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MR imaging of edema accompanying benign and malignant bone tumors

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Abstract. To evaluate the incidence, quantity, and presentation of intra- and extraosseous edema accompanying benign and malignant primary bone lesions, the magnetic resonance (MR) studies of 63 consecutive patients with histologically proven primary bone tumors were reviewed. MR scans were assessed for the presence and quantity of marrow and soft tissue edema and correlated with peroperative findings, resected specimens and follow-up data. The signal intensity and enhancement of tumor and edema prior to and after intravenous administration (if any) of gadolinium-labled diethylene triamine pentaacetate (Gd-DTPA) was analyzed. Marrow edema was encountered adjacent to 8 of 39 malignant tumors and 14 of 24 benign lesions. Soft tissue edema was found accompanying 28 of 39 malignancies and 10 of 24 benign disorders. On unenhanced T1-weighted MR images tumor and edema were difficult to differentiate. Tumor inhomogeneity made this differentiation easier on T2-weighted sequences. In 36 patients the contrast medium Gd-DTPA was used. Edema was present in 27 of these patients and the respective enhancement of tumor and edema could be compared. Edema always enhanced homogeneously, and in most cases it enhanced to a similar degree as or more than tumor. Marrow and, more specifically, soft tissue edema is a frequent finding adjacent to primary bone tumors. The mere presence and quantity of marrow and soft tissue edema are unreliable indicators of the biologic potential of a lesion. Unenhanced MR scans cannot always differentiate between tumor and edema, but the administration of Gd-DTPA is of assistance in differentiating tumor from edema. Awareness of marrow and/or soft tissue edema adjacent to bone lesions is of importance because edema can be a pitfall in the diagnostic work-up and staging prior to biopsy or surgery.

Key words: Bone marrow edema, MR studies – Bone neoplasms, MR studies – Bone neoplasms, therapy – Gadolinium, contrast enhancement

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Although conventional radiographs are usually more specific for making a radiological (differential) diagnosis, magnetic resonance (MR) imaging is nowadays regarded as the modality of choice for staging musculoskeletal tumors prior to surgery [1–3]. MR imaging is also increasingly used to monitor patients after surgery, chemotherapy, and/or radiotherapy [4–10]. The capability of MR to distinguish benign from malignant musculoskeletal lesions remains to this day controversial [11, 12].

Soft tissue edema accompanying musculoskeletal lesions has been reported earlier [4, 7, 8, 11–21]. More recently, several studies have mentioned the presence of marrow edema adjacent to bone tumors and several other conditions, indicated by a change in signal intensities on MR images [5, 8, 14, 18, 20–36]. None of these studies, concerning bone tumors or tumor-like lesions, focused specifically on the incidence and quantity of intraosseous edema or the potential impact of the presence of edema on the differentiation of lesions. To evaluate the phenomenon of edema more closely, we retrospectively studied the MR examinations of 63 consecutive patients with a histologically proven tumor or tumor-like lesion of bone for the presence of soft tissue edema and, more specifically, marrow edema. The effect of administration of gadolinium-labeled diethylene triamine pentaacetate (Gd-DTPA) on the signal intensities of tumor and edema is reviewed.

Materials and methods

From our records we retrieved the cases of 66 consecutive patients who presented in a single year with a solitary bone lesion caused by a bone tumor or tumor-like disorder. All patients were referred to our department for an MR study. Three of the 66 patients had undergone surgery prior to the initial MR examination and were excluded from the study; the remaining 63 patients were examined prior to biopsy.

Thirty-five (56%) of the 63 patients were male, 28 (44%) were female. The mean age was 30 years (range 10–68 years). In all patients the diagnosis was histologically confirmed. Thirty-nine (62%) had malignant and 24 (38%) benign lesions. The histologic

Table 1. Histologic diagnoses of lesions studied (63 patients)

Tumor or tumor-like lesion	No. of patients
Malignant tumors (39 patients)	
Osteosarcoma	18
Chondrosarcoma	13
Ewing's sarcoma	5
Malignant fibrous histiocytoma	1
Lymphoma	1
Adamantinoma	1
Benign tumors or tumor-like lesions (24 patients)	
Chondroblastoma	6
Osteoid osteoma	5
Giant cell tumor	4
Osteochondroma	4
Osteoblastoma	2
Fibrous dysplasia	2
Solitary bone cyst	1

diagnoses are listed in Table 1. In 51 patients (81%) the tumor was located in a long tubular bone, in 10 cases (16%) in the pelvis and in two (3%) in the tarsal bones. Of the patients with malignant tumors, 28 underwent a resection and 4 an amputation of the affected part of the skeleton. Seven patients with malignancies were inoperable for various reasons. Thirteen of the benign lesions were curetted. Of the remaining 11 patients, 7 underwent a resection and 4 an exicision. The follow-up period was at least 18 months.

