

Transarticular invasion of primary bone tumors abutting the sacroiliac joint: an MRI study in 128 patients

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Abstract

Background: To investigate magnetic resonance imaging (MRI) manifestation of transarticular invasion of primary bone tumors abutting the sacroiliac joint.

Methods: We conducted a retrospective analysis of MRI data in 128 patients with primary bone tumors abutting the sacroiliac joint from January 2004 to December 2015. The diagnoses were confirmed by surgical findings and pathological examination. The tumors of 87 patients located in the ilium and 41 patients in the sacrum. Tumors were divided into high-grade malignant tumor group (Group 1), low-grade (Group 2) malignant tumor group and intermediate tumor group (Group 3). Transarticular invasion routes included 3 types: across ligament (Type 1), across articular cartilage (Type 2) and across periarticular tissue (Type 3).

Results: Transarticular invasion were observed in 33 patients (25.8%): Group 1 (22 patients) included 15 patients (51.7%) with conventional osteosarcoma and 7 patients (43.8%) with Ewing's sarcoma; Group 2 (5 patients) included 4 patients (11.4%) with central chondrosarcoma and 1 patient (7.7%) with chordoma; Group 3 (6 patients) included 4 patients (20.0%) with giant cell tumor of bone, 1 patient (16.7%) with chondroblastoma and 1 patient (11.1%) with aneurysmal bone cyst. The difference of transarticular invasion incidence was not statistically significant between primary iliac and sacral tumors ($P > 0.05$). The differences were statistically significant between group 2 and group 1, group 3 and group 1, respectively ($P < 0.01$). Significant differences were observed among different invasion types ($P < 0.01$): type 1 (31 times), type 2 (15 times) and type 3 (5 times).

Conclusions: MRI is sensitive and useful to evaluate transarticular invasion of primary bone tumors abutting the sacroiliac joint.

Background

Due to the deep location of primary bone tumors abutting the sacroiliac joint, the tumors may invade the sacroiliac joint or even cross it at the time of diagnosis. Preoperative accurate diagnosis of transarticular invasion of the sacral or iliac tumor plays an important role in the design of surgical program^[1-4].^[2] For primary malignant bone tumors involving the sacroiliac joint, it is necessary to resect the ilium and sacrum invaded by the tumors together with the sacroiliac joint and to reach the safe boundary of oncology^[1]. The postsurgical recurrence rate of tumors in patients reaching the safe boundary was much lesser than that in patients not reaching the safe boundary^[3-5]. Imaging studies of pelvic bone tumors invading the sacroiliac joint have been rarely reported in the literature^[2, 6-9]. Review of literature on bone tumor invasion of the sacroiliac joint raises several questions for further study: (1) The accuracy of MRI in the diagnosis of sacroiliac joint invasion by tumor. (2) The sacroiliac joint includes the anterior-inferior synovial joint and posterior-superior ligamentous portion. Are the transarticular invasion incidences or invasion types similar between iliac and sacral tumors? (3) The differences of the transarticular invasion incidences and invasion types among different pathological types or different grades of tumors.

Therefore, this study was aimed at evaluating the value of MRI in detecting transarticular invasion of primary bone tumors abutting the sacroiliac joint based on the above questions.

