

Definitive histological examination revealed 12 large resections, 11 marginal resections and one contaminated resection. Of the 17 patients who received preoperative chemotherapy, only four were considered ''good responders'', with over 90% tumour necrosis.

Cancer results

The follow-up duration was on average 4.8 years (minimum: 4 months, maximum: 20 years). At final follow-up of the entire series, 12 patients were alive and in complete remission, one had metastases and 11 had died from their disease.

At the 5-year follow-up, of the 24 patients studied, six were lost to follow-up, nine had died and nine had survived (Fig. 5). The prognosis, based on resection margins, tumour histology and Enneking stages, is detailed in Table 3.

In this study, we found that age had no influence on tumour prognosis.

The initial tumour stage seemed to correlate with the evolution. The 2A stages (intracompartmental tumours) had the best survival (Fig. 6). If we consider the tumour type, chondrosarcomas and osteosarcomas had the best prognosis. In addition, of the four patients who had definitive anatomicopathology showing tumour necrosis of over 90%, all were alive and in complete remission at final follow-up. Satisfactory operative margins also seemed to improve survival.

Regarding the scope of resection, the six patients who underwent hemisacrectomy did not seem to have a higher mortality rate (one death in six subjects). The average duration of survival in this group was only 2.9 years.

Table 3 Survival analysis.

Predictive factors	Alive at 5 years	Dead at 5 years	Follow-up < 5 years
Resection margins			
Contaminated	0	1	0
Marginal	4	5	2
Large	5	3	4
Enneking stages			
1B	1	1	2
2A	3	1	2
2B	5	5	2
3B	0	2	0
Histology			
Chondrosarcoma	3	1	3
Ewing's sarcoma	2	4	2
Osteosarcoma	2	0	0
Other	2	4	1
Total	9	9	6
Average age at diagnosis (years)	32	33.6	35.6

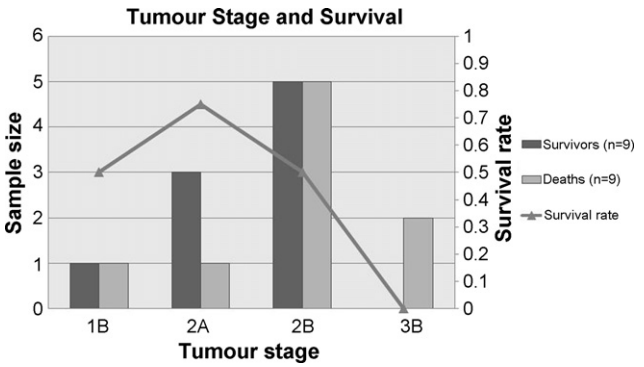

Figure 6 Enneking tumour grade and 5-year survival (only 18 out of 24 cases had a survival exceeding five years).

As for the effectiveness of complementary treatments, it should be noted that three patients who had received preoperative radiotherapy and the patient who had undergone intra-arterial chemotherapy did not survive.

Throughout the observation period, 15 patients had a recurrence:

- only three local recurrences were treated effectively by surgical revision and the patients were considered cured at final follow-up. There were two large and one marginal resections;
- eight local recurrences had evolved secondarily to metastases and death. Three resections were large and five marginal;
- there were four metastatic recurrences at the outset in patients whose tumour margins were at least marginal (one contaminated and three marginal resections).

Local recurrences appeared on average at 2 years (from 8 months to 4 years), while metastases occurred on average at 2½ years (from 5.5 months to 7.5 years).

Among the four patients managed initially for a local recurrence, only one survived (patient #2, with 6-year follow-up).

Functional results and Musculoskeletal Tumour Society score

Neurological status. Perineal neurological deficits were observed in hemisacrectomy cases in five of six patients. The postoperative findings were: five cases of urinary retention or incontinence, four perineal hypoesthesias and two anal openings. At final follow-up, the sensory and anal control problems had all resolved, but three patients presented with persistent urinary disorders on clinical examination and questioning. No postoperative perineal anomaly was found for the resections whose proximal limit remained outside the sacral foramina.