In all 63 patients both conventional radiographs and MR examinations were available for evaluation. In 15 patients (12 with an osteosarcoma and 3 with Ewing's sarcoma) follow-up MR studies were performed after chemotherapy to monitor response. This resulted in a total of 78 MR examinations available for study.

The MR studies were performed using a 0.5-T superconductive system (Gyroscan, Philips Medical Systems). Predominantly T1-weighted spin-echo (SE) images were obtained using a repetition time (TR) of 550 ms and an echo time (TE) of 30 ms. T2-weighted SE images were obtained using a TR of 2000 ms and TEs of 50 and 100 ms. Axial, sagittal, and coronal imaging planes were selected for optimal visualization of the lesion and surrounding bone marrow and soft tissues. Matrix size was 256×256. In 36 patients Gd-DTPA was administered intravenously after the usual precontrast series. The dose used was 0.1 mmol/kg body weight. An additional short TR/TE (550 ms/30 ms) sequence was done 5–15 min after injection. The reason for not using Gd-DTPA in the remaining 27 patients varied; the age of the patient, refusal by the patient, and logistical factors were all involved. At that time, patients under 15 years of age were not routinely studied after Gd-DTPA administration.

The MR examinations were evaluated visually from the hard copy images. Evaluation was performed by three radiologists in concert. The following items were analyzed: the presence and quantity of peritumoral edema, the signal intensity (SI) arising from the tumors, and when Gd-DTPA was administered, the enhancement of tumor and edema after administration. Discrepancies in interpretation were aligned by consensus.

Marrow and soft tissue edema were defined according to criteria derived from the literature. Marrow edema was defined as an ill-delineated area of homogeneous SI adjacent to the tumor with intermediate SI on T1-weighted images and high SI on T2-weighted images relative to the SI of normal bone marrow, indicating an excess of free water protons relative to fat protons [7, 8, 20, 22, 28, 29, 34, 35]. Soft tissue edema was defined as an area of ill-defined but homogeneous high SI in the soft tissues on T2-weighted images with a feather-like appearance, following the facial planes and without focal mass effect [4, 7, 13, 16, 24]. When present, peritumoral edema in the surrounding bone marrow and soft tissues was classified as minor, moderate, or extensive. The SI arising from the tumors was assessed on T1- and T2-weighted SE sequences and classified as low, intermediate, or high, and homogeneous or heterogeneous. Low SIs were those substantially less than that of skeletal muscle and approximating to that of cortical bone. Intermediate SIs were those between the SIs of fat and cortical bone and approximating to that of muscle. High SIs were those greater than or equal to the SI of normal subcutaneous fat on those images. In addition, the degree and pattern of enhancement of tumor and edema after intravenous administration of Gd-DTPA were evaluated. The degree of enhancement was expressed by the ratio of the enhancement of edema compared to that of tumor. The ratio was classified as greater than 1, equal to 1, or less than 1. The pattern of enhancement of tumor and edema was defined as homogeneous, heterogeneous, or serpentine.

Results

Peroperative, macroscopic, and microscopic findings

In 12 of 14 patients with benign lesions and marrow edema, the tumor dimensions as indicated by MR imaging studies were consistent with those found during surgery. In 2 patients, actual tumor dimensions as found during surgery were smaller than those indicated by MR imaging. Of the 14 patients with a bengin lesion and MR changes indicating intraosseous edema, 4 underwent a resection; 2 of these had an osteoblastoma, 1 had a giant cell tumor of bone, and 1 a chondroblastoma. Macroscopic inspection of the tumor specimens in these cases demonstrated that the actual tumor margins corresponded with those indicated by MR imaging. Macroscopically normal bone marrow was found in areas where MR imaging had suggested the presence of marrow edema. None of the 10 patients who underwent a curettage or excision for a benign lesion, and in whom only the macroscopic tumor tissue had been removed and the edematous areas had been left behind, suffered a recurrence of the lesion.

Of the eight patients with malignancies and MR signs of intraosseous edema on the initial MR studies, the resected specimen was available for histologic evaluation in six. Four patients had an osteosarcoma, one patient had Ewing's sarcoma, and the last patient had a chondrosarcoma. Macroscopic and microscopic study of the areas where marrow edema was suggested on the pre- and postchemotherapy MR studies demonstrated only preexistent normal bone marrow and did not show evidence of viable or necrotic tumor tissue, inflammation or fibrosis.

Edema

MR changes compatible with the presence of intraosseous edema were found in 22 (35%) of 63 cases (Tables 2, 3). Soft tissue edema was shown in 38 (60%) of all patients (Tables 2, 3).

