

MR Imaging of the Musculoskeletal Soft Tissue Mass: Is Heterogeneity a Sign of Malignancy?

Kwok Kuen Pang¹
Tudor Hughes²

¹ Department of Radiology, Mackay Memorial Hospital, Taitung Branch

² Department of Radiology, Christchurch Public Hospital, New Zealand

Key Words

benign;
malignant;
MRI;
soft tissue tumor

Magnetic resonance (MR) has been used extensively to study soft tissue tumors. It is considered superior to CT because of its sensitivity in identifying and staging soft tissue neoplasms of the musculoskeletal system.¹⁻³ However its ability to differentiate benign from malignant soft tissue masses is still controversial. Several authors have found MR imaging to be unreliable. A careful study published in 1992 from Crim and colleagues warned that the ability to distinguish benign from malignant soft-tissue masses with MRI was only 50% for benign masses and 80% for malignant masses.⁴ Kransdorf *et al.* reviewed their experience with 112 soft tissue masses.⁵ They found that MR appearances were only sufficiently characteristic to allow a specific diagnosis in 24% (10 lipomas, 8 hemangiomas, 6 pigmented

Background. Magnetic resonance (MR) is considered the imaging modality of choice to evaluate soft tissue lesions. Whether MR imaging can be used to differentiate benign from malignant soft tissue lesions is still controversial. To elucidate this controversy, MR images of 37 patients with soft tissue masses of the musculoskeletal system were reviewed at Christchurch Hospital, New Zealand.

Methods. There were 19 benign and 18 malignant lesions. MR images were evaluated with regard to lesion size, border definition, homogeneity, changes in pattern of homogeneity, signal characteristic (signal intensity on T1-weighted, T2-weighted), and demonstration of relation to neurovascular bundle and bone as well as edema in or around the lesion.

Results. Statistically significant imaging features favoring a diagnosis of malignancy included inhomogeneity at T2-weighted images ($p = 0.002$) and a change in pattern from homogeneity on T1-weighted images to inhomogeneity at T2-weighted images ($p = 0.003$). Malignant tumors also had neurovascular or bone involvement in 28% of cases, which was not seen in their benign counterparts. Size, border definition, and edema of surrounding tissues were generally not helpful in distinguishing benign from malignant soft tissue masses.

Conclusions. The inhomogeneity of lesions on T2, the change from homogeneity on T1 to inhomogeneity on T2 sequence, and involvement of bone or neurovascular structures are features that may be helpful in differentiating benign from malignant soft tissue masses.

villonodular synovitis, 2 hematomas and 1 arteriovenous malformation). On the other hand, other groups have thought it to be useful. Wetzel and Levine reported an accuracy of 86% in soft tissues of the foot.⁶ Bequist *et al.* reviewed their findings in 95 consecutive soft tissue masses and concluded that the benign or malignant nature of the lesion could be determined in 90% of cases.⁷ To further investigate this controversy, we reviewed our experience with MR imaging of soft tissue masses in patients admitted to Christchurch Hospital, New Zealand.

METHODS

MR images of 37 patients with soft tissue masses

Received: March 20, 2003.
Accepted: August 20, 2003.

Correspondence to: Dr. Kwok Kuen Pang, Department of Radiology, Mackay Memorial Hospital, 1, Lane 303, Chang Sha Street, Taitung, Taiwan.
Fax: +886-89-321-240; E-mail: a5324@ttms.mmh.org.tw

were retrospectively reviewed. Most of the images were performed at Christchurch Hospital, New Zealand. There were 27 men and 10 women ranging in age from 2 to 87 years. The average age of patients with benign lesions was 43 and, of those with malignant masses, 56. In several instances, the patients were referred to us for a second opinion or for surgery.

MR images were obtained on a 0.5T Gyroscan T5 II (Philips Medical Systems). Both T1-weighted and T2-weighted spin echo sequences were available for each examination. T2-weighted images were obtained with turbo spin echo technique (fast spin echo). In all cases, images were available in at least 2 planes. Section thickness varied from 4 to 6 mm. Surface coils appropriate to the site being examined were used.

The MR images were reviewed by 2 radiologists independently without knowledge of the data from surgery. The 2 reviewers agreed with each other in most of the examinations; when there was disagreement, a consensus was reached. MR images were evaluated with regard to lesion size, border definition, homogeneity, signal characteristic (signal intensity on T1-weighted and T2-weighted images), pattern, relationship of the mass to the neurovascular bundle and bone, and the presence or absence of edema in or around the lesion.