Methods

Patients

Inclusion criteria: (i) primary pelvic tumors abutting the sacroiliac joint (the distance between tumor margin and articular surface is less than 2 cm^[7]); (ii) underwent presurgical magnetic resonance imaging (MRI) and surgical treatment within 7 days in our hospital; and (iii) the tumor types were confirmed by pathology. Exclusion criteria: (i) hematologic tumors and metastases (difficult to identify transarticular invasion from multifocal lesions); and (ii) the number of tumors with a same type was less than 5 (sample size is too small for statistical analysis). According to inclusion and exclusion criteria, from January 2004 to December 2015, there were 2353 patients with pelvic tumors undergoing magnetic resonance imaging (MRI) scan in our hospital. The MRI images were reviewed by 2 radiologists specializing in bone tumor and the final diagnosis was reached a consensus. After the cases of hematologic tumors and metastases were excluded, which had a primary tumor history or two or more lesions, 317 patients were diagnosed as primary pelvic tumors by radiology. 205 patients of them had surgical treatment within 7 days after MRI scan in our hospital and confirmed by pathology. Of the 205 patients, 143 patients showed tumor extension within 2 cm from the sacroiliac joint on magnetic resonance imaging (MRI) scans. Diagnoses of the tumors were confirmed by surgical findings and pathological examination. 4 fibrosarcomas, 2 hemangiosarcomas, 4 osteoblastoma, 3 pleomorphic undifferentiated sarcoma and 2 uncertain types tumors were excluded. Finally, 128 patients were included in this study, including 80 men and 48 women with an average age of 32.5 years (range: 4-74 years). The primary tumors of 87 patients were originally located in the ilium and 41 patients in the sacrum. 29 patients were diagnosed with conventional osteosarcoma, 16 with Ewing's sarcoma, 35 with central chondrosarcoma (grade II), 13 with chordoma, 20 with giant cell tumor of the bone (6 of which were complicated with secondary aneurysmal bone cyst), 6 with chondroblastoma and 9 with primary aneurysmal bone cyst. Based on pathology grading systems, these tumors were divided into the high-grade malignant tumor group (Group 1, 45 patients with conventional osteosarcoma or Ewing's sarcoma), the low-grade malignant tumor group (Group 2, 48 patients with central chondrosarcoma or chordoma) and the intermediate tumors group (Group 3, 35 patients with giant cell tumor of the bone, chondroblastoma or aneurysmal bone cyst).

Examination method

All the patients underwent a Siemens Magnetom Vision 1.5 T or Magnetom Trio Tim 3.0T whole-body superconducting MRI scanners (Germany). The MRI sequence included a T1-weighted conventional spin echo sequence (TR = 450-600 ms, TE = 12-14 ms), T2-weighted fast spin echo sequence (TR = 3000-4500 ms, TE = 90-120 ms), T2WI with fat suppression (TR = 3000-4500 ms, TE = 90-120 ms), enhanced T1WI (TR = 450-600 ms, TE = 12-14 ms), and enhanced T1WI with fat suppression (TR = 450-600 ms, TE = 12-

14 ms). Gadolinium-diethylenetriamine pentaacetic acid (Gd-DTPA) at a concentration of 0.5 mmol/L was intravenously administered at a dose of 0.2 ml/kg and at a rate of 1.0 ml/s for enhanced scans. The slice thickness was 5-8 mm, and the interlayer spacing was 0.5-0.8 mm.

Imaging evaluation

Sacral or iliac tumors with less than 2 cm of distance between tumor margin and articular surface was defined as bone tumors abutting the sacroiliac joint^[7]. Transarticular invasion of the articulation was defined as direct contiguous tumour involvement, manifest by low T1 (enhanced on postcontrast images) and intermediate or high T2 signal abnormality, of opposing bones involving either component of the articulation to cause bone destruction^[1, 6-8]. The MRI images were reviewed by 2 radiologists specializing in bone tumor and the final diagnosis was reached a consensus. The tumor margins and extension were mainly assessed on precontrast T1WI and postcontrast T1WI with fat suppression, while T2WI and T2WI with fat suppression were for supplement^[10]. The types of transarticular invasion of a bone tumor abutting the sacroiliac joint include (1) transarticular invasion via the ligament located at the posterior-superior part of the sacroiliac joint (i.e., invasion across the ligamentous portion) (Type 1, Figure 1); (2) transarticular invasion via direct destruction of the cartilage located at the anterior-inferior part of the sacroiliac joint, across the articular space (i.e., invasion across the articular cartilage) (type 2, Figure 2); and (3) transarticular invasion across the muscles and ligaments around the sacroiliac joint (i.e., invasion across the periarticular tissue) (type 3, Figure 3). For tumors in which 2 or more types coexisted (including invasion across the entire sacroiliac joint, i.e., Type 1 + Type 2; invasion across the entire joint and periarticular tissues, i.e., Type 1 + Type 2 + Type 3), each type was separately counted once (Figure 4).

Statistical analysis

SPSS 17.0 statistical software was used for data analysis. The chi-squared test for count data was used to compare the differences of the transarticular invasion incidences and types among different locations, different pathological types and different pathological grades of primary bone tumors. A P value of less than 0.05 was considered statistically significant.

