European Journal of Radiology 85 (2016) 2090–2095

Contents lists available at ScienceDirect

European Journal of Radiology

journal homepage: www.elsevier.com/locate/ejrad

Superb microvascular imaging technology for ultrasound examinations: Initial experiences for hepatic tumors

Dong Ho Lee (M.D.), Jae Young Lee (M.D.)*, Joon Koo Han (M.D.)

Department of Radiology, Seoul National University Hospital, Republic of Korea

A R T I C L E I N F O

Article history:
Received 12 July 2016
Received in revised form
18 September 2016
Accepted 24 September 2016

Keywords:
Superb microvascular imaging
Hemangioma
Focal nodular hyperplasia
Hepatocellular carcinoma

A B S T R A C T

Purpose: To explore whether superb microvascular imaging (SMI) technology could be helpful for the evaluation of hepatic tumors.
Materials and methods: Our institutional review board approved this study, and informed consent was obtained from all of the patients. Twenty-three patients with 29 hepatic tumors were enrolled in our study. The tumors consisted of hemangiomas (n = 15), focal nodular hyperplasias (FNHs) (n = 7), and hepatocellular carcinomas (n = 7). All lesions were pathologically (n = 2) or radiologically (n = 27) confirmed. The mean tumor diameter was 1.9 cm (range, 0.9 cm to 5.0 cm). Using SMI technology, all lesions were scanned and categorized into subgroups according to the flow pattern on the SMI.
Results: The hemangiomas exhibited nodular rim patterns (33%) and spotty dot-like patterns (20%), and both of these findings were very specific for the diagnosis of hemangioma. The FNHs exhibited spoke-wheel patterns (43%) and radiating vessel patterns (29%) that were very specific findings for the diagnosis of FNH. The other tumors did not exhibit any specific patterns on SMI.
Conclusion: Evaluations of the inner vascularities of hepatic tumors with the SMI technique were feasible, and the SMI features were significantly different between the different types of hepatic tumors. These differences could aid the diagnoses of hepatic tumors with US.

1. Introduction

Although contrast-enhanced liver CT and/or liver MRI with liver-specific contrast agents can offer high diagnostic performance in the detection and characterization of focal liver lesions, ultrasound (US) has been chosen as a first imaging modality for screening and characterizing focal liver lesions primarily because it is non-invasive and widely available, it does not require radiation, and it possesses real-time imaging capabilities [1–3]. Additionally, the surveillance of hepatocellular carcinoma (HCC) in high-risk patient groups, such as those with liver cirrhosis or chronic hepatitis B viral infection, with liver US at six-month intervals has been demonstrated to reduce the mortality rate related to HCCs [4]. Therefore, US is recommend for patients at the risk of developing HCCs in the practice guidelines proposed by both the American Association for the Study of Liver Disease (AASLD) and the European Association for the Study of the Liver (EASL) [5,6]. Therefore, the detection and characterization of focal liver lesions on US are crucially important in clinical practice. However, the exact characterization of focal liver lesions using US images is often difficult due to the variable echogenicities and appearances of focal liver lesion [7–9].

Information regarding vascularity with an enhancement pattern provides an important clue for the exact characterization of a focal liver lesion. For example, central vessels radiating from the center to the periphery and spoke-wheel patterns of enhancement are key features that distinguish focal nodular hyperplasias (FNHs) from other focal hepatic lesions [10,11]. Color Doppler imaging can provide real-time information regarding the vascularity within a focal liver lesion, and a power Doppler examination can provide improved detectability of blood flow compared with color Doppler imaging [12–16]. However, there is a limitation to the detection of slow flows using Doppler-mode US examinations that has hindered the wider application of Doppler examinations for the evaluation of tumor hemodynamics [17–19]. In addition to Doppler examinations, contrast-enhanced ultrasound (CEUS) can also provide information regarding the detailed vascularities and enhancement patterns of focal liver lesions that can aid the differentiation between the various hepatic tumors [11]. However, additional evaluation time is required to perform CEUS, and the cost of the CEUS is greater than that of conventional US due to the use of an ultrasound contrast agent.

* Corresponding author at: Department of Radiology, Seoul National University Hospital, 101, Daehak-ro, Jongno-gu, Seoul 110-744, Republic of Korea.
E-mail addresses: leejy4u@snu.ac.kr, leejy4u@gmail.com (J.Y. Lee).

http://dx.doi.org/10.1016/j.ejrad.2016.09.026
0720-048X/

Superb microvascular imaging (SMI) technology has recently been developed as an innovative Doppler US technique. With the use of SMI technology, the imaging of very slow flow states is possible due to a unique algorithm that allows for the visualization of minute vessels with slow velocities without the use of a contrast agent [20]. Several recent studies have reported that the SMI technique provides microvascular flow information in breast lesions [20] and thyroid lesions [21]. Considering these previous study results, we surmised that SMI technology could also provide information regarding the microvascular structures of focal liver lesion and therefore aid the characterization of such lesions. Therefore, the purpose of this study was to explore whether SMI technology could be helpful in the evaluation of hepatic tumors.