In the lower limbs, we noted 19 cases of postoperative middle gluteal muscle deficit. This deficit was partial in six cases and complete in 13. It remained isolated in 13 patients, whereas it was associated with other disorders for the six patients who underwent hemisacrectomy. They all presented a global deficit (partial or complete) involving the tibialis anterior muscle, the triceps and the levator of the big toe. No complete recovery of middle gluteal muscle strength was observed. Four patients partially recovered from this impairment. The six peripheral deficits of hemisacrectomies persisted, which led to tibiotalar arthrodesis in one of them (complete paralysis of the antero-external compartment and back of the leg).

Five of the 12 surviving patients in complete remission at final follow-up needed canes to walk.

Musculoskeletal Tumour Society score. Overall, of the 12 patients in complete remission at final follow-up, the average MSTS score was 61.1%. The score was 38.6% (from 13.33 to 73.3%) in cases of hemisacrectomy with neurological sacrifice, and 77.1% (from 36.67 to 100%) for the rest of the group. Young subjects seemed to have a better functional score (66% among those under age 30 years, compared to 56% among those over age 30 years). This score also seemed to depend on bone healing (63.9% compared to 13.3% in pseudoarthrosis cases).

Complications

Eighteen patients (75%) presented with at least one premature complication (Table 4). We found eight scar necroses, eight deep infections, six hematomas, three urinary problems related to double-J catheters (one infection and two obstructions), three dural openings (resulting in two meningoceles) as well as one urinary infection. Of these, 10 patients were reoperated in the first postoperative month, while eight others presented with a complication that did not require correction. Six patients were free of any complication. The average hospital stay was 43 days (minimum 15 days, maximum 90 days).

Deep infections

The three patients who received preoperative radiotherapy all presented with a deep infection. This complication occurred in eight of the 17 chemotherapy cases. There was no infection among the seven patients treated exclusively with surgery. The scope of resection did not appear to be a factor (two infections in six hemisacrectomies).

Long-term healing and mechanical complications

Fourteen grafts (58%) had healed at final follow-up. Ten were considered pseudoarthrosis due to persistent, abnormal pain (Table 5):

- 11 were healed among the 12 patients who were in complete remission at final follow-up (the three local recurrences in remission had all healed);
- three were healed among the 12 metastatic patients (no patient with a metastatic recurrence at diagnosis was healed, but three patients presenting with local secondary metastatic recurrence were healed);
- no healing was found among the three patients who received preoperative radiotherapy;
- only one of the three patients who received postoperative radiotherapy was healed;
- the healing rate was 47% in cases of chemotherapy administration, and 86% for the other patients;
- four of six hemisacrectomies were healed;
- the use of allografts did not seem to change the healing rate because two of four massive allografts were healed.

Table 4 Complications and revision surgeries.

		Length of stay (days)	Rate of early repeated surgery (%)	Rate of infection (%)	Total number of revision surgeries
Total sample		44	10/24 (41)	8/24 (33)	1.37
Hemisacrectomy		76	3/6 (50)	2/6 (33)	1.16
Preoperative radiotherapy		75	1/3 (33)	3/3 (100)	1.66
Perioperative chemotherapy		38	9/17 (53)	8/17 (47)	1.64
ASA	1	38	8/17 (50)	6/16 (37)	1.31
stage	2	52	2/8 (25)	2/8 (25)	1.5
Age	< 30	40	7/13 (53)	6/13 (46)	1.54
	> 30	48	3/11 (27)	2/11 (18)	1.18

Of the 10 pseudoarthroses, only five were radiologically obvious (four screw displacements and two graft fractures). Breakage of fixation hardware (rods or screws) was never observed.

Three treatment courses of isolated aseptic pseudoarthrosis, with no associated tumour action, were required, including two lumbosacroiliac arthrodeses.

Number of revision surgeries

There were on average 1.4 revision surgeries per patient (from 0 to 6). Seventeen patients were reoperated at least once and seven twice. The time period before the first revision surgery in 10 cases was less than 1 month. The indications for revision surgery were: deep infection (13 cases), scar necrosis (six cases), tumour recurrence (six cases), pseudoarthrosis (six cases), and dural openings (two cases). The following procedures were also performed: one resection of pulmonary metastases, two total prostheses of the hip from osteoradionecrosis, and one tibio-astragalar arthrodesis for sciatic paralysis. Among the hemisacrectomies, we counted seven revision surgeries for six patients, or 1.16 per patient.

