Introduction

In countries with prevalent chronic hepatitis B and/or C, such as Taiwan, treatment of active hepatitis, the management of complications from liver cirrhosis, and the occurrence of hepatic tumors are becoming a major concern. Hepatocellular carcinoma (HCC) is the most common primary malignancy and a leading cause of cancer mortality in Taiwan. Detection of HCC and further differential diagnosis between HCC and other benign or malignant tumors are important issues in clinical practice. With advances in ultrasonography (US) and the laboratory examination of alpha-fetoprotein, the early diagnosis of HCC has become feasible. However, different kinds of tumors, both of a benign and a malignant nature, may be found in the liver, and the variable presentation of these tumors in imaging studies increases the difficulty in the differential diagnosis of hepatic tumors. Among the many
applications of US in the liver, the detection and differentiation of focal hepatic lesions is the most important issue.

By improving the resolution of images and enhancing the signal-to-noise ratio, the sensitivity of grayscale US is enough to detect hepatic tumors; in addition, grayscale US also has some differential diagnostic abilities [1]. However, with the use of traditional grayscale US imaging, it is still difficult to reach a specific diagnosis of hepatic tumor. Following the development of US, color and power Doppler US examinations have been added to the traditional grayscale images. Using color-coded imaging, blood flow in organ vessels and in the tumor vessels can be demonstrated. Different image acquisition techniques have also been applied to US examinations. In this article, advances in US techniques are reviewed, and the vascular pattern of different focal hepatic lesions and their application to differential diagnosis are discussed.

**Advances in US**

**Conventional grayscale ultrasound**
In the 20th century, grayscale US was applied to the liver and other abdominal organs instead of the original B-scan US. Grayscale US has been shown to have higher specificity and accuracy than scintigraphy in hepatic tumors [2] and provides a complementary role to radioisotope scanning in the differential diagnosis of hepatic lesions, including neoplasms, benign cysts and liver abscesses [1]. Besides visualization of liver anatomy [3] and the detection of intrahepatic vessels [4], grayscale US has also been used to detect and evaluate hepatic tumors and provide complementary information to scintigraphy and computed tomography (CT) [5]. Grayscale US provided effective differentiation between solid tumors and cystic tumors. With technological advances, real-time US became more effective and efficient in the examination of the liver. Using a combination of needle aspiration biopsy and CT or real-time US, the diagnosis of focal hepatic lesions was satisfactory for both benign and malignant lesions [6]. In a prospective study in 1985 by Sheu et al, real-time US was sensitive in the early detection of HCC [7]. Besides HCC, various kinds of hepatic tumors, such as echinococcal cysts [8], focal nodular hyperplasia [9], hepatic adenoma [10], nodular regenerative hyperplasia and metastatic tumors [11], were characterized by US image findings. However, it was still difficult to achieve a satisfactory result in the differential diagnosis of hepatic tumors using conventional grayscale US alone.

**Doppler ultrasound**
Although conventional grayscale US is cost efficient and easily performed in clinical practice, its diagnostic accuracy is less than that of other imaging modalities, such as CT and magnetic resonance imaging (MRI) [12]. Fortunately, diagnostic accuracy has increased because of advances in equipment and the application of color and power Doppler US. Doppler US with color-coded flow signaling was developed and introduced into clinical practice in 1980 [13]. By coloring the estimated mean Doppler frequency shift at a specific location, local blood flow and vasculature of the target lesion could be demonstrated. Different vascular patterns were observed in different kinds of focal hepatic tumors; thus, the detection of tumor vasculature can aid in differential diagnoses. Color Doppler US (CDUS) also provided the opportunity to detect smaller vasculature than that detected by noninvasive CT and MRI [14]. However, the detection ability of this technique is insufficient, as only major vessels could be shown by CDUS. Vessels of small caliber or with slower blood flow could not be shown by CDUS. Power Doppler US (PDUS) encoding the power in color Doppler signals was subsequently invented and was shown to have higher sensitivity in blood flow detection and was less angle-dependent than CDUS [15]. The random noise with low power can be decreased and no alias will be detected in PDUS. Although the sensitivity of PDUS is higher than that of CDUS, especially for HCC [16], hepatic adenoma, focal nodular hyperplasia [16,17], cholangiocarcinoma, metastatic tumors and hemangioma [16], slow blood flow is still difficult to demonstrate.
Besides CDUS and PDUS, an advanced dynamic imaging technique has also been used to demonstrate vasculature. Dynamic flow imaging is a wideband Doppler imaging technique where artifacts can be eliminated. A higher sensitivity for vascular signals and clearer images can be obtained for analysis. In addition, when combined with contrast-enhanced US, advanced dynamic flow imaging can provide better depiction of tumor vascularity and help in the diagnosis and assessment of the therapeutic effect of radiofrequency ablation [18].

