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Diagnosis of Soft-Tissue Masses with MR Imaging: Can Benign Masses Be Differentiated from Malignant Ones?[1]

A blinded, retrospective review of 83 soft-tissue masses (49 benign and 34 malignant) was performed to evaluate the ability to distinguish benign from malignant soft-tissue masses with magnetic resonance (MR) imaging. The correct histologic diagnosis was reached in 31% of cases by one reader and in 16% of cases by the second reader. Mean sensitivity was 50% for benign masses and 80% for malignant masses. The majority of both benign and malignant masses had inhomogeneous signal intensity and at least partially irregular borders. Malignant masses uncommonly had smooth borders and homogeneous signal intensity. MR imaging can be used to evaluate the extent of soft-tissue masses, but most masses will require biopsy to determine if they are benign or malignant.

Index terms: Desmoid, 44.369, 45.369 • Fibrosarcoma, 44.372, 45.372 • Hemangioma, 44.362, 45.362 • Histiocytoma, 44.376, 45.376 • Lipoma, 44.363, 45.363 • Liposarcoma, 44.371, 45.371 • Soft tissues, MR, 44.1214, 45.1214 • Soft tissues, neoplasms, 44.31, 44.32, 45.31, 45.32

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CAN magnetic resonance (MR) imaging be used to differentiate benign from malignant soft-tissue masses? Several authors have found MR imaging to be unreliable (1–4). Two recent studies, however, have suggested a higher degree of accuracy in differentiating benign from malignant soft-tissue masses: Wetzel and Levine (5) had an accuracy of 86% in soft-tissue tumors of the foot. Berquist et al (6) had an accuracy of 90% in soft-tissue masses at all sites. Berquist et al found that "benign lesions tend to be well marginated, have homogeneous signal intensity, and do not encase neurovascular structures or invade bone. Malignant lesions generally have irregular margins and inhomogenous signal and more often encase neurovascular structures and involve bone." To further investigate this controversy, we performed a blinded, retrospective review of MR imaging studies of soft-tissue masses.

MATERIALS AND METHODS

All MR images obtained in patients seen for evaluation of soft-tissue masses at one institution were reviewed. Recurrent tumors were excluded, since surgical changes could alter the MR imaging appearance. Only one image was obtained after biopsy, and the radiologists reading the images (hereafter called "readers") were informed of the prior biopsy. Ninety-one images were available, but eight were rejected because they were believed to be technically inadequate. This left 83 masses, 49 benign and 34 malignant. Diagnoses are shown in Table 1. Diagnoses of all malignant masses were surgically confirmed. They were also surgically confirmed in 38 benign masses. Four hemangiomas and one arteriovenous malformation were diagnosed with angiography or Doppler imaging together with clinical history. One hematoma, two cases of bursitis, one seroma, and one cyst were diagnosed on the basis of the combination of clinical findings and imaging studies, and one lipoma was diagnosed at MR imaging and followed clinically for 1 year without change.

MR images were obtained with several systems: 25 at 0.3 T, six at 0.5 T, seven at 1.0 T, and 45 at 1.5 T. Cases in which one or both readers believed the images were technically poor were excluded. Since this was a retrospective review of images obtained at several institutions, imaging protocols varied. In all cases, images were available in at least two planes. In 30 cases, T1-weighted and T2-weighted images were obtained; in 11 cases, balanced and T2-weighted images; and in 42 cases, balanced and T2-weighted images. Section thickness varied from 3 to 5 mm.

All images were interpreted without knowledge of clinical history or results of other imaging studies by two subspecialty-trained musculoskeletal radiologists (reader 1, L.Y.; reader 2, V.C.) who had no previous knowledge of the cases. Both readers practiced musculoskeletal radiology exclusively and participated in an active bone and soft-tissue tumor service. They were given checklists with which they evaluated each mass for signal intensity and homogeneity, margins, size, involvement of the neurovascular bundle, peritumoral edema, bone involvement, and presence of serpentine vessels. Signal intensity was characterized as homogeneous, homogeneous but septated, or inhomogeneous. Margins were considered smooth if there was less than 10% irregularity, partly irregular if 10%–50% of the margin was irregular, and irregular if greater than 50% was irregular. The margin was also evaluated for infiltration into surrounding structures. Readers were asked to determine if a lesion was benign, malignant, or indeterminate on the basis of the criteria of Berquist et al (6) and were asked to specify any additional criteria they used to arrive at a diagnosis. They were asked for specific diagnoses if they believed one could be made.