Results

MRI diagnostic accuracy

Bone tumors abutting the sacroiliac joint can cause bone destruction and show abnormal MRI signal. The tumor tissue can invade into the sacroiliac joint or spread along the surrounding structures to the contralateral bone of the joint, resulting bone destruction and replacement with tumor tissue meanwhile. In this study, 33 of 128 (25.8%) patients presented with transarticular invasion (Table 1), which was 100% consistent with the surgical findings and pathological examination. 4 of 128 (3.1%) cases dubiously showed transarticular invasion on MRI but were not confirmed by pathological examination, including 1 chondrosarcoma, 2 giant cell tumors and 1 aneurysmal bone cyst. The specificity of MRI in the diagnosis of transarticular invasion is 96.9%.

Comparison of transarticular invasion incidences in different locations

Of the 128 patients, 87 patients were diagnosed as iliac tumors, with 26 (29.9%) patients demonstrated evidence of transarticular invasion; 7 of 41 (17.1%) patients with sacral tumors patients demonstrated evidence of transarticular invasion (Table 1). In general, the incidences between the iliac and sacral primary tumors were not statistically different (χ^2 value = 2.39, $P > 0.05$). The difference of transarticular invasion incidence was not compared in Group 1 because their proportions were not comparable (43 iliac tumors and 2 sacral tumors). No statistically significant difference was observed in Group 2—26 iliac tumors and 22 sacral tumors, χ^2 value = 0.04, $P > 0.05$ —and Group 3—18 iliac tumors and 17 sacral tumors— χ^2 value = 0.14, $P > 0.05$.

Comparison of the transarticular invasion incidences in different pathological grades

The overall difference of transarticular invasion incidences were statistically significant among different pathological grades (χ^2 value = 19.84, $P < 0.01$). There were significant differences in Group 1 and Group 2, Group 1 and Group 3 respectively ($P < 0.01$) (Table 2), but no statistically difference between Group 2 and Group 3 (χ^2 value = 0.32, $P > 0.05$).

Comparison of the transarticular invasion incidences in different pathological types

The overall transarticular invasion incidence of malignant bone tumors (Group 1 + Group 2) was 29.0% (27/93). The transarticular invasion incidences were high in the patients with conventional osteosarcoma (51.7%) and those with Ewing's sarcoma (43.8%), but low in the patients with central chondrosarcoma (11.4%) and those with chordoma (7.7%) (Table 1). The overall incidence of transarticular invasion was 17.1% (6/35) in intermediate bone tumors (Group 3) and the differences were not statistically significant among the 3 sub-types (giant cell tumor, chondroblastoma and aneurysmal bone cyst) (χ^2 value = 0.25, $P > 0.05$).

Comparison of transarticular invasion types

The details of transarticular invasion type were shown in Table 3. Type 1 and type 1 + type 2 were common, whereas type 2 and type 3 were rare. Table 4 was the number of individual invasion type in the 33 patients. The overall transarticular invasion incidences were different among type 1, type 2 and type 3 (χ^2 value = 41.74, $P < 0.01$). Further pairwise comparison showed statistic differences among the three types (χ^2 values and corresponding P values were as follows: χ^2 value = 18.37, $P < 0.01$; χ^2 value = 41.31, $P < 0.01$; χ^2 value = 7.17, $P < 0.01$). Transarticular invasion across the ligamentous portion was the most common type, followed by the articular cartilage type and finally, the periarticular tissue type. The incidences of type 1, type 2 and type 3 were not significantly different ($P > 0.05$) among the three groups respectively.