Using color or power Doppler, or advanced dynamic flow techniques, only major vessel signals can be identified. According to the vascular patterns present in hepatic tumors, the vascularity of the tumors can be divided into hypervascular and hypovascular, which are helpful in the differential diagnosis of hepatic tumors (Table). When intratumoral vessels and/or prominent vascular signal spots are present, the vascular pattern of the tumor is designated as hypervascular. When no intratumoral vessels and only peritumoral vessels and/or spotty intratumoral signals are found, the tumor is designated as hypovascular.

**Contrast-enhanced ultrasound**

Contrast agents administered via the intravenous route introduced to increase the reflectivity of blood were applied to ultrasonography in 1980. Commercially available intravenous contrast agents have been shown to aid in the detection of slow (capillary) flow, which could not be demonstrated by previous color or power Doppler US techniques. Besides the vascular patterns demonstrated by CDUS and PDUS, contrast-enhanced US (CEUS) provided capillary signals and their dynamic changes in whole hepatic tumors. Therefore, in addition to the hypervascular or hypovascular characteristics of hepatic tumors, dynamic changes in enhancing patterns could be demonstrated by CEUS, which were similar to CT and MRI.

An US contrast agent is composed of a central microbubble and an outer stabilizing shell. Many contrast agents were developed with different types of central microbubbles and shell combinations. Increased signal-to-noise ratio helps CEUS to achieve higher sensitivity in the blood flow signal and better information on vascularity. Two major generations of contrast agents have been designated. First-generation contrast agents spread around the blood and tissues nonspecifically. These contrast agents are quickly destroyed by (high mechanical index) US beams, and only a short duration (several minutes) of enhancement could be maintained. The technique of flash echo may improve the image quality and also prolong the image acquisition duration by intermittent flashes on CEUS using first-generation contrast agents. In second-generation contrast agents, blood pool and tissue-specific contrast agents were developed, which had higher efficacy and longer duration of vascular depiction. These new contrast agents have a more flexible

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*Existence of intratumoral vessels and/or prominent intratumoral signal spots in color/power Doppler ultrasound; ‡no intratumoral vessels, only peritumoral vessels and/or spotty intratumoral signals in color/power Doppler ultrasound; †prevalence of the tumors according to intratumoral vasculature.
shell, which oscillates under low mechanical index US beams and emits harmonic signals during the scanning process. Therefore, longer duration and real-time US examination due to less bubble destruction can be achieved during low mechanical index US examination.

First-generation contrast agents, such as the galactose-based contrast agent (Levovist), improved intravascular blood flow detection in both benign and malignant lesions and aided in the differential diagnosis of focal hepatic lesions [19,20]. Newer second generation agents, such as SonoVue, Definity and Sonazoid, have been shown to be suitable for low mechanical index imaging and helpful for HCC detection [21]. CEUS showed high concordance with CT or MRI for hepatic tumor detection, especially for the arterial phase [22]. Various types of contrast agents have been widely used in the diagnosis of focal hepatic lesions and in the follow-up of tumors receiving local treatment modalities [23]. With the use of contrast agents, US had a comparable sensitivity to CT and MRI scanning [24]. The use of the contrast agent SonoVue in the examination of focal hepatic lesions significantly improved the detection rate (351 lesions versus 250 lesions) and provided a more complete diagnosis (96% vs. 52% of cases) [25] of these lesions compared to that without SonoVue.