Results were analyzed for sensitivity and specificity, positive and negative predictive value, and accuracy. "Indeterminate" was counted as a negative reading. Interobserver variability was measured by using the McNemar test (7).

Abbreviation: SE = spin echo.

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RESULTS

Reader 1 reached the correct histologic diagnosis in 26 (31%) of the masses, and reader 2 did so in 14 (17%). This difference reflects the difference in the number of cases in which a specific diagnosis was attempted. When both readers attempted to arrive at a diagnosis, the proportion of correct diagnoses was not significantly different ($P = .6250$).

Benign Masses

Twenty-six benign masses (53%) were called malignant by one or both readers: 14 by reader one and 21 by reader two. They agreed on nine of these. Table 2 shows the diagnoses of the benign masses that were thought to be malignant by one or both readers.

Reader 1 called one of six hemangiomas malignant, while reader two called four malignant. One of four cases of desmoid or fibromatosis was recognized as benign by both readers because it had low signal intensity on T2-weighted images. The other three cases had irregular, infiltrating margins and inhomogeneous signal intensity, and were called malignant.

In two cases, benign reactive lymphadenopathy encased the neurovascular bundle. Involvement of the neurovascular bundle was also visible in two hemangiomas. One abscess showed abnormalities in the underlying bone, in addition to inhomogeneous signal intensity, irregular margins, and peritumoral high signal intensity. It was called malignant by one reader but was recognized as infection by the other because of confinement to a single muscular compartment.

Peritumoral high signal intensity on T2-weighted images was seen in one case each of bursitis, myositis ossificans, neurilemoma, myxoma, abscess, and desmoid, and two cases each of hematoma and reactive lymph nodes.

Counting "indeterminate" as a negative reading, reader 1 had a sensitivity of 57%, a specificity of 94%, a positive predictive value for benignity of 93%, a negative predictive value of 60%, and an accuracy of 72%. Reader 2 had a sensitivity of 43%, a specificity of 97%, a positive predictive value of 95%, a negative predictive value of 54%, and an accuracy of 65%. When analyzed with the McNemar test, the difference in sensitivity was significant ($P = .0490$).

Table 1
Soft-Tissue Masses, by Diagnosis

Diagnosis	No. of Cases
Benign masses ($n = 49$)	
Lipoma	7
Hemangioma	6
Cyst	5
Desmoid/fibromatosis	5
Hematoma	5
Benign neural tumor	3
Reactive adenopathy	3
Bursitis	2
Abscess	2
Seroma	2
Myxoma	2
Pigmented villonodular synovitis	2
Other*	5
Malignant masses ($n = 34$)	
Liposarcoma	13
Fibrosarcoma/malignant fibrous histiocytoma	9
Soft-tissue osteosarcoma	2
Spindle cell sarcoma	2
Synovial cell sarcoma	1
Other†	7

* This category includes one case each of xanthoma, lymphangioma, arteriovenous malformation, popliteal aneurysm, and myositis ossificans.

† This category includes one case each of rhabdomyosarcoma, leiomyosarcoma, malignant schwannoma, dedifferentiated sarcoma, malignant mesenchymoma, epithelioid sarcoma, and clear cell chondrosarcoma.

Malignant Masses

Four malignant masses (12%; Table 3) were called benign by one or both readers, and they agreed on one of these. Both readers agreed that two low-grade liposarcomas had both homogeneous signal intensity and smooth margins. Reader 1 had a sensitivity of 82%, a specificity of 73%, a positive predictive value for malignancy of 68%, a negative predictive value of 86%, and an accuracy of 77%. Reader 2 had a sensitivity of 79%, a specificity of 59%, a positive predictive value of 57%, a negative predictive value of 80%, and an accuracy of 67%. When analyzed with the McNemar test, the difference in sensitivity was not significant ($P = .7539$).

