ORIGINAL ARTICLE

Differentiation of Benign and Malignant Superficial Soft-tissue Masses Using Grayscale and Color Doppler Ultrasonography

Hong-Jen Chiou[1,3]*, Yi-Hong Chou[1,3], See-Ying Chiu[1], Hsin-Kai Wang[1], Wei-Ming Chen[2,3], Tien-Hsung Chen[2,3], Cheng-Yen Chang[1,3]

Departments of [1]Radiology and [2]Orthopedic Surgery, Taipei Veterans General Hospital, and [3]National Yang-Ming University School of Medicine, Taipei, Taiwan, R.O.C.

Background: This study was performed to evaluate the usefulness of high-resolution grayscale and color Doppler ultrasound to distinguish benign from malignant soft-tissue masses on the basis of ultrasonographic patterns.
Methods: We enrolled 398 female and 420 male patients aged 1–104 years (mean, 49.8 years). All presented with a palpable nodule or mass located superficially in the body. Each lesion was examined by grayscale and color Doppler ultrasonography to assess its echogenicity, margin, shape, composition, acoustic transmission, size and other patterns. Spectral Doppler was applied in lesions with positive color flow signals. The nature of all masses was confirmed by aspiration cytology, biopsy, surgical pathology or long-term clinical follow-up.
Results: There were a total of 693 benign and 125 malignant masses. Five malignant and 14 benign histologies (including 6 types with inflammation-related, hematoma or pseudoaneurysm) occurred that had more than 10 subjects with each histology. Eight benign histopathologies included cysts, neoplasms, vascular and miscellaneous. Five malignant histologies included metastases, osteogenic sarcomas, lymphomas, malignant fibrous histiocytomas and liposarcomas. There were significant differences ($p < 0.05$) between the benign and malignant soft-tissue tumors in terms of parameters including tumor margin, shape and size. Benign lesions did not have infiltrated margins or a scalloped shape and malignant tumors tended to be large. However, there was no significant difference ($p > 0.05$) between the benign and malignant soft-tissue tumors in terms of echogenicity, composition and color Doppler features.
Conclusion: Ultrasonography with color Doppler imaging is a good modality for characterizing most soft-tissue masses, and tumor size > 5 cm and having infiltrated margin highly suggests malignancy. [*J Chin Med Assoc* 2009;72(6):307–315]

Key Words: color Doppler ultrasonography, neoplasm, soft-tissue mass, ultrasonography

Introduction

Soft-tissue tumors are not uncommon, and most are benign. In the United States, the annual incidence of soft-tissue tumors is around 3 cases per 1,000 people, and about 0.67% of these tumors are malignant.[1] Soft-tissue malignancy makes up about 0.64% of all malignant tumors in Taiwan and ranks 21st in terms of occurrence rate across all malignancies.[2] Primary sarcomas of soft tissue present with variable outcome, depending on factors such as the location, size, and grade of the tumor. For soft-tissue sarcomas, the prognosis is better for low-grade lesions than for high-grade lesions, and for small rather than large tumors.[3,4]

Several imaging modalities have been used to assess soft-tissue tumors, including plain radiography, nuclear medicine, ultrasonography (US), computed tomography (CT), magnetic resonance imaging (MRI), angiography and positron emission tomography (PET). However, none of these approaches are reliable for distinguishing benign from malignant lesions.[5] Although MRI offers good contrast resolution between soft-tissue

*Correspondence to: Dr Hong-Jen Chiou, Department of Radiology, Taipei Veterans General Hospital, 201, Section 2, Shih-Pai Road, Taipei 112, Taiwan, R.O.C.
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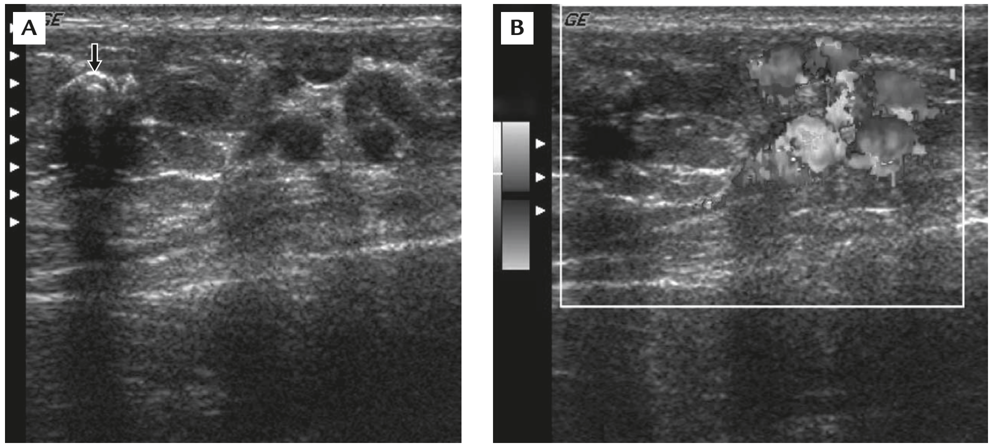

Figure 1. A 28-year-old male with cavernous hemangioma. (A) Grayscale ultrasonography shows heterogeneous echoic mass with ill-defined margins in the left forearm involving subcutaneous and muscle layers, presence of echogenic phlebolith (arrow) and tortuous hypoechoic tubular structure. (B) Color Doppler ultrasonography shows grade 3 vascularity within the hypoechoic tubular structure.

and the neoplasm, no single MRI feature can be reliably used to differentiate malignant from benign soft-tissue tumors. Even the use of dynamic contrast-enhanced MRI for differential diagnosis is controversial.[6]

US has a high sensitivity when detecting tumors, but it has not proven to be useful in differentiating benign from malignant conditions.[7] Power Doppler US (PDUS) or color Doppler US (CDUS) and spectral analysis can depict the vascular irregularities in malignant tumor, but the reported criteria for malignancy vary widely.[8–11]

The purpose of this study was to evaluate the usefulness of high-resolution grayscale and CDUS to differentiate benign from malignant soft-tissue masses.