Homogeneity of the MR signal was categorized as homogenous, mild, moderate, or complex. A lesion was considered homogenous when it was a cyst-like or nearly cyst-like mass and was completely homogenous; mild homogeneity was defined as less than 25% of the mass having inhomogeneity; moderate inhomogeneity as 25-50% of the mass having inhomogeneity; and complex as more than 50% of the mass having inhomogeneity. Any change in pattern between T1-weighted images and T2-weighted images was noted.

Signal intensity was categorized on both T1- and T2-weighted images as lower than, equal to, or greater than that for muscle and lower than, equal to, or higher than that for fat for each sequence.

Pathologic diagnosis was established in 32 cases. A tissue diagnosis was not available for the 3 posttraumatic hematomas, the post-surgical lymphocele and 1 case of lipoma. In these patients, a radiological diagnosis could be made with certainty by appropriate history and clinical follow up.

cal follow up.

Data analysis was performed with Winks Basic software, version 4.5 (TexaSoft). The Wilcoxon rank sum test was used for continuous variables; the chi-square test and Fisher exact test (two-tailed) for categorized variables. A *p* value of < 0.05 was considered to be significant.

RESULTS

The 37 soft tissue masses included 19 benign lesions and 18 malignant neoplasms. The specific diagnoses are listed in Table 1.

The size of malignant masses tended to be larger, averaging 7.84 cm vs 5 cm for benign masses. However, this difference was not statistically significant (*p* = 0.264).

On both T1- and T2-weighted images, 8 malignant lesions were well defined and 10 were partially or poorly defined. In the benign category, 13 were well defined and 6 were partially or poorly defined, with the exception of one which was poorly defined on T1 but became well de-

Table 1. Diagnosis of 37 soft tissue masses

Type of mass	Number of cases
Benign	
Schwannoma	1
Desmoid	1
Gout	1
Abscess	2
Post-surgical lymphocele	1
Synovitis	1
Aneurysm	1
Hematoma	3
Intramuscular hemangioma	1
Lipoma	7
Malignant	
Chondrosarcoma	1
Lymphoma	2
Leiomyosarcoma	3
Liposarcoma	2
Malignant melanoma	1
Malignant fibrous histiocytoma	4
Metastases	1
Myxoid sarcoma	1
Sarcoma	2
Synovial sarcoma	1

Table 2. Benign lesions in 19 patients

Tumor	Pattern	T1W1			Border	Pattern	T2W1			Border
		M	SI	F			M	SI	F	
Schwannoma	x	=	-	def	x	+	+	def		
Desmoid	x	=	-	poor	xxx	=	-	poor		
Gout	o	=	-	def	o	=	-	def		
Abscess	o	=	-	poor	xxx	+	+	poor		
Abscess	o	=	-	poor	o	+	+	def		
Lymphocele	o	-	-	poor	o	+	+	poor		
Synovitis	x	-	-	def	x	+	+	def		
Aneurysm	xxx	+	-	def	xxx	=	-	def		
Hematoma	x	+	-	poor	xxx	+	+	poor		
Hematoma	o	-	-	def	o	-	-	def		
Hematoma	x	+	-	part	x	+	+	part		
Hemangioma	o	+	-	def	o	+	+	def		
Lipoma	o	+	=	def	o	+	=	def		
Lipoma	o	+	=	def	o	+	=	def		
Lipoma	o	+	=	def	o	+	=	def		
Lipoma	o	+	=	def	o	+	=	def		
Lipoma	o	+	=	def	o	+	=	def		
Lipoma	o	+	=	def	o	+	=	def		
Lipoma	o	+	=	def	o	+	=	def		

Pattern: o, homogenous; x, mild inhomogeneity; xx, moderate; xxx, complex.

Border: def, defined; part, partially defined; poor, poorly defined.

SI: signal intensity; M, muscle; F, fat; (-), less than, (=), equal to; (+), greater than.