2. Materials and methods

2.1. Patients and focal hepatic lesion confirmation

The institutional review board (IRB) of our hospital approved this study, and informed consent was obtained from each patient. From March 2014 to November 2014, a total of 23 patients (M:F = 11:12; mean age, 52.0 ± 10.5 years; range, 34–66) with 29 hepatic tumors were included in this study. The tumors included the following: 15 hemangiomas in 11 patients (single hemangiomas in eight patients, two hemangiomas in two patients, and three hemangiomas in one patient) that were diagnosed based on typical contrast-enhanced CT and/or MRI imaging findings, i.e., peripheral gradual nodular enhancements with centripetal patterns that did not change over at least a 2-year follow-up period; seven FNHs in seven patients who were diagnosed using either pathology (one FNH in one patient using biopsy) or typical imaging findings on contrast CT and/or MRI, i.e., strong arterial enhancement with persistent enhancement on portal venous/delayed phase images combined with a central scar that did change with at least a 2-year follow-up period (six FNHs in six patients, and among the six patients with FHNs diagnosed with typical imaging finding, four patients underwent gadoxetic acid-enhanced MRI, two FNHs exhibited *iso*-signal intensity on hepatobiliary phase imaging, and the remaining two FNHs exhibited hyper-intensity on hepatobiliary phase imaging); and seven hepatocellular carcinomas (HCCs) in five patients (single HCCs in three patients and two HCCs in two patients) that were diagnosed using either pathology (one HCC in one patient) or the noninvasive criteria defined according to the recommendations of the European Association for the Study of the Liver (EASL), which consist of arterial enhancement followed by washout on portal venous or delayed phase images (six HCCs in four patients). Generally, the patients with hemangiomas or FNHs were invited for US examinations. For this purpose, we carefully reviewed the patients' medical records and imaging study results to select the patients who met the imaging diagnostic criteria for benign hepatic tumors with sufficient follow-up periods. Regarding the HCCs, the patients were planned for surgery (n = 1) or radiofrequency ablation (n = 4), and pre-procedural planning US including SMI-mode examination were obtained.

2.2. US examination and evaluation

All US examinations were performed with a curved transducer (PVT-375BT, Aplio500; Toshiba Medical Systems Corporation, Tochigi, Japan) by a single experienced radiologist (JYL with 20 years of experience in liver US). The radiologist initially scanned the liver with B-mode US and identified the focal liver lesion. When the focal lesion was detected, the size of the lesion was measured and recorded. Subsequently, an US examination in SMI mode was performed on the identified focal hepatic lesion. For the SMI mode examinations, the following settings were used: the color velocity scale of the SMI was adjusted to 1.0–2.0 cm/s, the color frequency was adjusted to 5–7 MHz, and the vascular information was enhanced by adjusting the temporal smoothing. During the SMI mode US examinations, the best efforts to detect any vascular structures were made, and the radiologist classified the SMI features of the hepatic tumors into the following eight patterns: circular nodular rim patterns, circular nodular rim with dot-like patterns, spotty dot-like patterns, spoke-wheel patterns, radiating patterns, non-specific vascular patterns, staining patterns, and no signal (Fig. 1) [22]. The SMI features of each hepatic tumor were recorded.

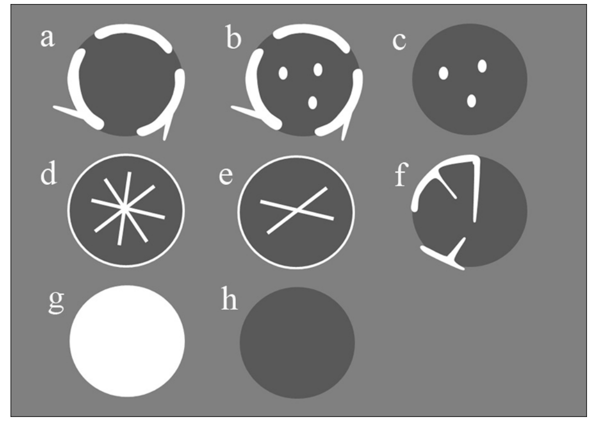

Fig. 1. SMI features of the hepatic tumors: (a) nodular rim pattern; (b) nodular rim with a dot-like pattern; (c) spotty dot-like pattern; (d) spoked-wheel pattern; (e) radiating pattern; (f) non-specific vascular pattern; (g) staining pattern; and (h) no signal.

2.3. Statistical analysis

We used Fisher's exact tests to compare the frequencies of the SMI features between the hepatic tumors. P values below 0.05 were regarded as indicative of statistically significant differences. For the statistical analyses, we used the commercially available MedCalc software program v. 12.2.1.0 (Mariakerke, Belgium).

3. Results

The evaluations of all 29 hepatic tumors in the 23 patients with SMI-mode US were possible. The SMI features of the 29 hepatic tumors are summarized in Table 1. The mean size of the 15 hepatic hemangiomas was 1.9 cm with a range of 0.9 cm to 5.0 cm. The SMI-mode US examinations detected vascularity within 10 of the 15 hemangiomas (67%, 10/15). The circular nodular rim pattern (Fig. 2) was the most common SMI feature of the hemangiomas (5/15, 33%) followed by the spotty dot-like pattern (3/15, 20%). One hemangioma exhibited a circular nodular rim with a dot-like pattern, and the remaining hemangioma exhibited a staining pattern on the SMI mode imagining.

The mean size of the seven FNHs was 2.1 cm with a range of 0.8 cm–2.8 cm. One of the seven FNHs did not exhibited any vascularity on SMI-mode US examination (14%, 1/7). The spoke-wheel pattern (Fig. 3) was the most frequent SMI feature among the FNHs (3/7, 43%) followed by the radiating pattern (2/7, 29%). The remaining FNH exhibited a non-specific vascular pattern on the SMI mode imaging.

Regarding the HCCs, the mean tumor size was 2.0 cm with a range of 1.0 cm–4.7 cm. The SMI-mode US examinations detected vascularity within four of the seven HCCs (4/7, 57%), and all four of these HCCs exhibited non-specific vascular patterns on SMI-mode