Intraosseous peritumoral edema was present in 8 (21%) of 39 malignant cases (Fig. 1). It was extensive in 4 patients (10%), moderate in 3 (8%), and minor in the remaining one (3%). In the patients with malignancies, extraosseous edema was present in 28 cases (72%) (Fig. 1); it was extensive in 3 (8%), moderate in 15 (38%), and minor in 10 patients (26%).

Table 2. Intra- and extraosseous edema in 39 patients with malignant tumors

Histologic tumor type	Degree	Intraosseous edema (*n*)	Extraosseous edema (*n*)
Osteosarcoma (18 patients)	None	13	2
	Minor	1	4
	Moderate	1	10
	Extensive	3	2
Chondrosarcoma (13 patients)	None	12	7
	Minor	–	3
	Moderate	1	3
	Extensive	–	–
Ewing's sarcoma (5 patients)	None	3	1
	Minor	–	3
	Moderate	1	–
	Extensive	1	1
Malignant fibrous histiocytoma (1 patient)	None	1	–
	Minor	–	–
	Moderate	–	1
	Extensive	–	–
Lymphoma (1 patient)	None	1	–
	Minor	–	–
	Moderate	–	1
	Extensive	–	–
Adamantinoma (1 patient)	None	1	1
	Minor	–	–
	Moderate	–	–
	Extensive	–	–
Total (39 patients)	None	31 (79%)	11 (28%)
	Minor	1 (3%)	10 (26%)
	Moderate	3 (8%)	15 (38%)
	Extensive	4 (10%)	3 (8%)

Table 3. Intra- and extraosseous edema in 24 patients with benign lesions

Histologic tumor type	Degree	Intraosseous edema (*n*)	Extraosseous edema (*n*)
Chondroblastoma (6 patients)	None	–	3
	Minor	1	–
	Moderate	1	1
	Extensive	4	2
Osteoid osteoma (5 patients)	None	–	4
	Minor	–	1
	Moderate	2	–
	Extensive	3	–
Osteochondroma (4 patients)	None	4	2
	Minor	–	1
	Moderate	–	1
	Extensive	–	–
Giant cell tumor (4 patients)	None	3	2
	Minor	1	2
	Moderate	–	–
	Extensive	–	1
Osteoblastoma (2 patients)	None	–	–
	Minor	–	–
	Moderate	–	–
	Extensive	2	2
Fibrous dysplasia (2 patients)	None	2	2
	Minor	–	–
	Moderate	–	–
	Extensive	–	–
Solitary bone cyst (1 patient)	None	1	1
	Minor	–	–
	Moderate	–	–
	Extensive	–	–
Total (24 patients)	None	10 (42%)	14 (58%)
	Minor	2 (8%)	3 (13%)
	Moderate	3 (12%)	2 (8%)
	Extensive	9 (38%)	5 (21%)

In patients with benign lesions, marrow edema was present in 14 (58%) of 24 cases (Figs. 2, 3). It was extensive in 9 (38%), moderate in 3 (12%), and minor in 2 patients (8%). Soft tissue edema was found in 10 patients (42%) with benign lesions (Fig. 2): in 5 cases (21%) extensive, in 2 moderate (8%), and in another 3 (13%) minor.

In six patients with malignant (15%) and seven with benign lesions (29%) both intra- and extraosseous edema were present (Figs. 1, 2).

Signal intensities of edema and tumor

As defined, intra- and extraosseous edema showed a homogeneous intermediate SI on T1-weighted sequences (Figs. 1–3) and a homogeneous high SI on T2-weighted images (Figs. 1, 3).

Of the 63 patients with tumors or tumor-like lesions, 51 (81%) demonstrated homogeneous SI on T1-weighted series (Fig. 1); this was low in 11 patients (17%), intermediate in 39 (62%) and high in 1 (>1%). Twelve patients (19%) had heterogeneous SI (Fig. 2); it was low in 6 (10%), intermediate in 4 (6%), and high in 2 (3%).

On T2-weighted sequences, 29 (46%) bone lesions demonstrated a homogeneous SI: low in 1 (<2%), intermediate in 6 (10%), and high in 22 (35%). Thirty-four bone lesions (56%) had a heterogeneous SI: in 31 (49%) predominantly high, in 2 (3%) predominantly intermediate, and in 1 low (<2%).

Gd-DTPA enhancement

Twenty-six (67%) of the 39 patients with malignant tumors and 10 (42%) of the 24 patients with benign lesions were also studied after intravenous administration of Gd-DTPA. Of these 36 patients, 21 out of 26 patients with malignant tumors and 6 out of 10 with benign lesions had changes in adjacent areas compatible with the presence of intra- and/or extraosseous edema. Eight of these 27 patients had both intra- and extraosseous edema. In contrast to the bone lesions, edema always enhanced homogeneously (Figs. 1, 2, Table 4).