Methods

In this retrospective study, we enrolled 398 female and 420 male patients aged from 1 to 104 years (mean age, 49.8 years). All were referred for US study because of a palpable mass. The study was approved by and followed the guidelines of the institutional review board of Taipei Veterans General Hospital (VGHIRB No. 96-03-24A).

All masses were examined using grayscale and CDUS. Spectral analysis was performed on some lesions where there were central positive color signal encodings in a solid lesion or peripherally strong color signal encodings in a cystic or necrotic lesion.

Settings for CDUS were as follows: the scale level and pulse repetition frequency were decreased, the color gain was increased until color noise became apparent, and the pressure of the probe on the lesion was lowered to avoid compressing the small vessels, which may cause low velocity signals to disappear. The Doppler spectral analysis technique was carried out in the same way as the CDUS technique.[12]

The machines used included a model Logiq 700MR with 546L linear and 548C curve transducers (GE Medical Systems, Milwaukee, WI, USA), a model Sequoia 512 with a 15L8 linear transducer at a 13-MHz setting (Siemens-Acuson, Mountain View, CA, USA), a model HDI 5000 with an L12-5 linear transducer (Philips-ATL, Bothell, WA, USA), and a model V730 with RAB 2-5 and SP10-16 probes (GE-Kretz, Kretztechnik, Zipf, Austria).

We assessed each nodule or mass on the basis of echogenicity, margin, shape, composition, sound transmission and size on grayscale US. Echogenicity was classified as heterogeneous or homogeneous for both the hyperechoic and hypoechoic aspects. Tumor margins were assessed as well-defined (clear-cut and thin capsule-like), ill-defined (uncertain margin with respect to adjacent normal tissue) (Figure 1) or infiltrated (certain irregular margin with adjacent normal tissue and wider transitional zone) (Figure 2). Shape was defined as round, ovoid, lobulated (Figure 3) or scalloped (Figure 2). Composition was solid, cystic, septate or solid, with cystic or necrotic content. Sound transmission was classified as posterior enhancement, no change, or attenuation. Tumor size was defined as large (> 5 cm), medium (1–5 cm) or small (< 1 cm). We also evaluated their grade on CDUS, the resistive index (RI) by spectral Doppler analysis, and other patterns that were present. The RI was measured only on detected vessels within the solid mass or solid component peripheral to the cystic part using CDUS. The CDUS grades were 0 (no color signal), 1 (1–5 color spots or segments), 2 (5–20 color spots or segments) or 3 (> 20 color segments) on 1 chosen image

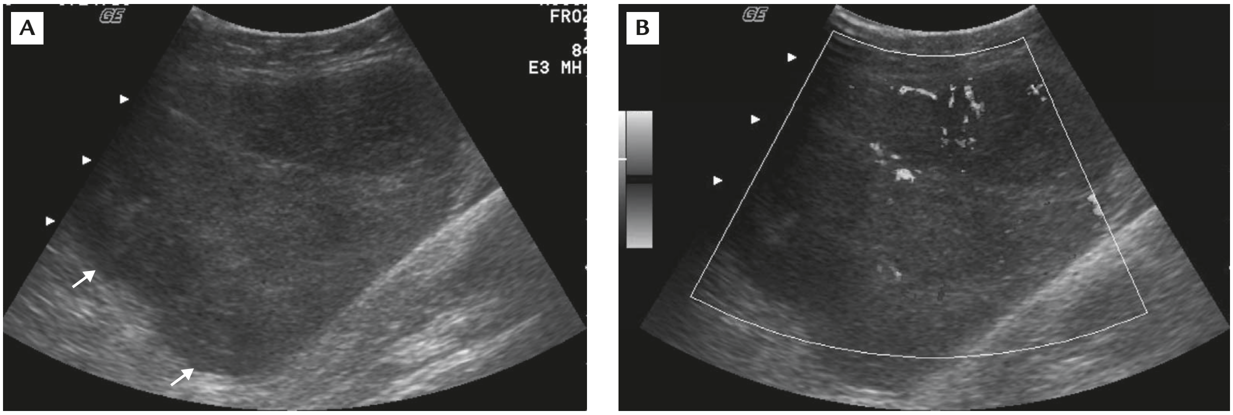

Figure 2. A 75-year-old female with a huge mass over the right upper arm for 3 months. (A) Grayscale ultrasonography shows heterogeneous hypoechoic mass in the right upper humerus region, with infiltrated margin, scalloped shape (arrows) and solid composition, measuring 9.1 × 6.3 cm. (B) Color Doppler ultrasonography shows grade 2 hypervascularity within the tumor. This turned out to be malignant fibrohistiocytoma.