Three-dimensional (3D) ultrasound
The hypervascular characteristic and the existence of intratumoral vessels are important in the differential diagnosis of hepatic tumors. However, in some situations, it is difficult to confirm these vessels as intratumoral or peritumoral and to demonstrate the vasculature comprehensively by conventional two-dimensional (2D) US. Conventional 2D US has several limitations, including difficulty in reproducing in sequence examinations, missing out-of-plane features, misdiagnosis of marginal tumor vessels as intratumoral vessels, and difficulty in arbitrary plane-cut demonstration [26]. Only limited plane-cut views can be provided by 2D US. 3D US is acquired and collected by serial plane-cut images and stored in digitalized datasets. After reconstruction, both grayscale and color images can be shown separately or in combination by 3D stereotype forms. Because of advances in image processing, 3D US can be reproduced and reviewed in any arbitrary view. The structure of the examined organs and the vascular structures can be demonstrated more comprehensively [26,27]. The potential benefits of 3D US include: (1) a reduction in the number of missing out-of-plane features seen in 2D US; (2) any plane cut of view images; (3) exact localization of vessels in and around the tumor; (4) opportunity for repeat reviewing of digitalized stored images; and (5) demonstration of structure of small-caliber vessels, avoiding misdiagnosis as noise seen in 2D US. When 3D power Doppler imaging was applied to assess the vascularity in liver tumors in Ohishi et al’s study, 3D images evaluated the entire tumor vasculature more easily than 2D US [28]. In the evaluation of HCC, 3D US can provide more information regarding the pattern of tumor vasculature, and the findings were comparable with those of angiography [29]. 3D power Doppler imaging showed more intratumoral Doppler signals than 2D images in more than 70% of lesions [30].

Tissue harmonic imaging, pulse inversion imaging, and flash echo imaging
In addition to CEUS and 3D US, tissue harmonic imaging of US was introduced to improve the signal quality of grayscale US and CDUS. With technological advances, the harmonic wave of US was received instead of the original reflected waveform. Harmonic signals from the nonlinear propagation of sound waves passing through the tissue were received, using second, third or even fourth harmonic waveforms for image formation. Using this method, side lobes and scattering of the waveforms was decreased, and the signal-to-noise ratio was improved. In a randomized study, tissue harmonic US provided more information in 14 of 48 patients (29%), and better image quality than conventional US [31]. In CEUS, harmonic imaging exploits the nonlinear behavior of microbubbles but forces a compromise between image sensitivity and axial resolution. Thus, pulse inversion imaging was
developed to overcome this compromise. Sequences of pulses of alternate phase are transmitted into the tissue, and the summed echoes are acquired for analysis and image formation. Higher contrast sensitivity and better image resolution were achieved using pulse inversion imaging than by harmonic imaging [32].

Flash echo imaging is an intermittent harmonic imaging system with application to CEUS. Flashes of intermittent high acoustic power are delivered for the destruction of accumulated contrast microbubbles. Low mechanical index acoustic power is used for continuous monitoring between flashes. Echo signals from the bubbles, tissue/lesion perfusions, and vascular signals can be obtained more efficiently [33] using the flash echo imaging system. Flash echo imaging may have higher sensitivity than conventional CDUS and PDUS and have similar sensitivity to dynamic CT and hepatic angiography. Flash echo imaging with CEUS is also effective in evaluating response to ethanol treatment in small HCCs [34], and radiofrequency ablation of HCC and liver metastases [18].