Table 3. Malignant lesions in 18 patients

Tumor	Pattern	T1W1			Border	Pattern	T2W1			Border
		M	SI	F			M	SI	F	
Chondrosarcoma	x	-	-	def	x	+	+	def		
Lymphoma	o	+	-	def	xxx	+	-	def		
Lymphoma	x	=	-	poor	xxx	+	-	poor		
Leiomyosarcoma	o	=	-	poor	xx	+	-	poor		
Leiomyosarcoma	x	=	-	poor	xx	=	-	poor		
Liposarcoma	x	+	=	def	x	+	=	def		
Liposarcoma	xxx	+	=	def	xxx	+	=	def		
Liposarcoma	o	+	=	def	o	+	=	def		
MFH	o	-	-	poor	x	+	+	poor		
MFH	x	=	-	poor	xxx	+	+	poor		
MFH	x	+	-	poor	xxx	+	+	def		
MFH	x	=	-	def	xxx	+	+	poor		
Melanoma	o	=	-	poor	xxx	+	-	poor		
Metastases	o	=	-	poor	x	+	+	poor		
Myxoid sarcoma	o	=	-	def	o	+	+	def		
Sarcoma	xxx	+	-	part	xxx	+	+	part		
Sarcoma	x	+	-	poor	xxx	+	-	poor		
Synovial sarcoma	x	=	-	poor	xx	+	+	poor		

Pattern: o, homogenous; x, mild inhomogeneity; xx, moderate; xxx, complex.

Border: def, defined; part, partially defined; poor, poorly defined.

SI: signal intensity; M, muscle; F, fat; (-), less than, (=), equal to; (+), greater than.

fined on T2. Statistical analysis with chi-square on the border between the 2 groups on T1 and T2 sequences yielded p values of 0.142 and 0.071, respectively. Fisher exact test also yielded nonsignificant p values of 0.191 and 0.099, respectively.

Homogenous signal intensity was seen in 68% of T1- and 63% of T2-weighted images of benign lesions (Table 2). Malignant lesions were less homogenous on T2-weighted images. Only 11% demonstrated homogeneity on T2- as compared to 39% at T1-weighted images (Table 3). Chi-square and Fisher exact test for homogeneity in benign and malignant lesions on the T1 sequence yielded nonsignificant p values of 0.072 and 0.103, respectively.

On T2-weighted images, half of the malignant lesions had complex inhomogeneity, compared with only

11% of benign lesions (Fig. 1). The difference between the 2 groups was significant by chi-square test ($p = 0.001$) and Fisher exact test ($p = 0.002$).

In 13 out of the 18 malignant lesions (72%), the pattern changed between T1- and T2-weighted images: 2 from homogenous to mild inhomogeneity, 1 from homogenous to moderate inhomogeneity, 2 from homogenous to complex heterogeneous, 2 from mild inhomogeneity to moderate inhomogeneity, 5 from mild to heterogeneous (Fig. 2), and 1 from moderate to complex heterogeneity. In contrast only 3 of the 19 benign soft tissue masses (16%) changed: 1 from homogenous to complex inhomogeneity, and 2 from mild to moderate inhomogeneity (Table 4). The difference between the two groups was significant by a chi-square test ($p = 0.001$) and Fisher exact test ($p = 0.003$).

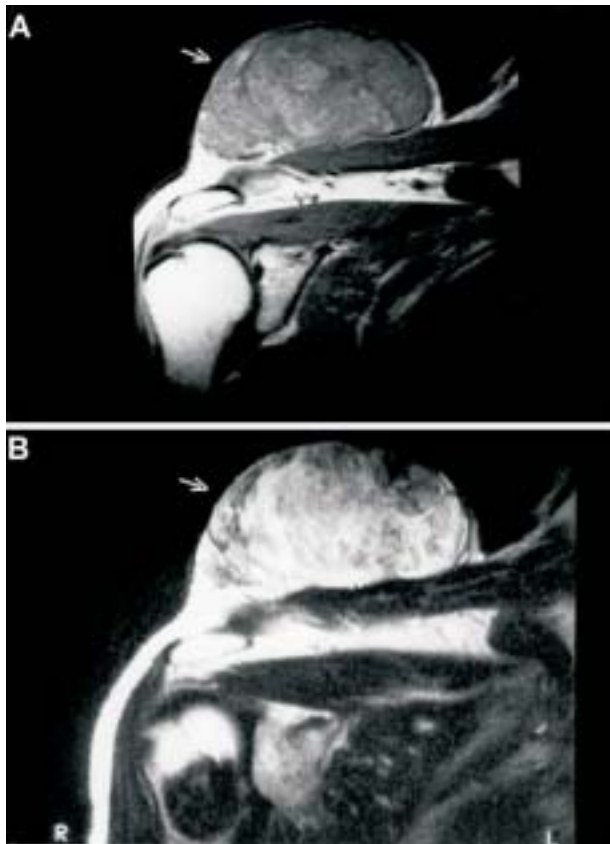


Fig. 1. Sarcoma of the right shoulder in a 79-year-old male. (A) Coronal T1-weighted (981/22/2) spin-echo image shows complex inhomogeneity (arrow). (B) Coronal T2-weighted (5500/130/6) spin-echo image also shows complex inhomogeneity (arrow).