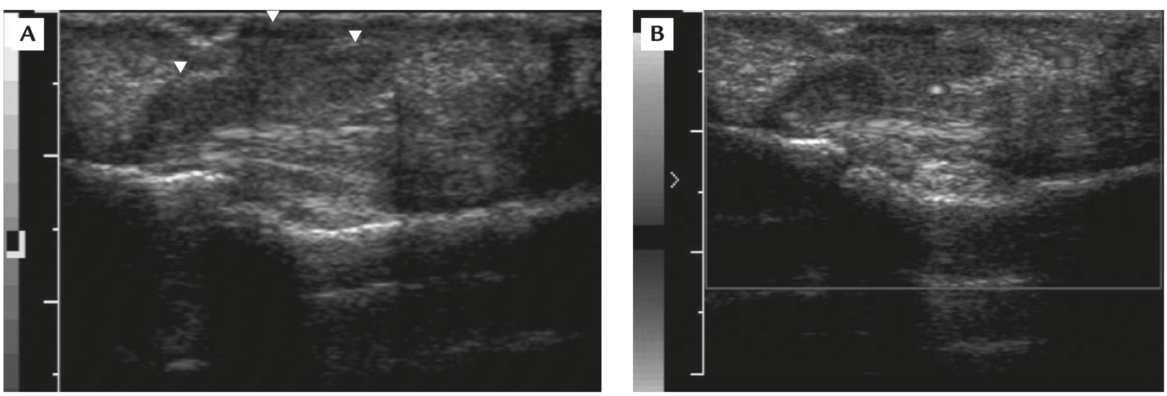

Figure 3. A 75-year-old female with giant cell tumor of the tendon sheath over the left middle finger. (A) Grayscale ultrasonography, palmar aspect, shows a lobulated (arrowheads), well-defined nodule above the flexor tendon. (B) Color Doppler ultrasonography shows grade 1 vascularity within the tumor, heterogeneous hypoechogenicity, lobulated shape with well-defined margin, solid in composition, and contact with the tendon.

with the most prominent color flow signals. The RI was high (> 0.9), moderate (0.6–0.9) or low (< 0.5). We also documented the presence or absence of phleboliths (Figure 1A) and periosteal reaction.

Associated findings or patterns other than the major tumoral sonomorphology included: myositis-like appearance, cellulitis-like appearance, involvement along a tendon, echoic spots, a to-and-fro flow pattern on CDUS, hyperechoic fat lobules, bowel gas and/or mesenteric fat, epimysium defects, C-shaped cyst, parallel echoic lines, an echogenic rim, hypoechoic fragments, gas bubbles, interruption of the bony cortex, a tortuous tubular structure (Figure 1), compressible in tumor, the presence of surrounding nerve, target patterns, overhanging erosion, central necrosis and hyperechoic fat in the tumor.

All US examinations were performed by 1 of the authors (HJC), and at least 2 sonologists interpreted the images independently. If they disagreed, a third sonologist was consulted to obtain a consensus. All readers were blinded to the pathologic diagnosis before reading. All images were interpreted on the PACS system. The histopathologic results were recorded. For each histology that occurred in more than 10 subjects, its US pattern was considered typical if it appeared in more than 50% of the subjects with a particular histopathology. Moreover, inflammatory processes, hematoma and pseudoaneurysm were not discussed in this study. All tumors except typical cysts, varices, pseudoaneurysms, neuritis lesions, degenerative joint disease and exostosis lesions were confirmed by aspiration cytology, biopsy or surgical pathology. All of those without histopathologic proof were followed in the outpatient department, and periodic US examination showed no evidence of any progression for more than 1 year.

SPSS version 12.0 (SPSS Inc., Chicago, IL, USA) for Windows was used for statistical analysis, and included the χ^2 test ($p < 0.05$), logistic regression and discriminant analysis. Discriminant analysis was performed to compare all criteria between the benign and malignant tumors.

Results

There were a total of 693 benign and 125 malignant tumors. Table 1 shows the distribution of benign tumors, and Table 2 shows the distribution of malignant tumors. Five types of malignant tumors and 8 types of benign tumors (excluding inflammatory process, hematoma and pseudoaneurysm) occurred in more than 10 subjects each.

US showed that the ganglion presented as a lack of internal echoes (i.e. echo-free) in 252 (94%) lesions. The margins were well-defined in 266 (99.3%). Shapes were lobulated in 64 (23.9%) and round or ovoid in 204 (76.1%). Contents were cystic in 180 (67.2%) and septate in 85 (31.7%). There were 267 (99%) lesions with posterior enhancement. There were 123 (45.9%) moderate and 143 (53.4%) small in size. Two hundred and sixty-seven (99.6%) were grade 0 on CDUS.

Table 1. Benign soft-tissue lesions

Lesions	Patients (*n*)
Ganglion	268
Lipoma	66
Baker's cyst	42
Bursitis	37
Hemangioma	32
Abscess	24
Hematoma	21
Giant cell tumor of tendon sheath	20
Pseudoaneurysm	17
Idiopathic myositis	13
Epidermal cyst	12
Chronic inflammation or granulation, tenosynovitis, schwannoma	11*
Neurofibroma	9
Foreign body, glomus tumor	8*
Hernia, lymphadenitis	7*
Exostosis, lymphangioma	5*
Varix, fibromatosis, traumatic neuroma, gout	4*
Rheumatoid arthritis with pannus formation, tuberculosis, muscle tear, degenerative joint disease, neuritis, pigmented villonodular synovitis, fibroma	3*
Enchondroma, arteriovenous malformation, leiomyoma, scar, perineuric fibrosis, tumoral calcinosis	2*
Aneurysmal bone cyst, amyloidosis, corn, elastofibroma, myositis ossificans, osteochondromatosis, chondroblastoma, chondroma, nonspecific synovitis, organized thrombosis	1*