In nine patients with bone lesions the intensity of enhancement of tumor and intraosseous edema could be compared. In four patients marrow edema enhanced more than the lesion (Fig. 1), in another four cases edema

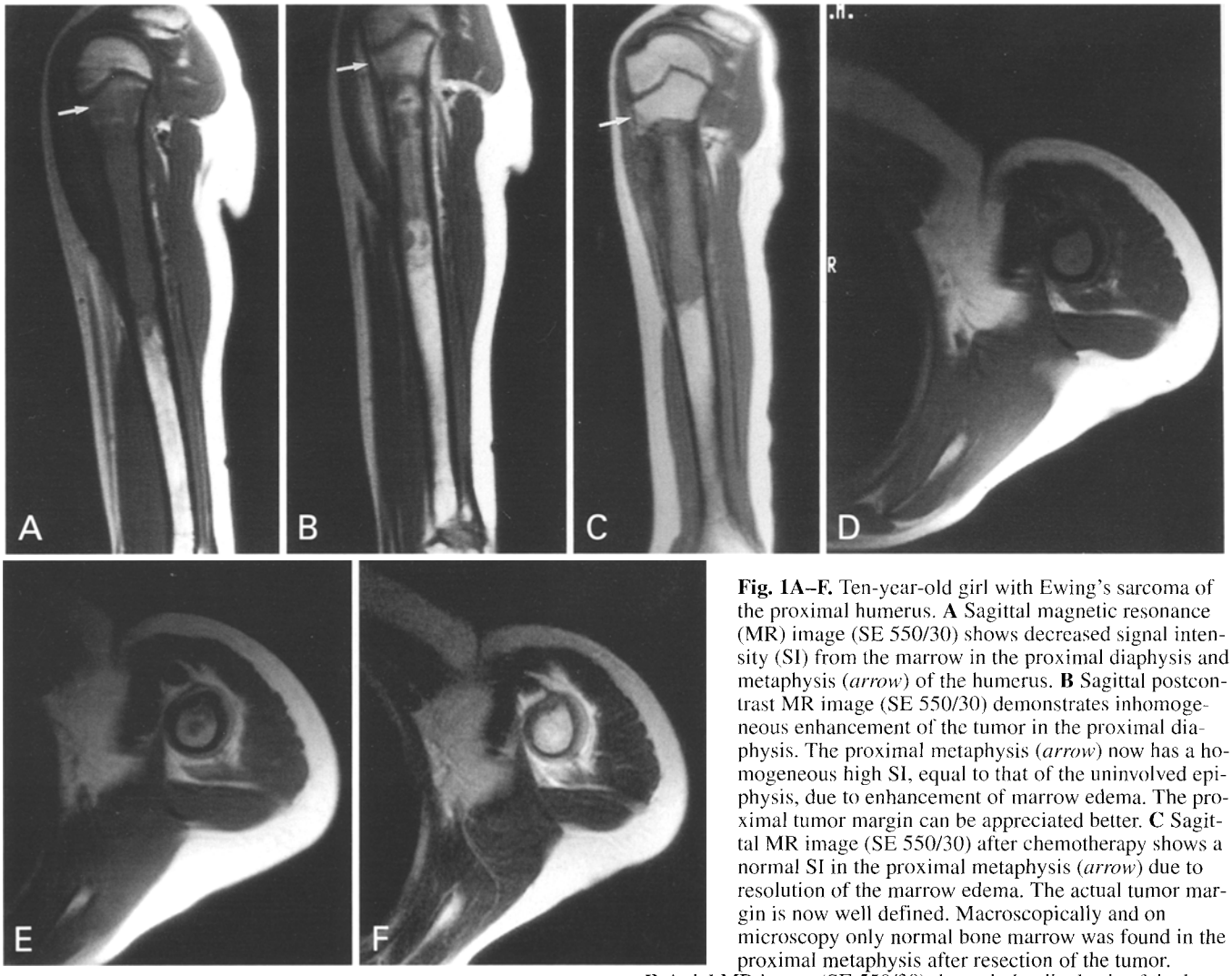

Fig. 1A–F. Ten-year-old girl with Ewing's sarcoma of the proximal humerus. **A** Sagittal magnetic resonance (MR) image (SE 550/30) shows decreased signal intensity (SI) from the marrow in the proximal diaphysis and metaphysis (*arrow*) of the humerus. **B** Sagittal postcontrast MR image (SE 550/30) demonstrates inhomogeneous enhancement of the tumor in the proximal diaphysis. The proximal metaphysis (*arrow*) now has a homogeneous high SI, equal to that of the uninvolved epiphysis, due to enhancement of marrow edema. The proximal tumor margin can be appreciated better. **C** Sagittal MR image (SE 550/30) after chemotherapy shows a normal SI in the proximal metaphysis (*arrow*) due to resolution of the marrow edema. The actual tumor margin is now well defined. Macroscopically and on microscopy only normal bone marrow was found in the proximal metaphysis after resection of the tumor. **D** Axial MR image (SE 550/30) through the diaphysis of the humerus showing low SI arising from the intraosseous tumor. **E** Axial postcontrast MR image (SE 550/30) at the same level as **D**. There is inhomogeneous enhancement of the intramedullary tumor and periosteal reaction surrounding the humerus. Homogeneous high SI in the soft tissues following fascial planes is caused by enhancement of soft tissue edema. **F** Axial MR image (SE 2000/100) also at the same level as **D** shows high SI from the intramedullary tumor, intermediate SI from the periosteal reaction, and homogeneous high SI from the soft tissue edema

and tumor enhanced equally (Fig. 2), and in the last case tumor enhanced more than edema. In one patient comparison was not possible due to variation in the scan planes.

Comparison of the intensity of enhancement of tumor and extraosseous edema was possible in 25 patients. In 13 cases, tumor and extraosseous edema demonstrated an equal degree of enhancement (Fig. 2), in 10 cases edema enhanced more (Fig. 1), while in 2 tumor tissue enhanced more.

Follow-up MR studies

For 15 patients with malignancies, follow-up MR studies after 3 months of chemotherapy were available. Five of these patients gave evidence of intraosseous edema prior to chemotherapy. In three cases an evident decrease in intraosseous edema could be discerned, while in the remaining two patients there was complete resolution (Fig. 1). Response to chemotherapy was established histologically in four of these fine patients. Three demonstrated a poor response, one a good response. The other ten patients did not show evidence of intraosseous edema before chemotherapy was administered and did not develop edema afterwards.

Extraosseous edema remained unchanged in this period in 5 of 15 cases. In the remaining 10 cases there was decrease of extraosseous edema in 8 and increase of edema in 2 patients.