Discussion

Among the imaging techniques (X-ray, CT, MRI, SPECT and PET/CT) assessing the bone tumors, MRI has its unique advantage to show the intramedullary, surrounding soft tissue, adjacent joint invasion and bone metastasis. Abnormal signal changes on MRI can not only clearly reveal the location, size and range of bone tumors abutting the sacroiliac joint, but also show the destruction of the cortex and invasion of the contralateral bone via different structures. According to the literature, the sensitivity and specificity of MRI were 92% to 100% when a strict definition of transarticular invasion was used [1, 6-8]. In our study, the sensitivity and specificity of MRI were 100% and 96.9% respectively, corresponding with the literature. MRI can detect transarticular invasion with high sensitivity and specificity. The iliac cartilage was thinner compared with the sacral cartilage, which is an anatomical characteristic of the sacroiliac joint. Although transarticular invasion incidence was higher in the iliac tumor than in the sacral tumor (29.9% vs. 17.1%), this difference was not statistically significant. 27 of 93 (29.0%) patients with malignant bone tumors—Group 1 and 2—were diagnosed with transarticular invasion. Of 35 patients with intermediate bone tumors (Group 3), only 6 patients (17.1%) presented with transarticular invasion, including 4 patients with giant cell tumor of bone, 1 patient with chondroblastoma and 1 patient with aneurysmal bone cyst. These results indicated that intermediate bone tumors are somewhat aggressive but the transarticular invasion incidence was significantly lower than that of high-grade malignant bone tumors. In conclusion, the invasion incidence was not associated with anatomical characteristic of the sacroiliac joint but associated with the malignant degree.

In our study, the incidence of transarticular invasion was highest in Group 1 (conventional osteosarcoma (51.7%) and Ewing's sarcoma (43.8%)), but was low in Group 2 (central chondrosarcoma (11.4%) and chordoma (7.7%)). The incidence of osteosarcoma was similar to the results reported in the literature [6-8]. Nevertheless, the incidences of chondrosarcoma and Ewing's sarcoma were obviously different from that in the literatures. Sun et al reported the transarticular invasion incidence of chondrosarcoma was 36.84%, for Ewing's sarcoma was 55.56% [6]. Ozaki et al. reported in two different studies [7, 8] that the transarticular invasion incidence of chondrosarcoma was 47.1% and 46.7% respectively, for Ewing's sarcoma was 4.3% and 8.7% respectively. We did not compare the results with other related studies because their sample sizes were too small [11-13]. These discrepancies may be attributed to differences in inclusion criteria. Firstly, Ozaki's study only included patients with the primary iliac tumor, whereas Sun's and our studies included patients with both primary iliac and sacral tumors. Secondly, minimum distance between tumor margin and joint surface less than 2 cm was not an inclusion criterion in Ozaki's study [8]. Secondly, patients with high-grade chondrosarcoma accounted for 80% of all patients with chondrosarcoma in the studies by Ozaki [7, 8], and the grade of chondrosarcomas in the studies by Sun were unknown, whereas patients with low-grade chondrosarcoma (well-differentiated central chondrosarcoma) were predominant in our study. For chondrosarcoma, the degree of malignancy may be a main reason for the transarticular invasion. The transarticular incidence of chordoma was 6.25% in the literature [6], which is similar to the incidence (7.7%) in our study. This may be associated with its low-grade malignancy and less invasive nature. In addition, chordoma is usually located at the midline of the lower sacrum [8], which is distant from the sacroiliac joint relatively. The transarticular incidence of intermediate bone tumors has not been reported. Nevertheless, our study showed the transarticular

invasion of intermediate bone tumors abutting the sacroiliac joint is not so rare, which had a similar incidence as low-grade malignant tumors.

Of the 33 patients with tumor invasion across the sacroiliac joint, a few patients showed involvement of two or more invasion types. The statistical results showed differences in incidences among the 3 types: type 1 was the most common type, followed by type 2 and then, type 3. In addition, the incidences of different types were not associated with the malignant degree of tumors. Isolated invasion across the articular cartilage was very rare, so type 2 was usually accompanied by type 1, indicating that the cartilage may prevent the joint to be invaded by the tumor to some degree. These findings were consistent with that in the previous literature^[7, 8]. The prevention mechanism of cartilage may be related to the following factors: ☒ There are no blood vessels in the articular cartilage. Thus, a direct anatomical channel and blood supply for tumor growth are lacking^[14]. ☒ Cartilage cells can produce a substance to inhibit tumor angiogenesis^[15] and collagenase activity^[16-18]. And when the tumor invades across the periarticular tissues, we should also confirm whether other structures (such iliolumbar ligament and lumbar vertebra) are invaded or not.