**Indicates number of patients with each different lesion shown in the left column on the same row, e.g. 11 patients had chronic inflammation or granulation, 11 had tenosynovitis, and 11 had schwannoma.*

Eighteen (27%) lipomas had heterogeneous hypoechogenicity and 40 (61%) had heterogeneous hyperechogenicity. There were 63 (96%) with well-defined margins, and 65 (99%) were ovoid in shape; all 66 (100%) were solid. There were 61 (92%) with no change in sound transmission. Forty (61%) were moderate and 23 (35%) large in size. On CDUS, 56 (85%) were grade 0. Parallel echogenic lines were observed in 59 (89%).

Thirteen (31%) Baker's cysts had heterogeneous hypoechogenicity, and 27 (64%) were echo-free. All 42 (100%) had well-defined margins, ovoid shapes, and posterior enhancement for sound transmission. Sixteen (38%) were moderately sized and 26 (62%) were large. CDUS grade was 0 for 39 (93%) cysts. Twenty-eight (67%) were C-shaped on transverse sections in the popliteal fossa. Seven (17%) had heterogeneous blood clots, 6 (14%) had loose bodies, and 3 (7%) had a pannus formation.

Among the hemangiomas, 16 (50%) were heterogeneously hypoechoic or hyperechoic (Figure 1). Twenty-nine (91%) had ill-defined margins. Shapes were ovoid in 22 (69%) and lobulated in 10 (31%). Six (19%) were solid and 26 (81%) were solid and cystic. There were 13 (41%) with posterior enhancement

Table 2. Malignant soft-tissue lesions

Lesions	Patients (*n*)
Metastasis	33
Osteogenic sarcoma	24
Lymphoma	18
Malignant fibrohistiocytoma	15
Liposarcoma	14
Synovial sarcoma	4
Sarcoma, hemangiopericytoma	3*
Fibrosarcoma, malignant peripheral nerve sheath tumor	2*
Small round cell tumor, rhabdomyosarcoma recurrence, leiomyosarcoma, fibromyxoid sarcoma, dermatofibrosarcoma, chondrosarcoma, alveolar soft part sarcoma	1*

**Indicates number of patients with each different lesion shown in the left column on the same row.*

and 19 (59%) with no change in sound transmission. Twenty-nine (91%) were moderate in size. Seventeen (53%) were grade 2 and 13 (41%) were grade 3 on CDUS. Ten (31%) tumors were associated with phleboliths, 22 (69%) had an echogenic rim, 20 (62%) had a tortuous tubular structure, and 20 (63%) had good compressibility.

All 18 (100%) giant-cell tumors were heterogeneously hypoechoic (Figure 2) and solid. Twelve (67%) had well-defined and 6 (33%) had ill-defined margins. Nine (50%) were ovoid or lobulated. There were 17 (94%) with posterior enhancement, and 17 (94%) were moderate in size. Nine (50%) were grade 1 and 8 (44%) were grade 2 on CDUS. All 18 (100%) had moderate RI, and 13 (72%) appeared along the tendon.

Among the epidermoid cysts, 4 (33%) were homogeneously hypoechogenic and 5 (42%) had heterogeneous hyperechogenicity. All 12 (100%) had well-defined margins, were solid, and had posterior enhancement for sound transmission. Eleven (92%) were ovoid, and 1 (8%) had a lobulated shape. Eleven (92%) were moderately sized, and 11 (92%) were grade 0 on CDUS. Seven (58%) contained hypoechoic cholesterol plaque.

All 11 (100%) schwannomas had heterogeneous hypoechogenicity and well-defined margins. Two (18%) were solid and cystic and 9 (82%) were solid. Eight (73%) were ovoid and 2 (18%) were lobulated. There were 10 (91%) with posterior enhancement. Nine (82%) were moderate in size. Five (45%) were grade 2 on CDUS. Ten (91%) had intermediate RI. Four (36%) prominently surrounded a nerve bundle, and 4 (36%) had a target pattern.

Seven (88%) glomus tumors were homogeneously hypoechoic (including 6 that occurred at the nail base of a finger and 1 at the lower tibia periosteum). All 8 (100%) had well-defined margins, were ovoid in shape, and had posterior enhancement for sound transmission. Seven (88%) were solid, and 1 (12%) was solid and cystic (large vessels). Seven (88%) were small and 1 (12%) was large. Two (25%) were grade 2 and 5 (63%) were grade 3 on CDUS. All (100%) had moderate RI.

Among the metastases, all of which were carcinomatous, 6 (18%) had heterogeneous hyperechogenicity and 27 (82%) had heterogeneous hypoechogenicity. Thirty-one (94%) had infiltrated margins. Twenty-one (64%) had a scalloped shape (Figure 4), and 31 (94%) were solid. Sixteen (48%) had surrounding bony destruction (Figure 4), and 11 (33%) had bony fragmentation. There were 23 (70%) with posterior enhancement and 10 (30%) with no change in sound transmission. Twenty-one (64%) were moderate and 10 (30%) were large in size. Twenty-two (67%) were grade 2 on CDUS. RI was moderate in 23 (70%).