DISCUSSION

Criteria of tumor margin, signal intensity homogeneity, size, peritumoral high signal intensity, apparent neurovascular bundle encasement or displacement, and bone invasion were not reliable in our series to differentiate benign from malignant masses at MR imaging (Table 4). Most malignant masses had irregular or partially irregular margins and inhomogeneous signal intensity. So many benign masses shared these characteristics, however, that the positive predictive value for malignancy (ie, the likelihood that a mass called malignant at MR imaging examination is actually malignant) was only 62%. When a mass appeared clearly benign at MR imaging, the positive predictive value for benignity was 93%. This means that even in this small group of

Table 2
Benign Masses Called Malignant by One or Both Readers

Diagnosis	No. of Cases
Hemangioma	4
Hematoma	4
Desmoid	4
Benign neural tumor	3
Reactive lymph nodes	2
Lipoma	2
Myxoma	2
Bursitis	2
Abscess	1
Myositis ossificans	1
Arteriovenous malformation	1

Table 3
Malignant Masses Called Benign by One or Both Readers

Diagnosis	No. of Cases
Liposarcoma, grade 1	2
Telangiectatic osteosarcoma	1
Dermatofibrosarcoma protuberans	1

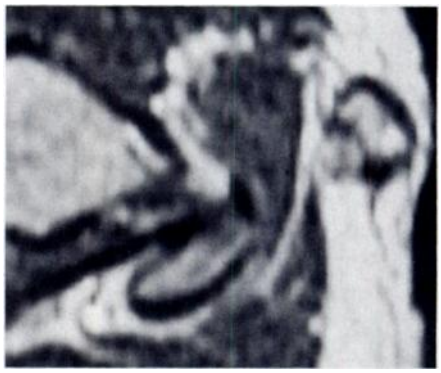
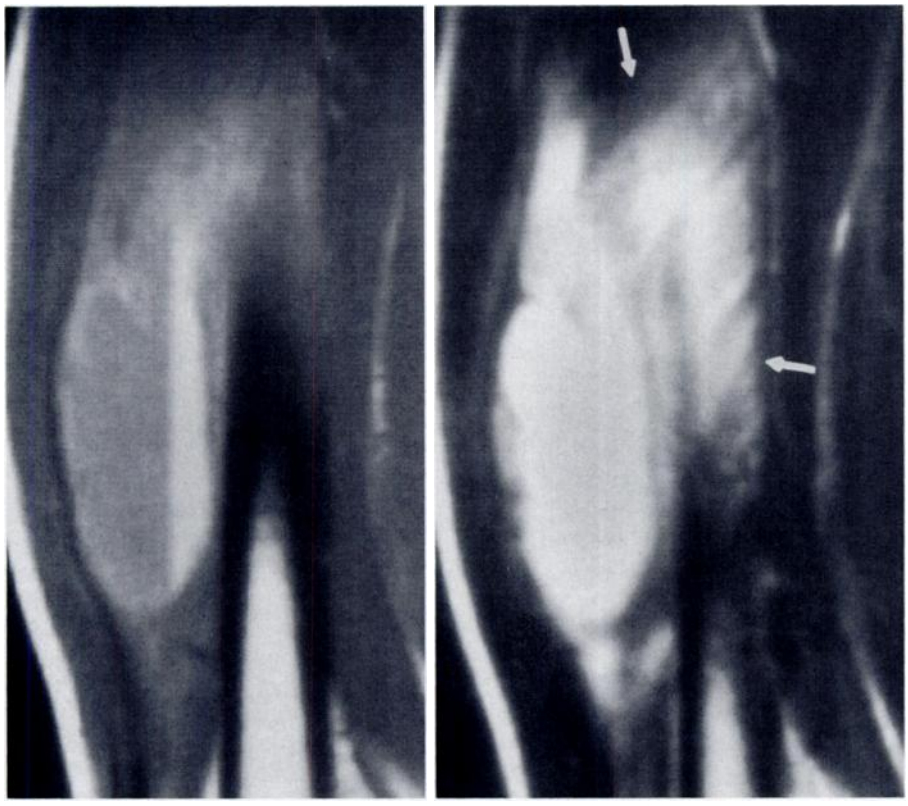