Discussion

We have taken specific interest in the problem of tumour resections of the sacroiliac joint interrupting pelvic ring continuity and removing the sacral ala or homolateral hemisacrum. Excluded are acetabular resections that present different reconstruction problems. Therefore, our series presents homogeneity of surgical techniques at the expense of histological heterogeneity. This is a continuous retrospective series of 24 patients managed for a rare clinical condition. Its main limitation is that the low patient numbers do not allow us to perform statistical analysis.

According to Ozaki et al. [14], few tumours actually cross bone articulations or joints, which form a natural barrier to tumour spread. Propagation, if it exists, generally occurs in the soft tissue, in the posterior section of the joint. Here, it is a matter of extracompartmental tumours [7].

Oncology results

The oncological results of pelvic tumours, particularly tumours invading the sacroiliac joint [15], are not as good as those observed for limbs [7,16]. In our series, the 5-year survival rate was 50%, which concurs with the data in the literature [6,15,16]. Factors that seem to influence survival are tumour type, initial tumour grade, response to chemotherapy and invasion of the resection margins. Multivariate analysis of 162 patients allowed Kawai et al. [15] to isolate initial tumour stage as an independent factor of metastatic recurrence. Hemisacrectomies had, in our

Table 5 Graft healing (95% CI on Student's *t* test).

		Healing rate	
Total		14/24	54% (95% CI: 33—75)
Recurrences	No recurrence	8/9	89% (95% CI: 65—112)
	Isolated local recurrence	3/3	100% (95% CI: 100—100)
	Local secondary metastatic recurrence	0/8	0% (95% CI: 0—0)
	Metastatic recurrence at diagnosis	3/4	75% (95% CI: 15—135)
Complementary treatments	Surgery alone	6/7	86% (95% CI: 55—117)
	Chemotherapy alone	7/12	58% (95% CI: 27—89)
	Preoperative radiotherapy	0/2	0% (95% CI: 0—0)
	Postoperative radiotherapy	1/2	50% (CI 95%: —102—202)
	Pre- + postoperative radiotherapy	0/1	0% (95% CI: 0—0)
Hemisacrectomies		4/6	66% (95% CI: 19—113)
Allografts		2/4	50% (95% CI: —19—119)

experience, a survival rate comparable to other types of sacroiliac joint resection.

Regarding tumour histology, we note that the prognosis of Ewing's sarcoma is not favourable. In our series, this fact is overestimated, as two of the Ewing's sarcomas were managed when they were already in the local recurrence stage. Despite these results, the prognosis seems better for resectable tumours with a combination of surgery and radiotherapy, rather than radiotherapy alone [17].

Our series presented a high rate of local recurrence (11/24 or 46%). In the literature, this rate varies between 4 [16] and 34% [15]. O'Connor and Sim [18] highlighted the higher frequency of recurrence in cases of tumour extension into the sacrum. In a multivariate analysis, Kawai et al. [15] isolated the quality of resection margins as an independent factor for local recurrence. We found no clear correlation between these two elements, though the patients who had a recurrence presented most often with narrow resection margins. The presence of tumour invasion in the pelvic venous plexus could explain a high recurrence rate despite apparently large resection margins [6]. In keeping with Kollender et al. [10], we have observed that, when there was local recurrence, it was a sign of poor prognosis, because it was frequently followed by metastatic diffusion and death of the patient.

Functional results

The functional findings were very different according to the type of resection, which corresponds to the data in the literature [6,19]. Overall, more than half of the patients could walk without canes. The hemisacrectomies had an average score twice as low as the others and presented with much heavier neurological sequelae. Thus, monoparesis was always found with a pluriradicular deficit, both on S1 that was sectioned and on L4 and L5 that were preserved. This can be explained by a stretched lumbosacral trunk or sciatic nerve in the region of the sacral notch. This peripheral deficit has not shown a trend to recovery, even at final follow-up, which should indicate exercising extreme caution during dissection and resection.