Among the osteogenic sarcomas, 10 (42%) were heterogeneously hypoechogenic (including 2 recurrences) and 14 (58%) were heterogeneously hyperechogenic. Twenty-three (96%) each had infiltrated margins, scalloped shape, and were solid. Twenty-one (88%) had surrounding bony destruction, and 19 (79%) had bony fragments. There were 10 (42%) with posterior enhancement and 14 (58%) with no change in sound transmission. Twenty (83%) were large in size, and 19 (79%) were grade 2 on CDUS. Twenty-one (88%) had moderate RI, and 19 (79%) were associated with sunburst periosteal reaction.

Sixteen (89%) lymphomas had relatively homogeneous hypoechogenicity. Thirteen (72%) had infiltrated margins, 11 (61%) were scalloped in shape, and all 18 (100%) were solid. There were 14 (78%) with

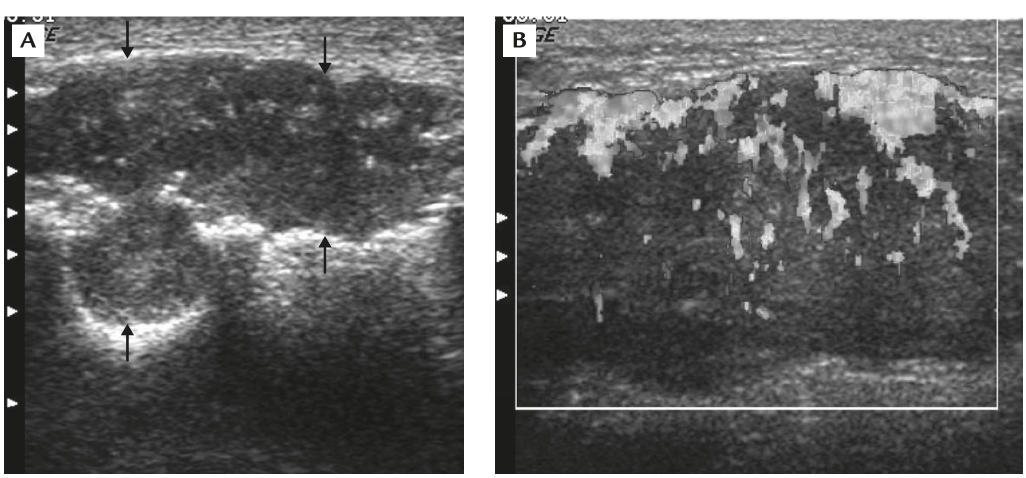

Figure 4. An 80-year-old male with palpable mass over the right lower knee. (A) Grayscale ultrasonography shows a tumor mass (arrows) with infiltrated margin, heterogeneous hypoechogenicity, scalloped and lobulated in shape, and solid in composition. (B) Color Doppler ultrasonography shows grade 3 hypervascularity.

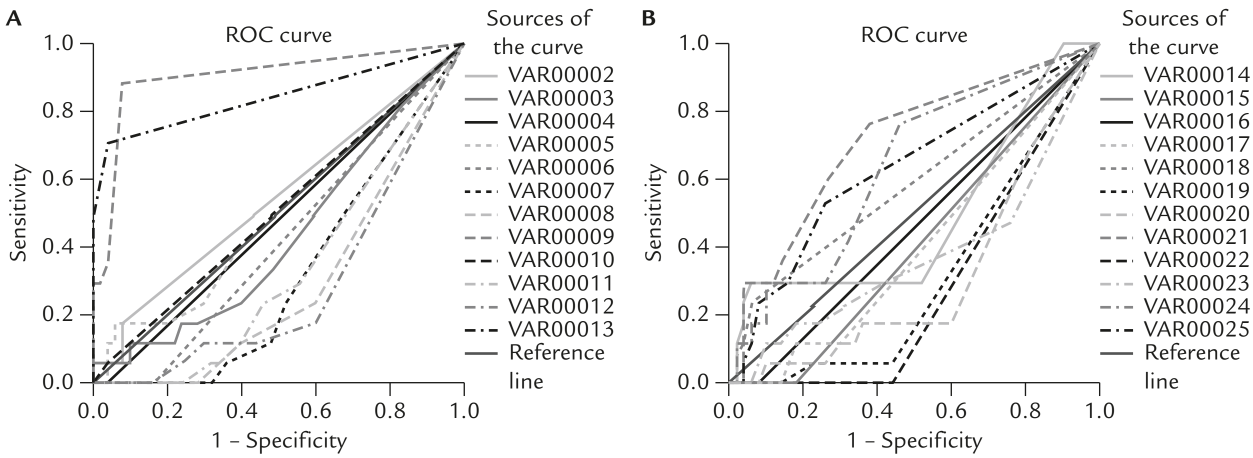

Figure 5. Receiver operating characteristic (ROC) curves of discriminate analysis between benign and malignant tumors. (A) ROC curves of the parameters to differentiate benign from malignant tumors. VAR00002 to 13 represent: homogeneous hypoechogenicity, heterogeneous hypoechogenicity, homogeneous hyperechogenicity, heterogeneous hyperechogenicity, echo-free, well-defined margin, ill-defined margin, infiltrated margin, round shape, ovoid shape, lobulated shape, and scalloped shape, respectively. (B) ROC curves of the parameters to differentiate benign from malignant tumors. VAR00014 to 25 represent: solid, cystic, cystic with septum, solid with cystic, solid with necrosis, tumor size < 1 cm, 1–5 cm, > 5 cm, CDUS grade 0, grade 1, grade 2, and grade 3, respectively.

posterior enhancement. Eight (44%) were moderate and 10 (56%) were large in size. Six (33%) were grade 2 and 11 (61%) were grade 3 on CDUS. The RI was moderate in 14 (78%). Two (11%) were associated with periosteal reaction; 5 (28%) involved a lymph node hilum; 5 (28%) involved several nodules; 3 (17%) had a myositis-like appearance; and 1 (6%) had a cellulitis-like pattern.