Figure 1. Axial MR image of the hip in a 50-year-old man (spin echo [SE], 2,000/30 [repetition time msec/echo time msec]). A subcutaneous malignant fibrous histiocytoma, lateral to the gluteus medius, was first seen at 2.5 cm in diameter. Margins are partially irregular, and signal intensity is inhomogeneous and slightly hyperintense to muscle on balanced images, with small foci of high signal intensity on T2-weighted images (not shown). Tumor was surrounded by a low-signal-intensity pseudocapsule with all sequences, and there was no peritumoral edema.

Table 4
Characteristics of Benign and Malignant Masses

Characteristic	No. of Masses*			
	Benign (n = 49)		Malignant (n = 34)	
	Reader 1	Reader 2	Reader 1	Reader 2
Margins				
Smooth	19 (39)	23 (47)	17 (50)	14 (41)
Partially irregular	16 (33)	7 (14)	13 (38)	11 (32)
Irregular	14 (29)	19 (39)	4 (12)	11 (32)
Infiltrative†	11 (22)	4 (8)	6 (18)	6 (18)
Signal intensity				
Homogeneous	11 (22)	15 (31)	1 (3)	3 (9)
Homogeneous, septated	9 (18)	12 (24)	2 (6)	2 (6)
Inhomogeneous	29 (59)	23 (47)	31 (91)	29 (85)
Size (cm)				
<1	0 (0)	0 (0)	0 (0)	0 (0)
<3	2 (4)	2 (4)	2 (6)	2 (6)
3–5	25 (51)	25 (51)	9 (26)	9 (26)
>5	22 (45)	22 (45)	23 (68)	23 (68)
Other				
Peritumoral edema	10 (20)	1 (2)	18 (53)	5 (15)
NVB‡ displaced	3 (6)	0 (0)	2 (6)	3 (9)
NVB encased	5 (10)	2 (4)	3 (9)	3 (9)
Bone involvement	0 (0)	1 (2)	2 (6)	2 (6)

* Numbers in parentheses are percentages.
† A mass could be considered infiltrative in addition to being either partially or fully irregular.
‡ NVB = neurovascular bundle.



a. **b.**

Figure 2. Sagittal MR images of the thigh in a 20-year-old man with 8-cm early myositis ossificans anterior to the middle of the femur, deviating the quadriceps anteriorly. **(a)** On this SE 1,000/30 image, fluid that is slightly hyperintense to muscle forms a layer above markedly hyperintense fluid. Margins are irregular. The hypointense line seen posteriorly represents calcification but cannot be distinguished from a pseudocapsule such as that seen in Figure 1. **(b)** On this SE 2,500/65 image, peritumoral high signal intensity (arrows) surrounds an inhomogeneous mass that is predominantly hyperintense to fat.

tumors appearing benign at MR imaging, there is a 7% chance of missing a malignant tumor and delaying treatment.

We did not find that size was useful in distinguishing benign from malignant tumors. The size at which a tumor is detected depends more on its location (superficial vs deep) than on its aggressiveness (Fig 1).

Peritumoral high signal intensity on T2-weighted images (Fig 2) may be due to edema or tumor extension into surrounding tissues (3). It has been previously reported in inflammatory, benign masses (3); we saw it in benign tumors such as myxoma as well, and we do not believe that it is a helpful sign. Bone involvement is rare in soft-tissue sarcomas (two in our series), and therefore is not a sensitive diagnostic sign. It is also not specific for malignancy: One benign mass (abscess) in our series showed MR imaging changes in the underlying bone. Apparent displacement or encasement of the neurovascular bundle was found by Berquist et al (6) in malignant tumors or desmoids only. We saw it also in cases of reactive lymph nodes and hemangiomas.