Differential Diagnosis of Hepatic Tumors

Hepatic tumors can easily be detected using traditional grayscale US; in addition, non-tumor lesions such as focal fatty infiltration or sparing of focal fatty infiltration can be differentiated easily [35,36]. However, the important differential diagnosis of benign and malignant tumors is still difficult. As previously described, with the use of CDUS, PDUS and advanced dynamic flow US, hepatic tumors can be divided into two main categories depending on vascular abundance: hypervascular and hypovascular. Using these characteristics, focal hepatic tumors can be divided into two groups: benign and malignant (Table). Focal nodular hyperplasia and hepatic adenoma are the two most commonly seen benign hypervascular tumors. In contrast, HCC is the most common hypervascular malignancy of all liver tumors. Some metastatic tumors are also hypervascular but are not so prevalent. In addition, few cholangiocarcinomas are hypervascular when imaged using Doppler US. Hemangioma is the most common hypovascular benign hepatic tumor. Hepatic cysts (including simple cyst and polycystic liver), liver abscesses, pseudo-tumors, hematoma, and focal fatty change are also benign hypovascular lesions. Among malignant tumors, most cholangiocarcinoma and some metastatic liver cancers have been shown to be hypovascular tumors. Hypervascularity in CDUS and PDUS studies is more prevalent in malignant tumors, and hypovascularity is more prevalent in benign tumors. Besides the vascularity of tumors, some enhancement patterns after contrast agent administration are characteristics of tumor types. Grayscale US presentations, vascular patterns and dynamic contrast enhancement patterns of these hepatic tumors are discussed as follows.

Malignant Hypervascular Tumors

**HCC**

HCC is the most common malignancy in the liver. In conventional US, HCC has a variable and nonspecific presentation on echo pictures. Most small HCCs less than 3 cm have been noted to be hypoechoic. Larger HCCs are hyperechoic, which correlates pathologically with a mixture of hemorrhage, fibrosis and necrosis [37]. As small HCCs grow, US shows an evolution from hypoechoic to isoechoic and then to an inhomogeneous hyperechoic pattern [38]. Some overlapping characteristics between HCC and regenerative nodules and a background of cirrhosis makes the diagnosis of HCC more difficult by conventional US only. With the increased depiction of vascularity detected by CDUS and PDUS, the accuracy of diagnosis and characterization of HCC have improved. However, smaller tumors with faint vascular patterns or tumors in a deep location make CDUS less sensitive and accurate in the differential diagnosis of HCC. With CEUS, the enhancement patterns are improved, and typical patterns of rapid arterial enhancement and rapid wash-out
in the portal phase can be demonstrated, similar to those seen in CT. More than 80% concordance in tumor vascularity between CEUS with a low mechanical index level and that of contrast-enhanced helical CT has been reported [39–41]. Homogeneous hypoechoic images in the portal phase are present in most HCCs, and isoechoic images were seen in a few cases. In contrast, regenerative nodules and dysplastic nodules show a lower incidence of hypervascularity on CEUS examination. In Fracanzani et al's study of Levovist CEUS, intratumoral enhancement could be detected in six of 21 (28%) nonmalignant tumors (regenerative nodules and dysplastic nodules), compared with 19 of 20 HCCs [42]. In these six nonmalignant tumors, one was a large regenerative nodule with venous flow, and the other five were dysplastic nodules with low-resistance arterial flow. For both small HCCs and dysplastic nodules, contrast-enhanced PDUS had a higher diagnostic accuracy than conventional US and fundamental PDUS [43]. Different patterns of vasculature including diffuse, basket-like, peripheral and central were demonstrated by both PDUS and 3D US [29,44]. Besides vascular imaging, tumor perfusion and liver perfusion imaging using contrast-enhanced PDUS have also provided tumor characteristics for differential diagnosis. Whole enhancement patterns in tumor perfusion imaging and whole defect patterns in liver perfusion imaging are characteristic of moderate and poorly differentiated HCC [45].

Benign Hypervascular Tumors

Focal nodular hyperplasia
Focal nodular hyperplasia (FNH) is an uncommon benign tumor of the liver with an incidence of 1–3% and predominantly occurs in women [46]. FNH or hepatic adenomas are represented by a solid mass or a mass containing sonolucent areas with hemorrhage or necrosis on grayscale US [10]. However, FNH on conventional US has nonspecific echogenicity with a homogeneous isoechoic or slightly hyperechoic echo picture. The acoustic characteristics of the tumor are similar to the surrounding normal liver [9]; therefore, it is difficult to differentiate FNH from other types of tumors using conventional grayscale US.