Fourteen (93%) malignant fibrous histiocytomas had heterogeneous hypoechogenicity (Figure 3). All 15 (100%) had infiltrated margins, 12 (80%) were scalloped, and 13 (87%) were solid. Five (33%) had bony destruction, and 10 (67%) had posterior enhancement. Fourteen (93%) were large in size. Ten (67%) were grade 2 on CDUS, and 14 (93%) had moderate RI.

Three (21%) liposarcomas had heterogeneous hypoechogenicity, and 11 (79%) had heterogeneous hyperechogenicity. Thirteen (93%) had infiltrated margins, and 11 (79%) had a scalloped shape; all 14 (100%) were solid. There were 4 (29%) with posterior enhancement, and 9 (64%) with no change for sound transmission. Thirteen (93%) were large in size. Six (43%) were grade 1, 7 (50%) grade 2 and 1 (7%) grade 3 on CDUS. Thirteen (93%) had moderate RI, while echogenic fat was observed in 11 (79%).

When we analyzed the usefulness of the sonographic findings in distinguishing between benign and malignant lesions using logistic regression and discriminant analysis, the significant features indicative of a malignant tumor were infiltrated margin (sensitivity, 83.2%; specificity, 98.8%; accuracy, 96.5%; $p < 0.05$), scalloped shape (sensitivity, 73.6%; specificity, 99.7%; accuracy, 95.7%; $p < 0.05$), and size > 5 cm (sensitivity, 64.8%; specificity, 87.4%; accuracy, 84%; $p < 0.05$). Tumoral echogenicity, composition, and CDUS features were not significant ($p > 0.05$). The receiver operating characteristic curve for US parameters for soft-tissue mass showed that a tumor that had infiltrated margins, was scalloped in shape and large in size was probably malignant (Figure 5).

Discussion

Scanning techniques are important, especially for examining small superficial lesions. To assess these lesions, the operator should apply additional jelly to the skin and hold the probe with gentle contact with the skin to avoid putting too much pressure on the lesion. In this way, even tiny cystic lesions or vessels can be clearly identified. When this technique is used with CDUS and spectral analysis, even small vessels and low-velocity signals can be detected.

Malignancies accounted for 15.3% of all soft-tissue tumors in this study. When osteogenic sarcomas and chondrosarcomas were excluded, the percentage was 12.2%. The prevalence of malignant soft-tissue tumor in this study was similar to that reported in others, which are between 5.1% and 15.5%.[13]

The study shows that the typical pattern of a ganglion was a lack of internal echoes, well-defined margins, a round or ovoid shape, a cystic composition, posterior enhancement, a small size and a grade of 0 on CDUS. More than 95% of ganglia were echo-free and well-defined, and they had no vascular supply. This pattern is similar to that previously reported.[14–16]

The typical pattern of lipoma was heterogeneous hyperechogenicity, well-defined margins, ovoid shape, solid composition, no change in sound transmission, moderate size, a CDUS grade of 0 and parallel echogenic lines in this study. Most lipomas occurred in the superficial soft tissues and were slightly hyperechoic compared with surrounding fat lobules or muscle. However, appearances varied and were sometimes isoechoic or hypoechoic.[17] Of note was a pattern of parallel echogenic lines, which was observed in 89.4% of the lipomas. No other soft-tissue tumors had this pattern. Therefore, these parallel echogenic lines were highly specific for peripheral soft-tissue lipomas. The study showed that soft-tissue lipomas should be avascular or, in rare cases, weakly vascular on CDUS.

The study showed that the typical pattern of a Baker's cyst was an echo-free pattern with well-defined margins, C-shaped cyst in transverse image and a grade of 0 on CDUS. Complex Baker's cysts due to synovial hyperplasia, hemorrhage or calcified loose bodies in the cyst sometimes result in heterogeneity.[18] When the cyst is due to an inflammatory process, such as rheumatoid arthritis, the synovial membrane may show hyperemic change, increasing the color encoding.

The hemangiomas in our study had heterogeneous echogenicity and hypervascularity, similar to other reports.[19,20] In addition, they had ill-defined margins and a solid and cystic composition. Findings of good compressibility, rim echogenicity and phleboliths had high positive predictive values for hemangioma. Our study also showed that the typical pattern of a hemangioma was heterogeneous hyperechogenicity or hypoechogenicity, ill-defined margins, ovoid shape, solid and cystic composition, moderate size, CDUS grade 2, an echogenic rim and good compressibility.

Few reports have described giant-cell tumors of the tendon sheath, and there is little mention of US findings for pigmented villonodular synovitis, the family to which the giant-cell tumors belong. One CDUS report of pigmented villonodular synovitis mentions complex heterogeneous hypoechoic masses, a thickened synovium and localized joint effusion and increased vascularity.[21] In this study, the typical pattern would be heterogeneous hypoechogenicity, well-defined margins, ovoid or lobulated shape, solid composition, moderate size, a CDUS grade of 1, a moderate RI and a location along the tendon.