Although reader 1 believed that more of the benign lesions had irregular and infiltrative margins and inhomogeneous signal intensity, he nevertheless had a better accuracy in diagnosing benign masses than did reader 2. Both readers were given the same instructions in how to evaluate the images, but their checklists showed that they applied them differently. Reader 2 used the Berquist criteria much more rigorously, calling every mass that had both irregular margins and inhomogeneous signal intensity malignant. Reader 1 used additional criteria to a greater extent. For example, he used location relative to a joint to indicate a case of bursitis or a hemorrhagic, inhomogeneous Baker cyst, location in bilateral tendons to indicate xanthoma, and confinement to one soft-tissue compartment to suggest an abscess. Reader 1 was more alert to the presence of prominent, serpentine vessels, and foci of high signal intensity on T1-weighted images as signs of hemangioma, but he still misdiagnosed one hemangioma as a malignancy. Even with these additional criteria, many benign masses had a malignant appearance at MR imaging.

Our study is in agreement with those of Totty et al (1), Sundaram et al (2), and Kransdorf et al (4) that MR imaging appearance of soft-tissue masses is nonspecific. It is useful to review and compare these studies with those of Berquist et al (6) and Wetzel and Levine (5), who found a greater accuracy for MR imaging, to

understand the differences in study results.

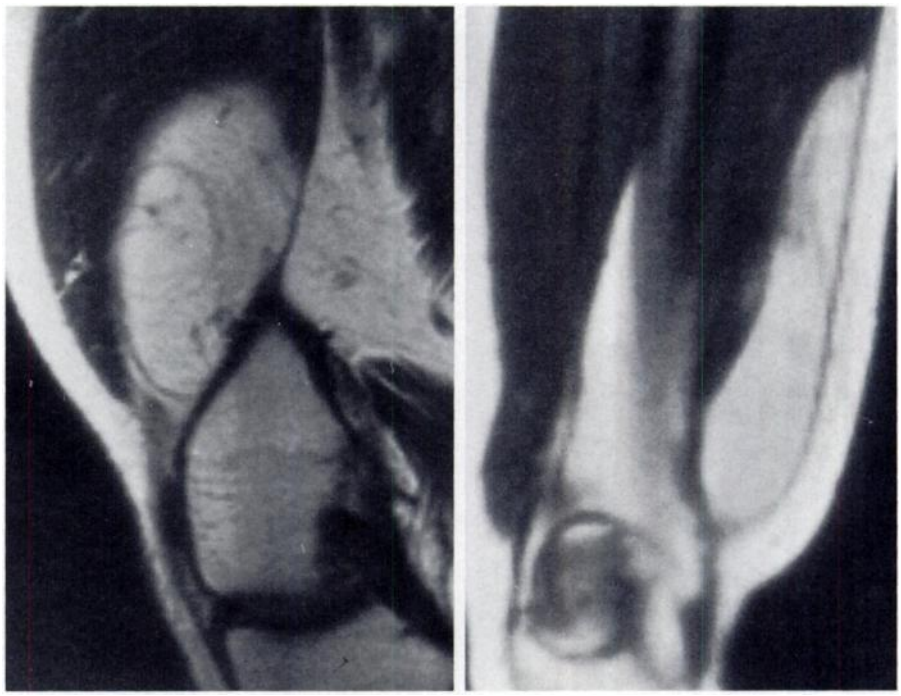
Totty et al (1) performed a nonblinded study of 32 soft-tissue masses, of which 10 were malignant. In that study, differences in signal intensity did not help to distinguish benign from malignant masses, and the majority of both benign and malignant masses showed inhomogeneous signal intensity. Two (20%) of the malignant lesions had sharply defined margins, and infiltrating margins were present in 27% of benign lesions and 30% of malignant ones (calculated from authors' data).

Sundaram et al (2) performed a nonblinded study of 53 soft-tissue masses, of which 23 were benign, 23 were malignant, and seven were intermediate (aggressive fibromatosis). The authors believed that there were no reliable criteria to distinguish benign from malignant masses.

Kransdorf et al (4) performed a blinded, retrospective study of 112 masses, 85 benign and 27 malignant. Criteria for benignity were smooth margins, homogeneous signal intensity, or characteristic findings (5,8–14) of hemangioma, pigmented villonodular synovitis, lipoma, or hematoma. Sensitivity for benign masses was 50%, and specificity, 85%. For malignant masses, sensitivity was 41%, and specificity, 84%. A correct histologic diagnosis was given in 24% of cases, all benign.