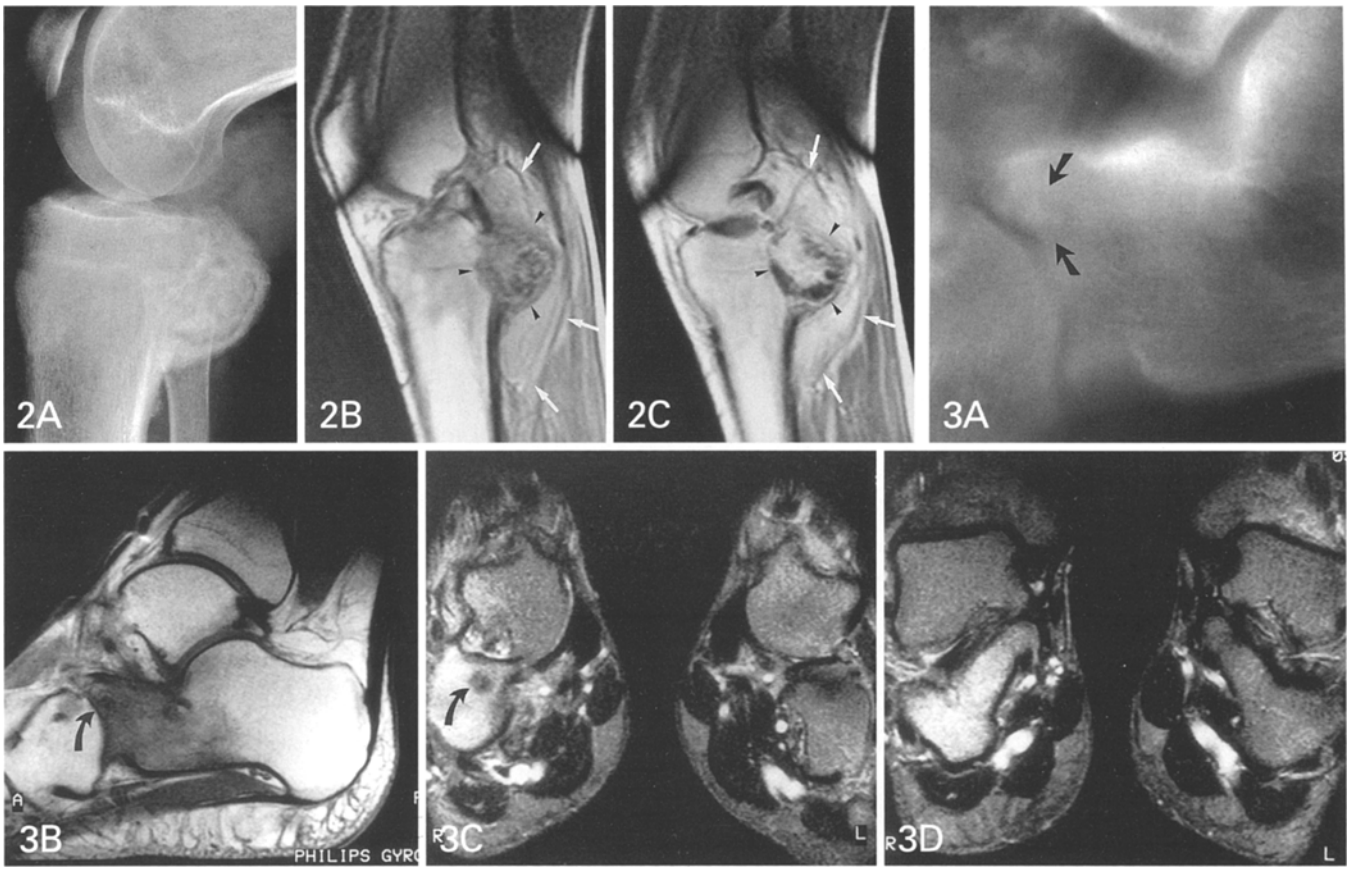

Fig. 2A–C. Twenty-year-old man with an eccentrically originating chondroblastoma of the proximal tibia. **A** Lateral radiograph of the knee showing the eccentric tumor in the epiphysis and metaphysis. **B** Sagittal MR image (SE 550/30) demonstrates indistinct areas of intermediate SI in the marrow in the epiphysis and metaphysis outside the well-defined margins of the tumor (*black arrowheads*). Soft tissue swelling dorsal to the tumor (*white arrows*). Loss of signal at the upper margin due to the use of a surface coil. **C** Sagittal postcontrast MR image (SE 550/30) showing inhomogeneous enhancement of the tumor (*black arrowheads*) and homogeneous enhancement of the edematous bone marrow and soft tissue swelling (*white arrows*)

Fig. 3A–D. Eighteen-year-old man with an osteoid osteoma of the calcaneus. **A** Lateral conventional tomogram shows the mineralized nidus surrounded by a thin lucent halo (*arrows*). No surrounding reactive sclerosis. **B** Sagittal MR image (SE 550/30) shows low SI arising from the well-defined nidus (*arrow*) and diffuse ill-defined intermediate SI in the surrounding bone marrow due to marrow edema. **C** Axial MR image (SE 2000/100) through the plane of the nidus. Low SI from the nidus itself (*arrow*) and homogeneous high SI from the surrounding bone marrow indicative of extensive marrow edema. **D** Axial MR image (SE 2000/100) slightly dorsal to the nidus also demonstrating extensive SI changes due to marrow edema well beyond the actual tumor margin. The normal left side is shown for comparison