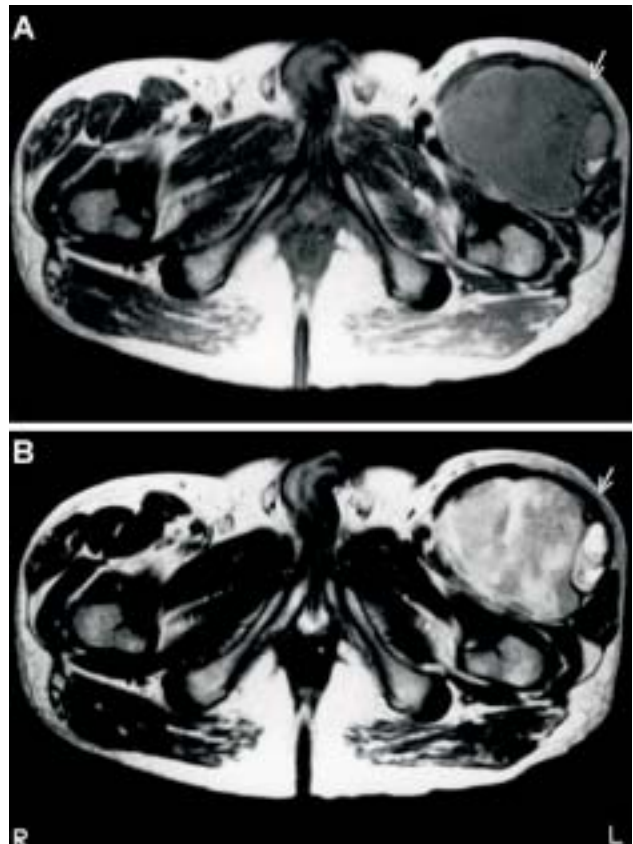


Fig. 2. Malignant fibrous histiocytoma of the left upper thigh in a 63-year-old male. (A) Axial T1-weighted (1321/13/2) spin-echo image shows mild inhomogeneity (arrow). (B) Axial T2-weighted (2998/110/4) spin-echo image shows complex homogeneity (arrow).

Table 4. Pattern change from T1- to T2-weighted image

	Benign	Malignant
Homogenous to mild inhomogeneity	0	2
Homogenous to moderate inhomogeneity	0	1
Homogenous to complex inhomogeneity	1	2
Mild inhomogeneity to moderate inhomogeneity	0	2
Mild inhomogeneity to complex inhomogeneity	2	5
Moderate inhomogeneity to complex inhomogeneity	0	1
Total number of cases	3	13

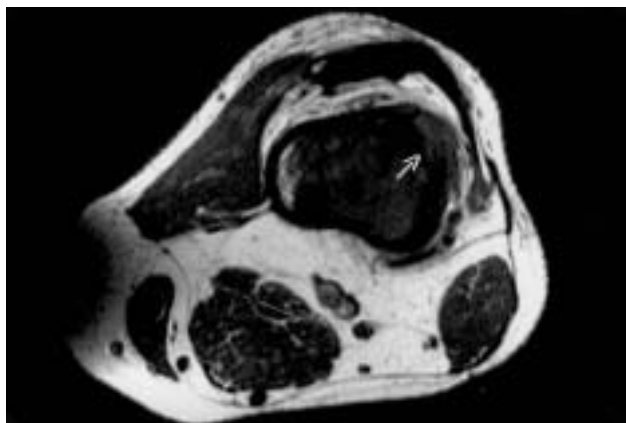


Fig. 3. Leiomyosarcoma of the left knee in a 40-year-old male. Axial T1-weighted (550/20/2) spin-echo image shows cortical destruction at the anterior lateral distal femoral shaft (arrow).

Neurovascular encasement or bone involvement was seen in 28% of malignant soft tissues neoplasms (Fig. 3) but not in any of the benign masses. Edema of the surrounding tissue was seen in 16% of benign and 11% of malignant lesions.

DISCUSSION

Although malignant tumors were larger than benign masses on average, this was not a useful parameter for distinguishing between them. Gelineck *et al.*⁸ observed that deep-seated fatty tumors greater than 5 cm had a greater risk of being malignant than smaller and superficially located tumors. In our series, we also found that liposarcomas tended to be more deep-seated than the benign counterpart, which was more likely to be superficial.