Wetzel and Levine (5) performed a nonblinded study of 14 soft-tissue tumors of the foot, nine benign and five malignant. They found that six benign masses had lobulated or irregular borders, and seven had inhomogeneous signal intensity, features that would suggest malignancy. By adding the criterion of serpentine vessels, or of a characteristic location analysis of signal intensity and margin characteristics, they were able to correctly diagnose eight of nine (89%) benign tumors (hemangiomas, pigmented villonodular synovitis, cysts, and plantar fibromatosis). Four of the five malignant tumors (80%) in their study were diagnosed as malignant; the other had homogeneous signal intensity, smooth margins, and a small size and appeared benign.

Berquist et al (6) studied 95 lesions, of which 45 were malignant. With the criteria described above, they had an accuracy for both benign and malignant masses of 90%. The most experienced reader in this group correctly predicted histologic diagnosis in 24 cases (25% of all lesions, 48% of benign lesions, calculated from authors' data).



a. b.

Figure 3. **(a)** Parasagittal MR image (SE, 800/20) of a knee in a 38-year-old man with a 9-cm suprapatellar lipoma deep to the quadriceps. Margins are smooth, but signal intensity is inhomogeneous. An incorrect MR imaging diagnosis of liposarcoma was made because of the numerous fibrous septa within a tumor that otherwise shows signal intensity characteristic of fat. **(b)** Coronal MR image (SE, 800/20) of the knee in a 53-year-old woman with a 9-cm-long grade 1 liposarcoma arising medially within the musculus vastus medialis, with smooth margins and a homogeneous but septated appearance. An incorrect MR imaging diagnosis of lipoma was made because of the tumor's homogeneously fatty appearance with all sequences.

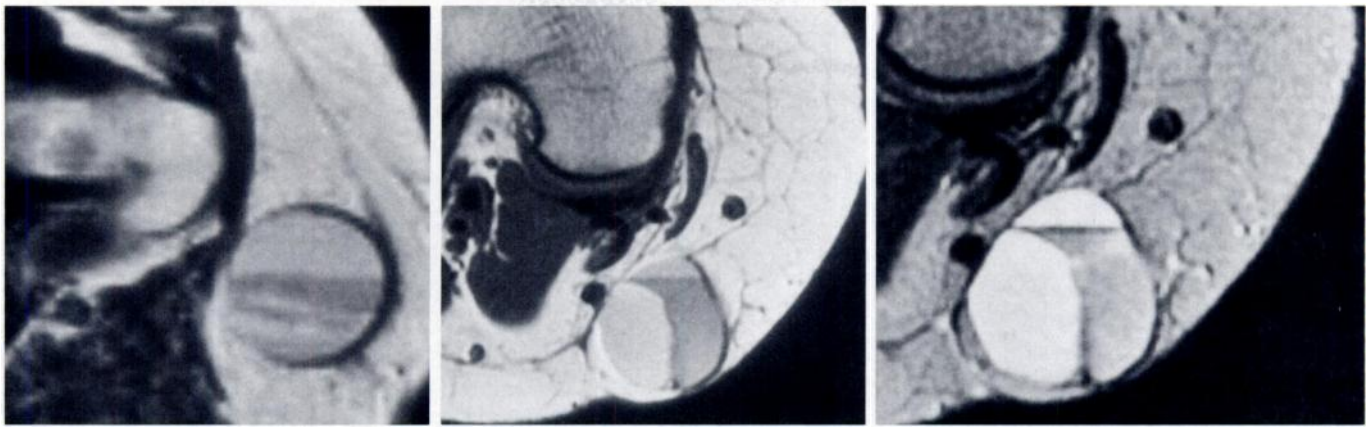
What factors might explain the differences in results among the different studies? Two important factors are differences in patient population and differences in the expertise of the radiologists reading the images.