Table 4. Enhancement of tumor versus edema after intravenous administration of Gd-DTPA in 36 patients

Pattern of enhancement	Malignant tumors		Benign lesions		Intraosseous edema		Extraosseous edema	
	n	%	*n*	%	*n*	%	*n*	%
Homogeneous	3	11	3	30	10	100	25	100
Heterogeneous	15	58	5	50	–	–	–	–
Serpentine	8	31	2	20	–	–	–	–
Total	26	100	10	100	10	100	25	100

Note: Eight patients studied after Gd-DTPA administration had both intra- and extraosseous edema

Discussion

Edema of the soft tissues on MR imaging has been reported accompanying hematoma [12], early myositis ossificans [18], osteomyelitis and other inflammatory disorders [15, 16]. Soft tissue edema is characterized on MR images as areas of diffusely increased SI on T2-weighted and short tau inversion recovery (STIR) series, following fascial planes and without local mass effect [16].

Bone marrow edema has been demonstrated with MR imaging in association with nonneoplastic conditions such as trauma or stress [20, 29, 34, 37, 38], acute osteomyelitis or septic arthritis [14–16, 20, 28], myositis ossificans [18], reflex sympathetic osteodystrophy [34], transient osteoporosis of hip [25, 35], ischemia [34], osteonecrosis of the hip [33], transient bone marrow edema in early Legg-Calvé-Perthes disease [30], and acute marrow infarction in sickle cell anemia [31]. On MR studies, the presence of marrow edema is suggested by indistinct areas of intermediate SI on T1-weighted images that increase on T2-weighted, fat saturation, and STIR sequences [7, 8, 20, 28, 30, 34–36, 38].