Border definition was generally not helpful. In our series, 45% of malignant lesions had well-defined borders on T2-weighted images as compared to 74% of benign lesions. An irregular border was noted in 55% of malignant tumors and 26% of benign tumors, including abscess, lymphocele, hematoma, and a desmoid tumor.

Although the margin of the lesion was not specific, inhomogeneity of signal intensity strongly suggested malignancy. This feature has been mentioned in other reports, and cellularity and necrosis were thought to attribute to the inhomogeneity of MRI signal intensity. In 1987, Sundaram *et al.* found that tumors which were relatively acellular and contained a large amount of collagen showed relatively low signal intensity on T2-weighted images, and concluded that the cellularity of a tumor rather than the histological diagnosis influenced the MRI signal on T2 WI.⁹ In 2002, Shuto *et al.* also found good correlation of cellularity with inhomogeneity in their study on desmoplastic fibroblastoma.¹⁰ They found that their lesion had inhomogenous low signal intensity on T1-weighted images and mixed signal intensity on T2-weighted images. Histologically, the areas showing low SI on both T1- and T2-weighted images consisted of dense collagenous components and reduced cellularity compared with the areas showing high signal intensity on them. Thus cellularity, mitotic rate, and the presence of necrosis all influence MRI signal intensity and can be of potential in predicting malignancy.

In our series, only 2 of the 18 malignant neoplasms (11%) were homogenous on T2-weighted image, as compared with 12 of the 19 benign lesions (63%). One of the benign lesions with complex inhomogeneity was a desmoid tumor, a very aggressive tumor that behaved like a malignant lesion. The patient had had 2 local recurrences

with repeated surgical resection and radiotherapy. Other benign lesions with complex inhomogeneity were a bleeding aneurysm of the popliteal artery, a hematoma, and an abscess. Schwannoma and synovitis also had a minor degree of inhomogeneity. T1-weighted images were generally not helpful in differentiating benign from malignant soft tissue mass, with inhomogeneity seen in 11 of the 18 malignant neoplasms and 6 of the 19 benign counterpart. Thus, it appears that inhomogeneity on T2-weighted images better distinguishes the 2 types of lesion.

Another criterion we found useful was a change in pattern from the T1- to the T2- weighted image. This change of pattern has also been mentioned by Herman.¹¹ His group observed that 72% of malignant tumors in their series were homogenous on T1-weighted images but inhomogenous on T2-weighted images, while 67% of benign tumors appeared unchanged. Only 3 of their 24 benign tumors (12.5%) changed from being homogenous to heterogeneous. Our results were similar. The pattern changed in only 3 of our 19 benign lesions, one of which was the desmoid tumor, changing from mild inhomogeneity on T1 to complex inhomogeneity on T2. Thirteen of our 18 malignant lesions did change.

Edema of the surrounding tissue on T2-weighted images might be due to tissue edema or tumor extension.¹² It was present in 2 abscesses, 1 traumatic hematoma, 1 lymphoma, and 1 malignant fibrous histiocytoma. Not only was tissue edema an uncommon finding, but we did not find it helpful in distinguishing benign from malignant lesions. However, if a lesion is already known to be malignant, it might be a good indicator of tumor extension.

Some authors have considered the presence of septa to be useful in differentiating benign from malignant tumors.^{8,13} In 1997 Hosono *et al.* observed that in liposarcoma, the septum usually exceeded 2 mm and enhanced considerably, while septa of benign lipomas were generally thin.¹⁴ While we believe septa may be helpful in differentiating well-differentiated liposarcoma from lipoma, only a small portion of our patients had septation on T2 weighted images. Therefore, it does not seem to be a useful parameter overall.

Neurovascular encasement or bone involvement was

seen in 28% of the malignant neoplasms but not in benign soft tissue lesions, a finding also noted by Bequist *et al.* They stated that neurovascular encasement and bone involvement suggested malignancy until proven otherwise.⁷

Various dynamic gadolinium-enhanced MR techniques have been developed for differentiating benign from malignant musculoskeletal masses.^{15,16} A study of a turbo gradient-echo technique found that arterial and early tumor enhancement (sensitivity 91%, specificity 72%), the pattern (peripheral or diffuse) of enhancement (sensitivity 73%, specificity 97%), and the progression of tumor enhancement (sensitivity 86%, specificity 81%), as visualized on time-signal intensity curves, helped differentiate benign from malignant soft-tissue masses. Due to the limitations on our scanner, we have had little experience in dynamic imaging of soft tissue masses.