Patient population is a variable that can markedly affect the results of a study. For instance, Berquist et al had a greater number of small, benign masses (22% of benign masses were smaller than 3 cm in diameter, compared with 4% in our study). Small masses are more likely to have homogeneous signal intensity than are large ones. An additional variable in patient population is the types of masses included. In our study, 6% of the masses were cysts, while in the study of Berquist et al, more than 12% of the masses were synovial or meniscal cysts. Synovial and meniscal cysts are usually easily diagnosed at MR imaging because they have characteristic locations and are homogeneous, smoothly marginated masses low in signal intensity on T1-weighted images and high on T2-weighted images (15). Because typical cysts are readily diagnosed, a study that includes a large number of cysts will probably demonstrate a greater accuracy in identifying benign masses than would one that contains few cysts.

It is possible that the readers in our study and that of Kransdorf et al (8) were simply less skilled than those of Berquist et al. There was a difference in performance between the two readers in our study, who had approximately the same level of experience. Such differences will always be found among radiologists; a system that can be used by only a small number of radiologists has a limited value. Furthermore, one of our two readers reached the correct histologic diagnosis in about the same number of cases (31%) as in the studies of Berquist et al (25%) and Kransdorf et al (24%), suggesting equivalent expertise.

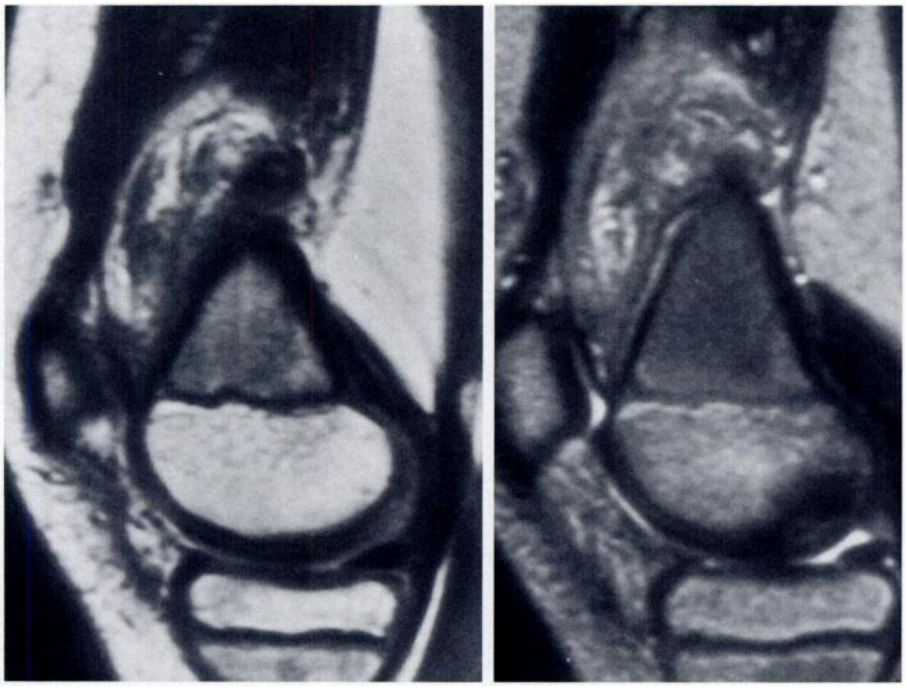
The study of Wetzel and Levine (5) was nonblinded and had a small number of patients. It is, nonetheless, helpful because it suggests that criteria such as location relative to joints (for pigmented villonodular synovitis, cysts) or in the plantar fascia (fibromatosis) are more useful in identifying benign tumors than are smooth margins or homogeneous signal intensity.

Diagnosis with MR imaging is more accurate for some masses than for others. Lipomas have a typical ap-



a. b. c.

Figure 4. **(a)** Axial MR image (SE, 2,000/30) of the hip in a 72-year-old woman with a 7-cm infected hematoma in subcutaneous tissues, adjacent to the greater trochanter and gluteus medius. There is a fluid-fluid level, with a high-signal-intensity region above the inhomogeneous layer of lower signal intensity. Portions of the mass and the strands of peritumoral high signal intensity became more intense than fat on T2-weighted images. **(b)** Axial MR image (SE, 2,000/15) of the knee in a 51-year-old woman with a 3-cm telangiectatic osteosarcoma arising in the subcutaneous soft tissues, preserving fascial planes and deviating the medial head of the gastrocnemius. Its margins are sharp, and it contains both a vertical and a horizontal septation, with two areas isointense to fat and one that is hyperintense to muscle but hypointense to fat. **(c)** Axial MR image (SE, 2,000/80) of the knee (second echo of image shown in **b**) shows that the tumor has increased in signal intensity, and the areas previously isointense to fat are now hyperintense to fat. Strands of peritumoral high signal intensity are minimal.



a. b.