Despite unilateral section of the sacral nerve roots in cases of hemisacrectomy, we found more or less significant perineal disorders among five of six patients. The perineal sensory deficit and the anorectal motor disorders have a classically favourable prognosis with normally complete recovery [20—22]. In our experience, anomalies of hypoesthesia and atonic anal sphincter actually receded, while urinary disorders persisted in three of five patients at final follow-up. For Court et al. [6] and Kawai et al. [15], the predictable significance of sequelae and the difficulty of obtaining healthy resection margins in the event of invasion of the sacrum could lead to a discussion about performing hemipelvectomy.

Reconstruction

For fixation, we used spinal osteosynthesis material, allowing extension in the direction of the lumbar spine through the same approach. The overall healing rate was 58%, but it seemed to depend on tumour status. Eleven of 12 patients in complete remission at final follow-up had healed, while in cases of metastases, the proportion was three out of 12. We also found a notable influence of radiotherapy and of chemotherapy on healing. This result can be explained by the toxic effects of complementary treatments as well as by the local persistence of tumour cells preventing healing. These two factors are closely linked, and, given the small number of patients, it is impossible to draw a conclusion about the predominant influence of tumour recurrence or complementary treatment. It should be noted that four of the six hemisacrectomies had not healed. Two of them required revision surgery for complementary bone grafting. Like Court et al., [6], we could therefore consider first performing posterior lombosacral contralateral arthrodesis in this group of patients.

In our patients, reconstruction was performed in a preferential manner by autograft [19]. The use of frozen allografts is a secondary solution in the event of extensive loss of bony substance, but the future of allografts is heavily debated. Langlais et al. [9] and Delloye et al. [23] reported good results and mechanical sturdiness maintained over time, while Beadel et al. [11] noted a high rate of fractures. The use of cement associated with the allograft could reduce the frequency of complications [24]. The effectiveness of allografts in our series could be explained by their combination with sturdy osteosynthesis that limits the risk of fracture.

The high rate of infectious complications has led some teams to propose temporary reconstruction with plate and cement [10]. This combination is aimed to stay in place during the chemotherapy cycles and is subsequently replaced by a bone autograft.

We did not perform microvascularized grafting in our series [8,25]. Even if the healing rates seem satisfactory (3/4 for Sakuraba et al. [8] and 2/3 for Nagoya et al. [25]), there is no evidence today that this technique is superior. Although vascularised autografting is appealing, it requires good technical expertise to perform and considerably lengthens the duration of the operation. Its promoters claim it has a protective effect against infections, but it was not demonstrated in this situation (serious sepsis in four patients in each of two previous series requiring graft ablation). For us, nonvascularised autografting remains the best compromise between morbidity at the donor site, reproducibility of the technique, effectiveness of fusion in the long-term and infection risk.

Complications

The rate of incision and infectious complications that we observed was comparable to that in the literature [3—5,16,19]. The surgical approach via a single incision and a single installation made it possible to control both sides of the sacroiliac joint. It required lifting a myocutaneous flap whose main vascular pedicle was the superior gluteal artery. Its lesion during the procedure or its secondary thrombosis increased the risk of incisional scar necrosis.

Three patients in our series, with an initially unresectable tumour, received preoperative radiotherapy; another received intra-arterial chemotherapy. These treatments did not result in remission, and, unfortunately, all these patients presented with a significant rate of

complications, particularly infections. Currently, these complementary treatments are no longer given, since their risk-to-benefit ratio is considered unfavourable.

In the case of major tumour extension towards the sacrum or a primarily sacral tumour, the median cut should go through the sacral foramina. It seems that in the literature perioperative morbidity increases considerably in this type of presentation [6]. In our series, hemisacrectomies presented a rate of complications and a number of surgical revisions that were comparable to those of other patients, despite significantly longer operating times.

Conclusion

Tumour resection of the sacroiliac joint is a difficult surgical procedure whose prognosis is uncertain. The quality of the resection margins and the initial tumour grade are determining factors for complete remission of the disease. Ewing's sarcoma of the pelvis is a tumour with a poor prognosis. Local recurrences should be considered as an element of unfavourable prognosis. Performing an extensive procedure such as hemisacrectomy generates more serious functional consequences in the long-term, without influencing the oncological prognosis if healthy resection margins are obtained.