A central radiating spoke-wheel arterial pattern of vessels is characteristic of FNH and can be demonstrated by CDUS or PDUS. Administration of contrast agent improves the detection of feeding vessels and the radiating spoke-wheel vascular pattern [47]. Strong arterial phase and (early) portal venous phase enhancement of FNH can be observed in low mechanical index level CEUS or pulse inversion harmonic studies [48]. The enhancement may persist, and echo enhancement is isoechoic or even hyperechoic at the late phase in CEUS [48,49]. Central scars may also be seen on CEUS with unenhanced hypoechoic characteristics [47,50].

Adenoma
Hepatic adenomas are related to oral contraceptives (hormones) in pathogenesis and are predominant in women. Hepatic adenomas are well-demarcated with hypoechoic or hyperechoic characteristics on grayscale US. Intratumoral fat accounts for this variation. Non-specific Doppler US signals may be detected in the tumor. In a prospective study of hepatic adenomas, CDUS showed intratumoral veins and peritumoral arteries and veins, which were correlated with pathologic examination and provided clues for differential diagnosis of hepatic adenomas from focal nodular hyperplasia [51]. In contrast to FNH with enhancement at arterial and early portal
venous phases, adenomas show homogeneous enhancement during the arterial phase and no enhancement could be demonstrated during the portal venous phase on CEUS. [48]

Malignant Hypovascular Tumors

Cholangiocarcinoma
Cholangiocarcinoma is ranked as the second most common hepatic malignancy. In peripheral-type cholangiocarcinoma, more than half of these tumors are hyperechoic on conventional US and one-third had a peripheral hypoechoic rim or peripheral bile duct dilatation [52]. Associated biliary structure dilatation may be seen and provides a hint for the diagnosis of cholangiocarcinoma, although this is not pathognomonic. Most cholangiocarcinomas are relatively hypovascular on CDUS and PDUS, and only a few have intratumoral vascular signals. Peritumoral vessels could be identified by color and PDUS. Intrahepatic cholangiocarcinoma showed peripheral hyperechoic enhancement in the arterial phase of CEUS and was hypoechoic (wash-out) in the portal venous phase [53].

Metastatic tumors
Metastases of hepatic tumors mostly originate from the gastrointestinal tract (especially the colon), lungs, and breast. The common routes for metastatic liver tumors are the blood stream (portal venous system, hepatic artery), lymphatic drainage and, less frequently, from direct invasion. Multiple scattered nodules in both lobes of the liver are characteristic for metastatic liver tumors. Calcification of metastatic lesions is another characteristic feature and is more frequently associated with colon origin [54]. Grayscale US has various different patterns: discrete echogenic pattern, discrete hypoechoic, anechoic and diffuse inhomogeneity [11]. Diagnostic accuracy of metastatic tumors using US is about 84% [55]. However, the ultrasound pattern does not provide enough information to confirm the origin of the metastasis. Echotexture can be hyperechoic, isoechoic or hypoechoic. A hypoechoic rim or sonographic halo sign can sometimes be observed in the ultrasound study, which is due to parenchymal compression by pathologic features [56]. Some metastatic tumors have cystic components; therefore, differential diagnosis with other cystic lesions should be carried out. Wall thickness, mural nodules, septation and the fluid–fluid level on ultrasound are used to differentiate metastasis from simple cysts [57].