On US, epidermoid cysts usually appear as solid, well-defined and echogenic masses with internal echoes resulting from debris.[22] About 58% of subjects had a homogeneous hypoechoic segment or plaque-like material disseminated over the lesion, which was possibly due to clustered cholesterol material or oil droplets. Some intraperitoneal teratomas also have this homogeneous hypoechoic pattern due to oil or cholesterol. Therefore, the typical pattern of epidermoid cyst would be a well-defined margin, ovoid shape, solid composition, posterior enhancement, moderate size, grade 0 on CDUS and presence of hypoechoic cholesterol plaque.

The study showed some tumors surrounding the nerve bundle and some having target pattern, similar to other reports.[23–26] Differentiating schwannoma from solitary neurofibroma is difficult. From our previous experience, neurofibromas are usually centrally located within the peripheral neurobundle.[27]

Glomus tumors were clear-cut in this study because of their typical presentations. Most occurred at the bases of the fingernails and had homogeneous hypoechogenicity.[15,28] In this study, the typical presentation was homogeneous hypoechoic, ovoid or round in shape, well-defined margins, and with posterior enhancement and hypervascularity.

This study showed that the most common types of peripheral soft-tissue lymphomas were mass and nodal types, which are similar to our previous report.[12] In this study, the typical pattern was relatively homogeneous hypoechogenicity, infiltrated margins, scalloped shape, solid composition, large size, grade 3 on CDUS and moderate RI.

Most metastases were from carcinomas if the tumor was close to the bony cortex; the surrounding bone was usually destroyed. This study showed that the typical pattern of soft tissue metastasis was heterogeneous hypoechogenicity, infiltrated margins, scalloped shape, solid composition, moderate size, grade 2 on CDUS, a moderate RI and surrounding bony destruction.

The typical pattern of osteogenic sarcoma in this study was heterogeneous hyperechogenicity, infiltrated margins, scalloped shape, solid composition, surrounding bony destruction, large size, grade 2 on CDUS, a moderate RI, bony fragments and sunburst periosteal reaction. Most such tumors occurred in the lower limbs, especially adjacent to the knee joint (63%). Two recurrent lesions occurred elsewhere, 1 in the thigh and 1 in the forearm, which was a well-defined, ovoid and hypoechoic nodule. Therefore, it should be noted that the US pattern of a recurrent osteogenic sarcoma might not be the same as the original pattern.

Malignant fibrous histiocytomas are histologically divided into pleomorphic, myxoid, giant-cell, inflammatory and angiomatoid subtypes, where the pleomorphic type is the most common. The reflection of echoes differs depending on the subtype. The study showed that 5 subjects had bony destruction. This pattern was different from that of osteogenic sarcoma on the basis of a lack of sunburst periosteal reaction with only soft-tissue periosteal thickening. One subject had advanced amorphous calcification in the tumor; this should be differentiated from myositis ossificans, which shows relatively linearly laminated calcification.

The echogenicity of liposarcomas differs depending on the cell type. In well-differentiated liposarcomas, US often demonstrates hyperechogenicity, whereas US of the myxoid type (the most common liposarcoma) typically shows heterogeneous hypoechogenicity with or without hyperechoic retained lipoblastic nets. Abnormal fat-cell hyperplasia in liposarcomas enhances the sonoreflective interface and thus increases the echogenicity. Even liposarcomas with myxoid change can contain mature fat or lipoblast cells that result in a focally hyperechoic area. This feature is quite useful to differentiate liposarcoma from benign lipoma, which present with ovoid shape, well-defined margins, parallel echogenic lines and avascularity (see lipomas). This study showed that the typical pattern of liposarcoma was heterogeneous hyperechogenicity, infiltrated margins, scalloped shape, solid composition, a large size, grade 2 on CDUS, a moderate RI and echogenic fat in the tumor.

Tumor margin, shape and size seem to be significant indicators for differentiating benign from malignant soft-tissue tumors ($p < 0.05$). Benign tumors did not have infiltrated margins or scalloped shape, and malignant tumors tended to be large. Echogenicity, composition and CDUS features of soft-tissue tumors were not good indicators for differentiating between benignancy and malignancy. Actually, CDUS only reflects the vascularity detected (enough velocity of blood flow); therefore, microcirculations, especially in malignant tumors, could be omitted. Because some malignant tumors usually have necrosis due to insufficient blood to supply the rapidly growing tumor, a large amount of tumor vessels could be destroyed. In benign tumors, less necrosis occurs. Although malignant tumors need more nutrients, the vessel network will be more complicated. Therefore, the color encodes the vessels detected in benign and malignant tumors, so using only the grading of color encoding is not enough to differentially diagnose a benign tumor from a malignant one. Perhaps more parameters need to be added, such as vessel morphology and the consistency of vessel walls.

In conclusion, echogenicity, margin, shape, composition, size, vascularity and other specific patterns on US permit differential diagnosis of ganglia, hemangiomas, lipomas, Baker's cysts, glomus tumors, epidermoid cysts, tenosynovitis lesions, bursitis lesions, hematomas, abscesses and pseudoaneurysms. US is also a good modality for detecting soft-tissue tumors and for differentiating benign from malignant lesions. Tumor size > 5 cm and with infiltrated margins are highly suggestive of a malignant tumor.