Conclusions

In summary, MRI can accurately diagnose transarticular invasion of primary bone tumors abutting the sacroiliac joint. The transarticular invasion incidence is associated with pathological type, benignity or malignancy, and the malignant degree of a tumor rather than its location (sacrum or ilium). Not only malignant tumors but also intermediate tumors can invade across the sacroiliac joint, although the incidence of them is lower than high-grade malignant tumors. The invasion type is not related to the malignant degree of a tumor. Transarticular invasion across the ligamentous portion is quite common. The cartilage portion may be a barrier against tumor invasion, but as the tumor grows the cartilage can be destroyed and subsequently cause transarticular invasion. So, we should pay more attention to confirm the extension of the tumors abutting the sacroiliac joint, especially the ligamentous part, to confirm whether there is transarticular invasion, which has guiding significance for the formulation of surgical treatment.

Abbreviations

MRI: magnetic resonance imaging

Gd-DTPA: Gadolinium-diethylenetriamine pentaacetic acid

CT: computerized tomography

SPECT: single photon emission computed tomography

PET: positron emission tomography

Declarations

Ethics Approval and Consent to Participate

The current study was approved by the Institutional Ethics Committee of the First Affiliated Hospital of Sun Yat-Sen University, and the need for signed informed consent was waived.

Consent for Publication

We have obtained consent to publish from all the participants.

Availability of data and materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declared that they have no conflict of interest. No authors have received any funding from any institution, including personal relationships, interests, grants, employment, affiliations, patents, inventions, honoraria, consultancies, royalties, stock options/ownership, or expert testimony for the last 12 months.

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Authors' Contributions

LD and JQY participated in design of the study, collected the patients' data, and drafted the manuscript. FLZ, YQW, CYZ processed the figures, helped draft the manuscript, and performed critical revision of the manuscript. ZHG conceived and designed the study, supervised the project. All authors read and approved the final version of the manuscript.

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Tables

Table 1 Transarticular invasion incidences of 128 patients with primary bone tumors abutting the sacroiliac joint

Tumor type	Total number of patients	Number of patients with transarticular invasion (Ilium/sacrum)	Transarticular invasion incidence (%)
Conventional Osteosarcoma	29 (27/2)	15 (13/2)	51.7
Ewing's sarcoma	16 (16/0)	7 (7/0)	43.8
Central chondrosarcoma	35 (26/9)	4 (2/2)	11.4
Chordoma	13 (0/13)	1 (0/1)	7.7
Giant cell tumor of the bone	20 (8/12)	4 (2/2)	20.0
Chondroblastoma	6 (4/2)	1 (1/0)	16.7
Aneurysmal bone cyst	9 (6/3)	1 (1/0)	11.1
Total	128 (87/41)	33 (26/7)	

Table 2 Comparison of transarticular invasion incidences among different pathological grades

Patient group	Total number of patients	Number of patients with transarticular invasion	Transarticular invasion incidence (%)	χ^2 value between the groups	P-value
Group 1	45	22	48.9	Group 1 vs. 2 16.68	0.01
Group 2	48	5	10.4	Group 1 vs. 3 0.32	0.05
Group 3	35	6	17.14	Group 2 vs. 3 8.72	0.01

Table 3 Transarticular invasion types of 33 patients (cases)

Tumor type	Across the ligament portion	Across the articular cartilage	Across the whole joint	Across the periarticular tissue	Across the whole joint and periarticular tissue	Total
	Type1	Type2	Type1+Type2	Type3	Type1+Type2 +Type3	
Inventional teosarcoma	6	0	5	0	4	15
ng's sarcoma	4	1	2	0	0	7
Central ndrosarcoma	3	0	1	0	0	4
Chordoma	0	0	0	1	0	1
nt cell tumor f the bone	2	0	2	0	0	4
ndroblastoma	1	0	0	0	0	1
arysmal bone cyst	0	0	0	0	1	1
Total	16	1	10	1	5	33

Table 4 Number of individual transarticular invasion type in 33 patients (times)

Tumor type		(Type 1)	(Type 2)	(Type 3)
Group 1	Conventional osteosarcoma	100% (15/15)	60% (9/15)	26.7% (4/15)
	Ewing's sarcoma	85.7% (6/7)	42.9% (3/7)	0 (0/7)
Group 2	Central chondrosarcoma	100% (4/4)	25% (1/4)	0 (0/4)
	Chordoma	0 (0/1)	0 (0/1)	100% (1/1)
Group 3	Giant cell tumor of the bone	100% (4/4)	25% (1/4)	0 (0/4)
	Chondroblastoma	100% (1/1)	0 (0/1)	0 (0/1)
	Aneurysmal bone cyst	100% (1/1)	100% (1/1)	0 (0/1)
Total		93.9% (31/33)	45.5% (15/33)	15.2% (5/33)