Figure 5. Sagittal MR images of the knee show a 7-cm suprapatellar hemangioma in an 11-year-old boy. The mass is centered in the prefemoral fat but is infiltrating into the quadriceps. **(a)** On this SE 2,300/20 image, vessels are difficult to identify. **(b)** On this T2-weighted image (SE, 2,300/80), the hemangioma has a malignant appearance, with infiltrating, irregular margins and inhomogeneous signal intensity.

pearance of homogeneous high signal intensity on T1-weighted images that, like other fat, decreases slightly on T2-weighted images. Lipomas and liposarcomas, however, can overlap in signal intensity characteristics (8,16). Benign fatty tumors such as atypical lipomas and fibrolipomas may have prominent fibrous septa and fibrous regions, while grade 1 liposarcomas may be purely fatty (17).

The category of "homogeneous signal intensity but septated" was introduced in our study to see if it was useful in distinguishing lipomas from low-grade liposarcomas, but it did not increase accuracy. In the study of Kransdorf et al (8), only eight of 11 (73%) lipomas were correctly diagnosed; data on the accuracy of diagnosing liposarcomas are not given. In our study reader 1 recognized six (86%) lipomas as benign, and reader 2 recognized five (71%). Both readers misdiagnosed grade 1 liposarcoma as lipoma (Fig 3).

Hematomas can mimic hemorrhagic tumors (Fig 4) on MR images. The diagnosis of hematoma must depend on carefully obtaining the history, since patients often do not report a history of trauma unless they are specifically questioned. The diagnosis must then be confirmed by means of close clinical follow-up to distinguish hematoma from hemorrhage into a tumor.

Some hemangiomas can be diagnosed fairly reliably because of their serpentine vessels (9,10). They tend to have infiltrative margins, however, and vessels may not be recognizable (10). In our study and that of Berquist et al, hemangiomas were misdiagnosed because of an atypical appearance (Fig 5). Hemangiosarcomas of the soft tissues are rare (17), and at our institution we have not performed MR imaging of a hemangiosarcoma. If an apparent hemangioma is growing rapidly, however, the possibility of sarcoma should be raised.

Pigmented villonodular synovitis is distinctive because of its location (usually in the knee, hip, or hindfoot), its lobular contour, and regions of low signal intensity on both T1- and T2-weighted images due to hemosiderin deposition (11–14). Its appearance at MR imaging may be confused with

that of synovial chondromatosis, and possibly hemosiderotic synovitis.

Fibromatosis may appear irregular, infiltrative, and of low signal intensity on T2-weighted images, in which case an MR imaging diagnosis can be made. It may also, however, show high signal intensity on T2-weighted images (18,19) and be indistinguishable from malignant tumors.

We have not routinely administered gadopentetate dimeglumine as part of the MR imaging evaluation of soft-tissue masses, since we do not believe that it has been proved sufficiently useful to justify the expense to the patient. Therefore, the role of gadolinium could not be addressed in this retrospective study. Erlemann et al (20) found that dynamic gadolinium-enhanced fast low-angle shot imaging allowed differentiation between benign and malignant musculoskeletal neoplasms with an accuracy of 79.7%. This is not significantly better than the accuracy achieved without gadolinium, and aggressive, benign lesions may show enhancement similar to that of malignant ones (21). Another possible method of increasing accuracy is the use of techniques sensitive to flow to improve visualization of vessels in vascular lesions.

Some soft-tissue masses can be diagnosed with MR imaging: typical cysts, pigmented villonodular synovitis, and sometimes fibromatosis and hemangiomas. In the majority of cases of soft-tissue masses, the accuracy of MR imaging is insufficient to allow determination of malignancy or benignity. ■

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