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References

1. Damron TA, Beauchamp CP, Rougraff BT, Ward WG. Soft-tissue lumps and bumps. *J Bone Joint Surg* 2003;85A: 1142–55.
2. Bureau of Health Promotion, Department of Health, The Executive Yuan. Soft tissue malignancy. *Cancer Registry Annual Report, 2002, Republic of China*. Taiwan, Republic of China, 2005:74.
3. American Joint Committee on Cancer. Soft tissues. In: Fleming ID, Cooper JS, Henson DE, Hutter RVP, Kennedy BJ, Murphy GP, O'Sullivan B, et al. *AJCC Cancer Staging Manual, 5th edition*. Philadelphia: Lippincott-Raven, 1997:149.
4. Tierney JF, Stewart LA, Parmar MKB. Adjuvant chemotherapy for localised resectable soft tissue sarcoma of adults: meta-analysis of individual data. Sarcoma Meta-analysis Collaboration. *Lancet* 1997;350:1647–54.
5. Kransdorf MJ, Murphey MD. Radiologic evaluation of soft-tissue masses: a current perspective. *AJR Am J Roentgenol* 2000;175:575–87.
6. Van der Woude HJ, Bloem JL, Schipper J, Hermans J, van Eck-Smit BL, van Oostayen J, Nooy MA, et al. Changes of tumor perfusion in bone sarcomas induced by chemotherapy: color Doppler flow imaging and three-phase bone scintigraphy. *Radiology* 1994;191:421–31.
7. Lagalla R, Iovane A, Caruso G, Lo Bello M, Derchi LE. Color Doppler ultrasonography of soft-tissue masses. *Acta Radiol* 1998;39:421–6.
8. Bodner G, Schocke FH, Rachbauer F, Seppi K, Peer S, Fierlinger A, Sununu T, et al. Differentiation of malignant and benign musculoskeletal tumors: combined color and power Doppler US and spectral wave analysis. *Radiology* 2002;223: 410–6.
9. Latifi HR, Siegel MJ. Color Doppler flow imaging of pediatric soft tissue masses. *J Ultrasound Med* 1994;13:165–9.
10. Ozbek SS, Arkun R, Killi R, Memis A, Dagdeviren A, Sevinc E. Image-directed color Doppler ultrasonography in the evaluation of superficial solid tumors. *J Clin Ultrasound* 1995;23:233–8.
11. Van deer Woude HJ, Vanderschueren G. Ultrasound in musculoskeletal tumors with emphasis on its role in tumor follow-up. *Radiol Clin North Am* 1999;37:753–66.
12. Chiou HJ, Chou YH, Chiou SY, Chen WM, Chen W, Wang HK, Chang CY. High-resolution ultrasonography of primary peripheral soft tissue lymphoma. *J Ultrasound Med* 2005;24:77–86.

13. Myhre-Jensen O. A consecutive 7-year series of 1331 benign soft tissue tumors: clinicopathologic data-comparison with sarcomas. *Acta Orthop Scand* 1981;52:287–93.
14. Cardinal E, Buckwalter KA, Braunstein EM, Mih AD. Occult dorsal carpal ganglion: comparison of US and MR imaging. *Radiology* 1994;193:259–62.
15. Fornage BD, Rifkin MD. Ultrasound examination of the hand and foot. *Radiol Clin North Am* 1988;26:109–29.
16. Fornage BD, Schernberg FL, Rifkin MD. Ultrasound examination of the hand. *Radiology* 1985;155:785–8.
17. Fornage BD, Tassin GB. Sonographic appearances of superficial soft-tissue lipomas. *J Clin Ultrasound* 1991;19:215–20.
18. Pathria MN, Zlatkin M, Sartoris DJ, Scheible W, Resnick D. Ultrasonography of the popliteal fossa and lower extremities. *Radiol Clin North Am* 1988;26:77–85.
19. Paltiel HL, Burrows PE, Mulliken JB. Color Doppler ultrasound of soft tissue vascular anomalies. *Radiology* 1994;193:292–5.
20. Tseng JJ, Chou MM, Chen WH. Prenatal 3- and 4-dimensional ultrasonographic findings of giant fetal nuchal hemangioma. *J Chin Med Assoc* 2007;70:460–3.
21. Lin J, Jacobson JA, Jamadar DA, Ellis JH. Pigmented villonodular synovitis and related lesions: the spectrum of imaging findings. *AJR Am J Roentgenol* 1999;172:191–7.
22. Yasumoto M, Shibuya H, Gomi N, Kasuga T. Ultrasonographic appearance of dermoid and epidermoid cysts in the head and neck. *J Clin Ultrasound* 1991;19:455–61.
23. Simonovsky V. Peripheral nerve schwannoma preoperatively diagnosed by sonography: report of three cases and discussion. *Eur J Radiol* 1997;25:47–51.
24. Obayashi T, Itoh K, Nakano A. Ultrasonic diagnosis of schwannoma. *Neurology* 1987;37:1817.
25. Kececi Y, Gurler T, Gundogan H, Bilkay U, Cagdas A. Benign giant schwannoma located in the upper arm. *Ann Plast Surg* 1997;39:100–2.
26. Fornage BD. Peripheral nerves of the extremities: imaging with US. *Radiology* 1988;167:179–82.
27. Tsai WC, Chiou HJ, Chou YH, Wang HK, Chiou SY, Chang CY. Differentiation between schwannomas and neurofibromas in the extremities and superficial body: the role of high-resolution and color Doppler ultrasonography. *J Ultrasound Med* 2008;27:161–6.
28. Fornage BD. Glomus tumors in the fingers: diagnosis with US. *Radiology* 1988;167:183–5.