Figures

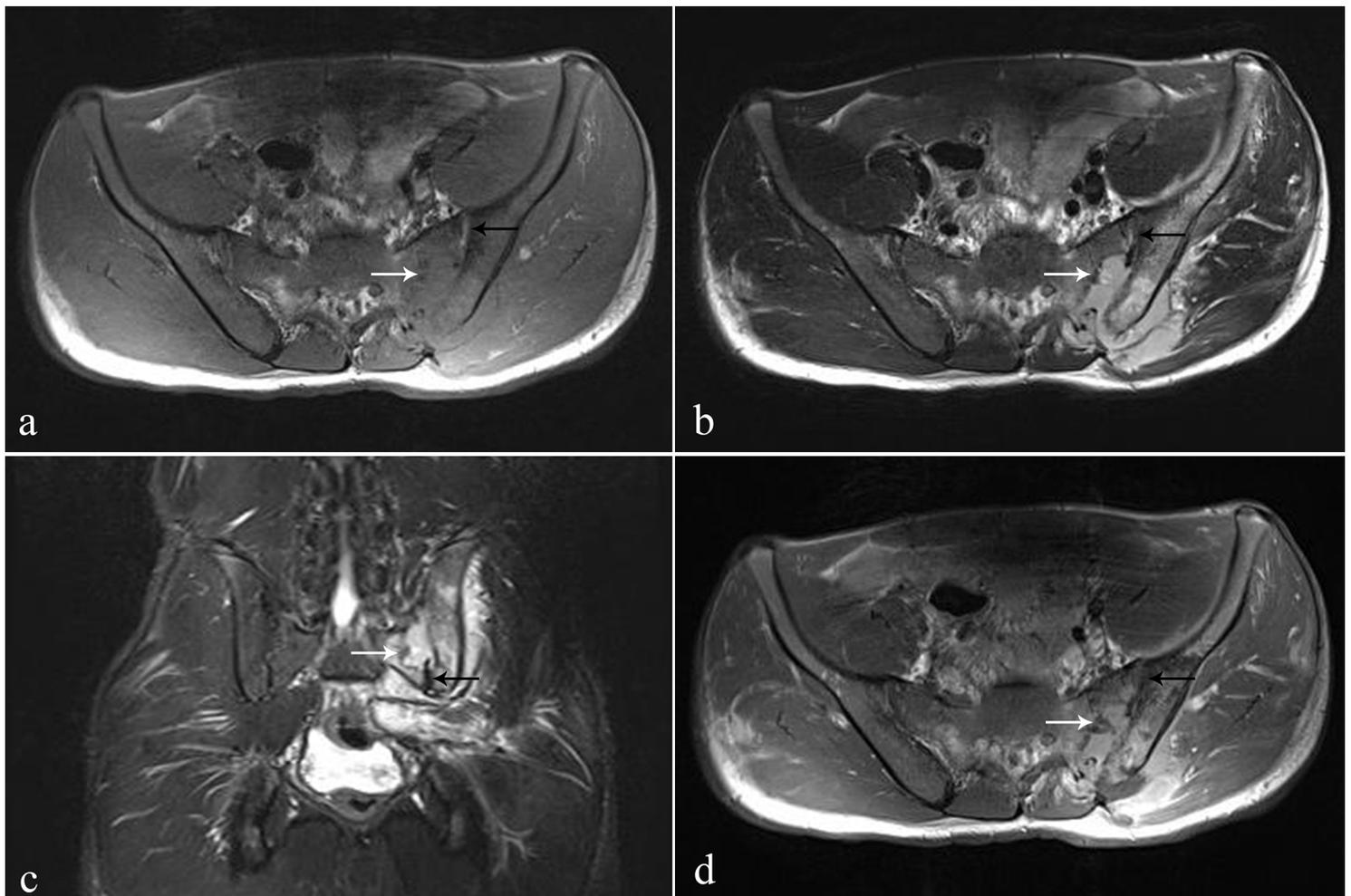


Figure 1

An 18-year-old boy with left iliac Ewing's sarcoma, presenting transarticular invasion across the ligamentous portion, which was confirmed by surgical findings. MR T1WI (a), T2WI (b), T2WI with fat suppression (c), and enhanced T1WI (d) showed bone destruction of the sacrum (white arrow), the posterior space of the sacroiliac joint and the left portion of the sacrum were filled with tumor tissue with intermediate signal intensity on T1WI and high signal intensity on T2WI. Tumor signals were not observed in the anterior-inferior space (cartilage portion) of the sacroiliac joint (black arrow).



Figure 2

A 15-year-old girl with left iliac Ewing's sarcoma, presenting transarticular invasion to the sacrum across the articular cartilage, which was confirmed