The vascularity of metastatic liver tumors vary; some are hypervascular, and most, however, are hypovascular. Hypervascular metastatic tumors are mostly hyperechoic and vice versa on grayscale US [58]. The most frequently observed Doppler US pattern is hypovascular with peripheral signal (66.7% and 83.3% in tumors of 1–4 cm and 1–2 cm, respectively) in Gaiani et al’s study [59]. Intranodular and diffuse vascular signals could only be detected in one-third and one-sixth of tumors of sizes 1–4 cm and 1–2 cm, respectively [59]. PDUS demonstrates vasculature better than CDUS in metastatic lesions; PDUS demonstrated 18 of 20 metastatic tumors of 1–4 cm in Hosten et al’s study [16]. However, in 12 of 18 detected metastases, vasculature was located at the periphery and was intranodular in one of 18. The diffuse vasculature in metastases (27.7%) is lower than that of other hypervascular tumors such as HCC (36%) or FNH (52.8%). In addition, the contrast agent Levovist improved the detectability of vasculature by US in Hosten et al’s study from 12 of 19 (peripheral flow signal) metastases without contrast agent to 17 of 19 (two at center and 15 at periphery) metastases after contrast administration [16]. CEUS in combination with phase inversion mode also significantly improved the diagnosis and characterization of metastases from 63 to 91% [60].

Hepatic lymphoma and leukemia
Lymphoma or leukemia with liver involvement is rare. The most common ultrasonographic pattern of hepatic lymphoma is that of hypoechogenic, although diffuse hypoechogenic, patterns; target and echogenic patterns have been reported [61]. Leukemia with liver involvement may present as multiple hypo- to anechoic solid masses without acoustic enhancement. A “bull’s-eye” appearance with a hyperechoic...
dense center due to tumor necrosis may also be present on US [62].

**Benign Hypovascular Tumors**

**Hemangioma**

Capillary hemangioma is the most common benign tumor of the liver. A capillary hemangioma is represented as a round or irregular shaped, single or multiple lesions with varying size. These lesions are mostly homogeneously hyperechoic with sharp margins, or hypoechoic with or without a hyperechoic rim on grayscale US. Posterior acoustic enhancement is more frequently present in hemangiomas of larger size [63]. Heterogeneous echotexture with hypoechoic portions may be seen in hemangioma due to necrosis, hemorrhage, thrombosis or fibrotic scarring [64]. Inhomogeneous enhancement of these portions may be seen in the late phase of contrast US [64]. Incidences of hypoechoic halo, posterior attenuation and calcification are low. Large hemangiomas are usually heterogeneous in echotexture and may have a central scar.

On CDUS and PDUS, intratumoral vessels are not present, and only rarely are intralesional vascular spots seen. An increase in the rate of central spots has been observed following injection of the first-generation contrast agent Levovist [16]. However, this vascular pattern is nonspecific and has a low accuracy when compared with other imaging modalities such as CT or MRI [65]. With advances in contrast agents and US techniques, typical initial marginal rim or nodular enhancement in the arterial phase and central filled-in patterns, and delayed homogeneous enhancement in the portal phase can be demonstrated by CEUS [66,67], similar to those in contrast CT and MRI.

**Cystic lesions**

Tissue fluid, including blood, is anechoic on US. Cystic lesions of liver were reported with grayscale US as early as 1978 [68]. Simple cysts are common on US examinations with an incidence of 1–4%. A prevalence of 3.6% in a survey of 3,600 patients was reported in southern Taiwan [69]. Cysts can be single or multiple, with or without septa. Numerous cystic lesions are found in polycystic liver disease, which is commonly associated with polycystic kidney disease in patients with autosomal dominant hereditary predisposition. These benign cystic lesions are anechoic with thin walls and acoustic enhancement on grayscale US [68,70]. When bleeding or infection occurs in these cysts, the inner echogenicity increases and becomes heterogeneous in appearance. No vascular flow was detected in these cystic lesions. The diagnostic accuracy of ultrasound is high in these lesions and can be up to 95–100% [70]. Among the cystic lesions, differential diagnosis includes simple cysts, necrotic metastases, echinococcal cysts, hematoma, abscesses, and hepatic cystadenocarcinoma. Cystadenocarcinoma should be considered when multiloculated cystic lesions are noted with local thickening of the septa with a solid component [71,72]. In contrast, cystadenomas have thin and smooth walls. The presence of color signals in the solid part of cystic lesions provides diagnostic information for the differentiation of simple cysts and abscesses [73]. CEUS is also helpful in demonstrating the mural nodulation or wall thickening of cystic lesions.