References

[1] Masterson EL, Davis AM, Wunder JS, Bell RS. Hindquarter amputation for pelvic tumors: the importance of patient selection. Clin Orthop 1998;350:187—94.
[2] 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.
[3] Enneking WF, Dunham WK. Resection and reconstruction for primary neoplasms involving the innominate bone. J Bone Joint Surg Am 1978;60:731—46.
[4] Capanna R, Van Horn JR, Guernelli N, et al. Complications of pelvic resections. Arch Orthop Trauma Surg 1987;106:71—7.
[5] Somville J, Van Bouwel S. Surgery for primary bone sarcomas of the pelvis. Acta Orthop Belg 2001;67:442—7.
[6] Court C, Bosca L, Le Cesne A, Nordin JY, Missenard G. Surgical excision of bone sarcomas involving the sacroiliac joint. Clin Orthop 2006;451:189—94.
[7] Wirbel RJ, Schulte M, Mutschler WE. Surgical treatment of pelvic sarcomas: oncologic and functional outcome. Clin Orthop 2001;390:190—205.
[8] Sakuraba M, Kimata Y, Iida H, Beppu Y, Chuman H, Kawai A. Pelvic ring reconstruction with the double-barreled vascularized fibular free flap. Plast Reconstr Surg 2005;116: 1340—5.
[9] Langlais F, Lambotte JC, Thomazeau H. Long-term results of hemipelvis reconstruction with allografts. Clin Orthop 2001;388:178—86.
[10] Kollender Y, Shabat S, Bickels J, et al. Internal hemipelvectomy for bone sarcomas in children and young adults: surgical considerations. Eur J Surg Oncol 2000;26:398—404.
[11] Beadel GP, McLaughlin CE, Aljassir F, et al. Iliosacral resection for primary bone tumors: is pelvic reconstruction necessary? Clin Orthop 2005;438:22—9.
[12] Enneking WF, Spanier SS, Goodman MA. A system for the surgical staging of musculoskeletal sarcoma. Clin Orthop 1980;153:106—20.
[13] 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 1993;286:241—6.
[14] Ozaki T, Rödl R, Gosheger G, et al. Sacral infiltration in pelvic sarcomas: joint infiltration analysis. Clin Orthop 2003;407:152—8.
[15] 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.
[16] Shin KH, Rougraff BT, Simon MA. Oncologic outcomes of primary bone sarcomas of the pelvis. Clin Orthop 1994;304:207—17.
[17] Indelicato DJ, Keole SR, Shahlaee AH, et al. Impact of local management on long-term outcomes in Ewing tumors of the pelvis and sacral bones: the University of Florida experience. Int J Radiat Oncol Biol Phys 2008;72:41—8.
[18] O'Connor MI, Sim FH. Salvage of the limb in the treatment of malignant pelvic tumors. J Bone Joint Surg Am 1989;71:481—94.
[19] Hillmann A, Hoffmann C, Gosheger G, Rödl R, Winkelmann W, Ozaki T. Tumors of the pelvis: complications after reconstruction. Arch Orthop Trauma Surg 2003;123:340—4.
[20] Nakai S, Yoshizawa H, Kobayashi S, Maeda K, Okumura Y. Anorectal and bladder function after sacrifice of the sacral nerves. Spine 2000;25:2234—9.
[21] Gunterberg B, Kewenter J, Petersén I, Stener B. Anorectal function after major resections of the sacrum with bilateral or unilateral sacrifice of sacral nerves. Br J Surg 1976;63:546—54.
[22] 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.
[23] Delloye C, Banse X, Brichard B, Docquier P, Cornu O. Pelvic reconstruction with a structural pelvic allograft after resection of a malignant bone tumor. J Bone Joint Surg Am 2007;89:579—87.
[24] Gerrand CH, Griffin AM, Davis AM, Gross AE, Bell RS, Wunder JS. Large segment allograft survival is improved with intramedullary cement. J Surg Oncol 2003;84:198—208.
[25] Nagoya S, Usui M, Wada T, Yamashita T, Ishii S. Reconstruction and limb salvage using a free vascularised fibular graft for periacetabular malignant bone tumours. J Bone Joint Surg Br 2000;82:1121—4.