by surgical findings. MR T1WI (a), T2WI (b), and enhanced T1WI (c) showed tumor invasion of the sacroiliac joint across the anterior portion of the joint and the articular surface of sacrum was destroyed (white arrow). Tumor signal was also observed in the posterior joint space (ligamentous portion), but the sacral cortical exhibited normal (black arrow).

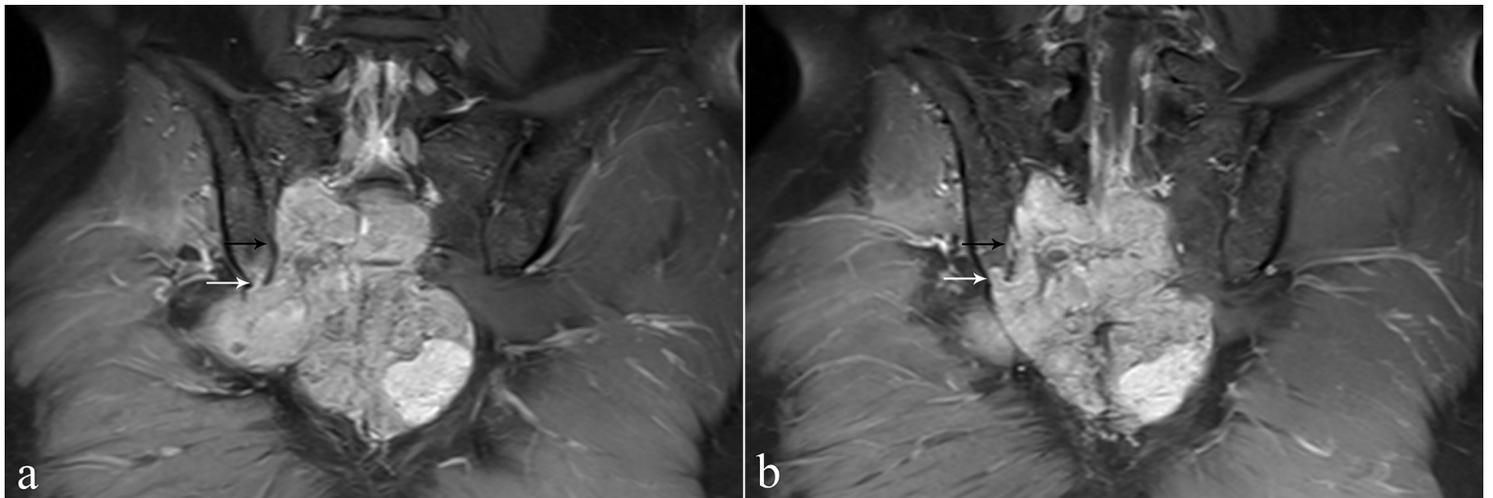


Figure 3

A 38-year-old male with sacral chordoma, presenting transarticular invasion to the ilium across the periarticular tissue, which was confirmed by surgical findings. MR enhanced T1WI (a, b) showed tumor invasion of the right ilium across the inferior portion of the sacroiliac joint (white arrow), and the articular surface of sacrum was interrupted. But the cortical bone of the right ilium was intact (black arrow).