The first substantial report on MR changes indicative of edema accompanying musculoskeletal tumors was published in 1987 [13]. These changes in SI, however, were located only in the skeletal muscles adjacent to primary soft tissue tumors and soft tissue metastases. The finding of edema in the soft tissues adjacent to tumors was confirmed by other authors [4, 8, 11, 12, 17, 20, 21, 24]. Later the presence of intraosseous or bone marrow edema on MR studies in patients with musculoskeletal tumors of bone was reported upon [7, 8, 20–22, 26, 27, 29, 36].

In the present study, as in previous reports, peritumoral marrow and/or soft tissue edema was found in association with both benign and malignant lesions [11, 12, 21, 29]. MR changes consistent with the presence of intraosseous edema were encountered in more than one-third of all the patients in this study. Soft tissue edema adjacent to the bone lesions was found more frequently, namely in nearly two-thirds of all patients studied. Regularly, both intra- and extraosseous edema were seen within the same patient. These observations were encountered in patients with malignant as well as benign lesions of bone.

In our study, bone marrow edema was more often found in association with benign lesions of bone than in patients with malignancies. Half the patients with benign disorders showed features indicative of bone marrow edema, versus one-fifth of the patients with malignant tumors of bone. Within the group of patients with benign disorders marrow edema was specifically found in association with chondroblastoma, osteoid osteoma, and osteoblastoma. Similar findings have been reported or demonstrated in illustrations of these lesions elsewhere [20, 21, 26, 36, 39, 40–42]. The high frequency of marrow edema we encountered in patients with chondroblastoma of bone agrees with findings in previous reports [21, 26]. In our patients, osteosarcoma was also the most common malignant tumor accompanied by intraosseous edema [7]. When present, intraosseous edema was most frequently moderate to extensive in both patients with benign and those with malignant lesions. Therefore, the presence of marrow edema in itself and the quantity of MR signs of bone marrow edema do not seem to be safe indicators of the biological potential of a solitary bone lesion.

Soft tissue edema in our patients also occurred in association with benign as well as malignant tumors, but was more frequently found in the patients with malignancies. The explanation for this observation probably lies in the fact that a large number of malignant lesions are accompanied by cortical destruction and soft tissue extension, while most benign lesions are confined to the affected part of the skeleton without soft tissue involvement, as was the case in the patients we studied. The quantity of soft tissue edema was not a reliable indicator of the malignant nature of the lesion. Conversely, when present, soft tissue edema was often more extensive in the benign tumors than in the malignant ones. We do not have a specific explanation for this observation. It has been suggested that the lack of surrounding soft tissue edema as demonstrated by MR imaging is useful in the differentiation of neoplastic from nonneoplastic processes [43]. The results of our study do not support this idea.

Possible mechanisms generating edema surrounding tumors have been described [44]. The development of edema is a nonspecific response of tissue to a stimulus, e.g., a tumor. The increase of extracellular water is most likely modulated by the severity of hypervascularity and hyperperfusion [20, 30, 34]. A number of reports have related edema in association with a tumor of bone to a diffuse reactive inflammatory response of the marrow and soft tissues [21, 26, 36, 40–42]. It has therefore been suggested that this phenomenon be termed "inflammatory edema". Histologic examination of these areas has shown considerable edematous fluid together with fibroplasia and chronic inflammatory cells [36, 40]. This inflammatory response, however, is not invariably found during histologic examination of areas of presumed marrow edema [8, 18, 19, 22]. In our study, we did not find signs of (previous) inflammation in areas of marrow edema in those patients in whom histologic confirmation was possible.

The importance of acknowledging the phenomenon of an edema pattern on MR images adjacent to tumors and distinguishing tumor from edema has been recognized by others [21, 22, 24, 26, 27, 29, 36, 40–42]. Not only can the presence of edema lead to marked overestimation of the size of a lesion, and consequent incorrect staging or biopsy sample errors, it can also lead to an erroneous diagnosis on the basis of MR images alone [21, 22, 29, 40]. This is especially important in small lesions with marked peritumoral reactive marrow response on MR studies such as osteoid osteomas and osteoblastomas (Fig. 3) [24]. This underlines the necessity of correlating MR findings to those of other radiologic modalities. Because of the importance of recognizing edema, we looked for criteria in our patients enabling us to discriminate between actual tumor and edema.

The SIs and the signal (in)homogeneity of the lesions studied are common and consistent with findings previously published [1]. Because of the similar SIs of marrow edema and tumor, tumor and edema were often hard to distinguish on T1-weighted sequences with predominantly homogeneous and intermediate SIs. Although on T2-weighted series it also was frequently difficult to tell tumor from intraosseous edema, the inhomogeneity of many tumors versus the homogeneous SI of edema was an aid in differentiating between them.

Within the soft tissues, differentiation between tumor and edema was almost always possbile on the T2-weighted sequences and facilitated by the homogeneous high SI of the accompanying edema and its feathery appearance without disruption of fascial planes (Fig. 1). This finding is in accordance with those of earlier studies [4, 7, 11, 13, 17].