**Liver abscess**

Infection of the liver may cause abscess formation, including pyogenic, amebic and candidal liver abscesses. In pyogenic liver abscesses, the US features include: (1) variable size, (2) right lobe abscess (more common), (3) variable shape (mostly round), (4) single or multiple, (5) irregular and poorly delineated abscess wall, (6) echotexture from anechoic to hyperechoic (mostly with lower echogenicity), and (7) acoustic enhancement of varying degree [74,75]. Among these features, acoustic enhancement is the most important diagnostic feature in the differential diagnosis of liver abscesses. A liver abscess appears as a solid or fluid-filled cystic mass with variable internal echogenicity [76]. Intra-abscess gas formation may cause a marked increase in echogenicity of the abscess. No vascular structures are detected on CDUS. On contrast enhancement,
the abscess margin can be irregular and unevenly enhanced.

In amebic liver abscess, US presentations are numerous in the literature. US features suggestive of the diagnosis include: (1) lack of wall echoes, (2) round or oval in shape, (3) homogeneous lower echogenicity, (4) location contiguous with liver capsule, and (5) distal echo enhancement [77]. Although these features help in the diagnosis, US findings alone were inadequate in distinguishing pyogenic from amebic liver abscesses. Amebic liver abscess diagnosis is confirmed by serum indirect hemagglutination assay. A combination of US findings and clinical as well as laboratory data can aid in the correct diagnosis (86%) and differential diagnosis of amebic liver abscess from pyogenic liver abscess [78].

In immunocompromised/immunodeficiency hosts and patients receiving chemotherapy or immunosuppressant therapy, candidal and other fungal infections are common. The simultaneous occurrence of abscess formation in both the liver and the spleen is not uncommon. The fungal abscess is often multiple in number and of variable size (often small size) and is hypoechoic on ultrasound examination. Centrally increased echogenicity may be seen in some patients as a “bull’s-eye” or “target” lesions [79].

On CDUS and PDUS, no or sometimes faint vascular signals can be identified at the margin of a liver abscess. After contrast agent administration, the peripheral portion of the abscess becomes heterogeneous with mosaic enhancement. Honeycomb structure and septa formation are also observed on CEUS.

**Pseudo-tumors**

Hepatic pseudo-tumors are normal liver tissue presenting as hypoechoic tumors without halo on ultrasound and are frequently (75%) observed in a fatty infiltrated liver. Ultrasonographic characteristics are a missing mass effect, a landscape-like configuration with angulated margins and slender extensions of hypoechoic tissue, and typical locations of below the capsule, near the gallbladder and ventral to the portal veins [80]. In contrast to the fat-sparing pseudo-tumors, increased focal fatty infiltration of the liver is represented as a homogeneous hyperechogenic tumor. The echotexture of these fat infiltrated areas is the same as that of the surrounding liver parenchyma and normal inner vascular structure.

In pseudo-tumors, no obvious vascular signal besides the normal organ vasculature is observed on color or PDUS. Likewise, no particular enhancement pattern on CEUS is demonstrated.

**Summary**

Conventional grayscale US is a good screening tool in the detection of focal hepatic tumors. However, differential diagnosis of tumors is difficult with conventional US alone because of the variable and nonspecific presentation of these tumors. CDUS and PDUS demonstrate the vasculature in and around the tumor. The prominence of vascularity, characterization and patterns of tumor vasculature provide clues for differential diagnosis, and contrast agent enhancement improves the sensitivity of vasculature detection and characterization. 3D US with harmonic imaging and pulse inversion imaging provide additional information and better image quality to improve differential diagnosis. Using various features of focal hepatic lesions, US can be very successful in the diagnosis and differential diagnosis of focal hepatic lesions. US had similar diagnostic efficacy to that of CT and MRI. A combination of these imaging modalities may allow for easy and noninvasive diagnosis of hepatic tumors.

**References**


Differential Diagnosis of Hepatic Tumors


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