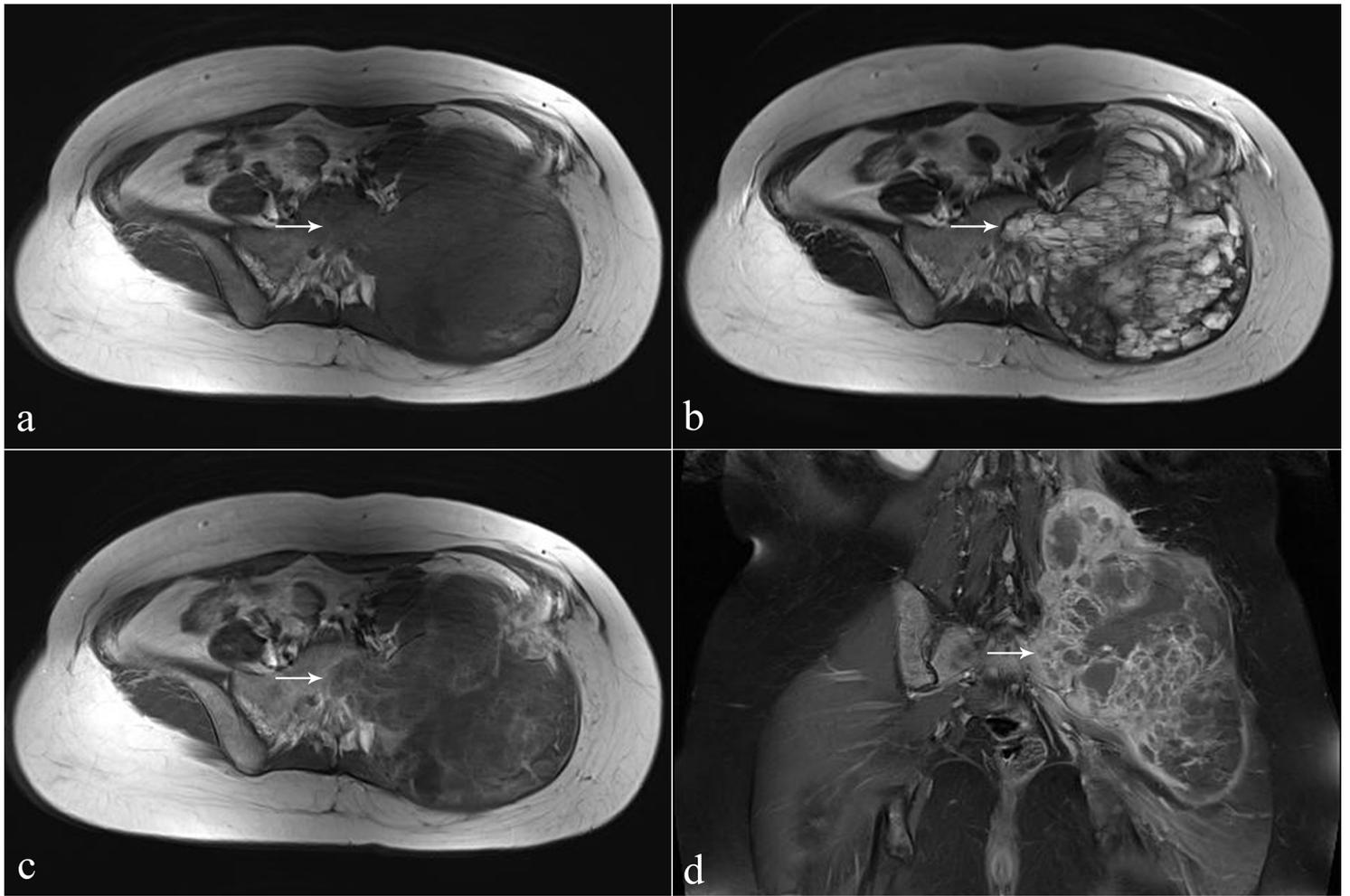


Figure 4

A 36-year-old female with giant bone cell tumor of the left ilium combined with an aneurysmal bone cyst, presenting invasion of the sacrum across the whole sacroiliac joint (including cartilage and ligamentous portions), which was confirmed by surgical findings. MR T1WI (a), T2WI (b), enhanced T1WI (c), and enhanced T1WI with fat suppression (d) showed tumor invasion of the sacrum across the whole left sacroiliac joint (white arrow).