Enhancement of both tumor and soft-tissue and/or marrow edema after intravenous administration of Gd-DTPA has been reported [5, 17, 19, 20, 23, 40, 45]. Normal bone marrow does not enhance significantly after intravenous contrast administration [46]. Enhancement was invariably homogeneous in marrow and extraosseous edema and most frequently inhomogeneous or serpentine in tumor tissue, thus making it possible to differentiate between the two in most cases. This assists in defining the true tumor margins. Homogeneous tumor enhancement, however, does occur, making this differentiation not entirely reliable (Table 4). Enhancement of edema after administration of Gd-DTPA is probably modulated by the same mechanisms which cause edema in the first place. Gd-DTPA is distributed by the vascular system, from which it quickly passes into the extracellular space. Hypervascularity and hyperperfusion increase the local concentration of Gd-DTPA in the extracellular interstitial space, thus influencing the relaxation times of protons in edematous tissues. Because edematous marrow is likely to be more homogeneous than tumor tissue, the pattern of enhancement after Gd-DTPA is also more inclined to be more homogeneous than that of tumor. In both benign and malignant tumors, enhancement of marrow and soft tissue edema was equal to or more than that of tumor tissue. This is corroborated by the findings of Seeger and coworkers [32]. We do not know the precise cause of this phenomenon. In only one patient, with an osteosarcoma, was enhancement of the tumor greater than that of edema. There was no evident histologic explanation for this finding, but probably it was caused by a very high degree of vascularity and perfusion in this tumor in comparison to the other lesions studied. The stronger enhancement of edema compared to tumor is in contrast to earlier observations [17, 47]. Erlemann et al. [17] found a significantly lower and more gradual increase in SI in edema than in adjacent neoplastic tissue immediately after intravenous administration of Gd-DTPA. Other studies [48, 49] have also indicated that tumor enhances earlier than edema. This difference in observation can be caused by the fact that in these studies early post-contrast MR imaging was dynamic, which was not the technique used in our patients. Another factor is the longer time interval between administration of Gd-DTPA and static MR imaging in this study.

In the patients with malignant bone neoplasms and follow-up examinations, intraosseous edema decreased or disappeared entirely after preoperative chemotherapy. Decrease of marrow edema after chemotherapy has been reported before, but does not seem to be a reliable indicator of a good tumor response [4, 5, 7, 8]. This is supported by the findings in four of our patients in whom the response to chemotherapy was established histologically: despite the decrease or disappearance of marrow edema in all four, three demonstrated a poor response to chemotherapy. Soft tissue edema remained stable or decreased in our patients after preoperative chemotherapy. Disappearance of reactive bone marrow changes accompanying osteoblastoma has been documented after surgical removal of the lesion [40].

Histologic confirmation of the presence of edema in association with the bone lesions studied was not always possible. In the patients with benign disorders and marrow edema, most tumors were excised or curetted and only a small number were resected. Inspection of the resected specimens in these latter patients, however, demonstrated the actual tumor size to correspond with the size as indicated by MR imaging. Macroscopically normal bone marrow was found in the areas of presumed edema on MR images. In the remaining patients peroperative inspection and follow-up of the patients was needed for confirmation of the actual extent of the lesions. In these patients, the tumors were excised or curetted until only macroscopically normal bone marrow was visible. The size of all but two benign lesions corresponded with the size as estimated on MR imaging. In two patients the actual tumor size was overestimated by the MR study. The areas of presumed edema on MR imaging proved during surgery to be macrocopically normal bone marrow. The absence of recurrences in these patients supports the idea that the MR changes accompanying these lesions were not due to tumor invasion but to a peritumorous marrow reaction. In the six patients with malignancies accompanied by MR changes compatible with marrow edema and resected specimens available for histologic mapping, normal bone marrow was found without viable or necrotic tumor, hemorrhage, fibrosis, or signs of an inflammatory reaction in the areas where edema was suspected.

From our study we conclude that marrow edema and, more specifically, soft tissue edema is a frequent MR finding in association with both benign and malignant tumors or tumor-like lesions. The mere presence and quantity of marrow and soft tissue edema are unreliable indicators of the biologic potential of a lesion. Recognition of the occurrence of edema accompanying tumors or tumor-like lesions of bone is of importance because the presence of edema can be a pitfall in the diagnostic work-up and staging of these patients prior to biopsy or definite surgery. Differentiation between tumor and edema can be difficult on T1- and T2-weighted SE sequences only. The more intense and homogeneous enhancement of edema compared to tumor on SE imaging 5–15 min after administration of Gd-DTPA may assist in defining the true tumor margin from surrounding edema.

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