Another important limitation in our study was that it was retrospective. Not all patients been studied with the sequences we wanted. The short tau inversion recovery (STIR) sequence reportedly showed complete fat suppression in benign lipomatous lesions but not in liposarcomas.¹⁷ Also, the small numbers in our study made drawing strong conclusions difficult.

Our study does support the contention that inhomogeneity of lesions on T2, a change from homogeneity on T1 to inhomogeneity on T2 sequences, and involvement of bone or neurovascular structures may be helpful in differentiating benign from malignant soft tissue masses.

ACKNOWLEDGEMENTS

We wish to thank Dr. Mike Hurell, radiologist in charge of MRI, Christchurch Public Hospital, and Dr. Lun Yick Wong, senior radiologist, Mackay Memorial Hospital, for their advice and assistance in the present study.

REFERENCES

1. Totty WG, Murphy WA, Lee JKT. Soft-tissue tumors: MR imaging. *Radiology* 1986;160:135-41.

2. Petasnick JP, Turner DA, Charters JR, Gitelis S, Zacharias CE. Soft tissue masses of the locomotor system: comparison of MR imaging with CT. *Radiology* 1986;160:125-33.
3. Sundaram M, Mcleod RA. MR imaging of tumor and tumorlike lesions of bone and soft tissue. *AJR* 1990;155:817-24.
4. Crim JR, Segger LL, Yoo L, Chancnani V, Eckardt JJ. Diagnosis of soft tissue masses with MR imaging: can benign masses be differentiated from malignant ones? *Radiology* 1992;185:581-6.
5. Kransdorf MJ, Jelinek JS, Moser RP, Utz JA, Brower AC, Hudson TM, Hudson Berry B. Soft tissue masses: diagnosis with MR imaging. *AJR* 1989;153:541-7.
6. Wetzel LH, Levine E. Soft tissue tumors of the foot: value of MR imaging for specific diagnosis. *AJR* 1990;155:1025-30.
7. Berquist TH, Ehman RL, King BF, Hodgman CG, Ilstrup DM. Value of MR imaging in differentiating benign from malignant soft tissue masses: study of 95 lesions. *AJR* 1990;155:1251-5.
8. Gelineck J, Keller J, Jensen M, Steen Nielsen O, Christensen T. Evaluation of lipomatous soft tissue tumors by MR imaging. *Acta Radiologica* 1994;35:367-70.
9. Sundaram M, Mcquire MH, Schajowicz F. Soft-tissue masses: Histological basis for decreased signal (short T2) on T2-weighted MR images. *AJR* 1987;148:1247-50.
10. Shuto R, Kiyosue H, Hori Y, Miyake H, Kawano K, Mori H. CT and MR imaging of desmoplastic fibroblastoma. *Eur Radiol* 2002;12:2474-6.
11. Herman G, Abdelwahab IF, Miller TT, Klein MJ, Lewis MM. Tumor and tumor like conditions of the soft tissue: magnetic resonance imaging features of differentiating benign from malignant masses. *Br J Radiol* 1992;65:14-20.
12. Beltran J, Simon DC, Katz W, Weiss LD. Increased MR signal intensity in skeletal muscle adjacent to malignant tumors: pathologic correlation and clinical relevance. *Radiology* 1987;162:251-5.
13. London J, Kim EE, Wallace S, Shirkhoda A, Coan J, Evans H. MR imaging of liposarcomas: correlation of MR features and histology. *J Comput Assist Tomogr* 1989;12:832-5.
14. Hosono M, Kyobayashi H. Septum like structure in lipoma and liposarcoma. MR imaging and pathologic correlation. *Skeletal Radiol* 1997;26:150-4.
15. Verstraete KL, De deene Y, Roels H, Dierick A, Uyttendaele D, Kunnen M. Benign and malignant musculoskeletal lesions: dynamic contrast-enhanced MR imaging--parametric "first-pass" images depict tissue vascularization and perfusion. *Radiology* 1994;192:835-43.
16. van der Woude HJ, Verstraete KL, Hogendoorn PC, Taminiau AH, Hermans J, Bloem JL. Musculoskeletal tumors: does fast dynamic contrast-enhanced subtraction MR imaging contribute to the characterization? *Radiology* 1998;208:821-8.
17. Pang KK, Hughes T. Magnetic Resonance imaging of lipoma and liposarcoma: Potential of short tau inversion recovery as a technique in of fat suppression. *Australas Radiol* 2000;44:412-6.