Evaluation of 2D-Shear Wave Elastography for Characterisation of Focal Liver Lesions

Ludmila Gerber1*, Daniel Fitting1*, Kajana Srikantharajah1, Nina Weiler1, Georgia Kyriakidou1, Joerg Bojunga1, Falko Schulze3, Dimitra Bon2, Stefan Zeuzem1, Mireen Friedrich-Rust1

INTRODUCTION

Detection and characterisation of focal liver lesions (FLLs) poses a frequent challenge in the daily clinical practice. Ultrasound (US) is regarded as the first-line imaging method due to its low cost, safety, and ubiquitous availability. However, etiologic classification cannot be achieved by conventional US techniques in all cases [1]. The introduction of contrast-enhanced (CE) US significantly improved overall sensitivity and specificity for the diagnosis of malignant liver lesions to 93% and 90%. This means equivalence or even superiority in comparison to other contrast-based imaging techniques such as computed tomography (CT) or magnetic resonance imaging (MRI) [2-4]. Nowadays, CEUS has become the standard method for characterisation of liver nodules found on surveillance and routine US [5]. The drawbacks are the cost of contrast agents, very rarely side effects, and remaining diagnostic uncertainty in some cases, as for instance the differentiation of cholangiocarcinoma (CCC) and hepatocellular carcinoma (HCC) [6].
In these uncertain cases, percutaneous biopsy is mandatory, which means discomfort and risk of morbidity and mortality to the patient [7, 8].

Because of the knowledge that mechanic properties of tissue are altered by fibrosis, inflammation, or tumor infiltration, elastography as a new imaging technique was developed [9, 10].

The first generation of liver shear wave elastography is transient elastography (Fibroscan®, France), which was developed to measure liver tissue stiffness [11, 12]. It represents the current standard for non-invasive methods in staging of liver fibrosis and detection/exclusion of cirrhosis, and international guidelines have been established [13]. However, no B-mode visualisation is possible with the Fibroscan® and therefore focal liver lesions cannot be assessed. The second generation liver shear wave elastography method (point shear wave elastography, pSWE) is integrated in conventional ultrasound systems allowing the performance of surveillance ultrasound in addition to pSWE. pSWE uses push pulses of focused acoustic radiation force to deform the tissue and induce shear waves [14]. It shows comparable results to TE for the assessment of liver fibrosis [15, 16]. In addition, it enables the evaluation of FLLs with elastography. A meta-analysis of pSWE using acoustic radiation force impulse (ARFI) showed high sensitivity and specificity (86% and 89%, respectively) for the differentiation of benign and malignant FLLs [17]. Complementary effects of CEUS and ARFI have been shown in the differentiation of benign and malignant liver lesions [18]. The region of interest (ROI) size is 5x10mm, hence spatial resolution is low [19].

2D-shear wave elastography (2D-SWE) using Supersonic shear imaging (Aixplorer™, France) is one of the most recent diagnostic liver elastography imaging systems developed. Focused ultrasonic beams lead to a cylindrically shaped shear wave and enable the formation of real-time shear wave images with a spatial resolution of one micrometre [20].

Feasibility has been proven for the assessment of liver fibrosis [21–23], characterization of breast masses [24, 25], and prostate and thyroid nodules [26]. In addition, recently published pilot studies have revealed promising results for the evaluation of FLLs [27–31]. However, contradictory stiffness values and cut-offs between several lesions require further elucidation.

The purpose of this study was to evaluate the diagnostic contribution of the 2D-Shear Wave Elastography (2D-SWE) (Aixplorer™) for the differentiation of benign and malignant liver lesions.

**STUDY POPULATION AND METHODS**

**Participants**

This is a prospective single center study, approved by the lead Ethical Committee of the Goethe University of Frankfurt; it was performed in accordance with the Helsinki Declaration of 1975.

The patients were recruited during US examinations for surveillance of chronic liver disease or work-up of incidentally detected FLLs at the Hepatology department of the Goethe University Hospital (Frankfurt, Germany). All patients were at least 18 years old and provided written informed consent to participate in the study.

In B-mode, colour-doppler ultrasound and 2D-Shear Wave Elastography (Aixplorer™) in B-mode the number of lesions, their location in segments using the Couinaud anatomical classification and the largest diameter of the representative FLL were assessed. They were further characterized by shape and form, skin to liver-capsule as well as liver-capsule to lesion distance. Vascularisation pattern was judged using colour-doppler ultrasound. Presence of liver steatosis was recorded.

All patients received 2D-SWE by experienced physicians blinded to the histology and partially to the contrast-enhanced imaging method, if the lesion was not detected by imaging prior to study inclusion. Patients were fasting for at least six hours at the time of the 2D-SWE examination.

2D-SWE was performed using the Aixplorer® ultrasound system (SuperSonic Imagine, Aixen-Provence, France) with a SC6–1 convex probe. In 2D-SWE, the combination of an acoustic radiation force induced in tissues by focused ultrasonic beams and a very high frequent ultrasound imaging sequence, which captures the propagation of resulting shear waves, enables the assessment of tissue elasticity in real time. A series of these push pulses creates plane shear waves which spread from the focal point in the tissue of interest. Then, the velocity of the shear wave is estimated by Doppler-like capturing of a region and is used to calculate tissue elasticity [20]. Elasticity values are displayed in a color-coded 2D quantitative SWE images (kPa) of tissue stiffness in box form over a conventional B-mode image (Fig. 1a). The size and position of the 2D-SWE image box as well as the circular region of interest (ROI) in a 2D-SWE image is operator-adjustable.

At least four 2D-SWE acquisitions were performed in the largest dimension of the FLL and saved as colour-coded elastography image. In addition, two 2D-SWE acquisitions (ROI...
ROI placement for quantitative measurement was selected as follows: 1. ROIs were placed in the regions with a stable Colour signal overtime; 2. on the same image, one ROI was placed in full size over the FLL, one ROI (10x10mm) peripherally in the FLL, and another ROI (2x2mm) in the hardest area within the FLL (Fig. 1b); 3. inappropriate measurements due to artefacts induced by major steatosis, liver capsula, or proximity of vessels were excluded; 4. measurement failure was defined as no successful 2D-SWE measurement after 10 attempts. In the case of very large lesions we placed the ROI in the most representative part of the focal lesion. Margins and central necrosis in larger lesions were spared. Elastogram quality was reviewed by a further evaluator. SWE maps with inappropriate filling of artefacts were excluded from further analyses.

The median value of at least 4 2D-SWE measurements was calculated. In addition, minimum and maximum value within the ROI as well as the standard deviation (SD) was recorded.

Blood markers

The following blood parameters were determined in all patients in the same laboratory within 4 weeks before or after 2D-SWE measurement: aspartate aminotransaminase (AST), alanine aminotransaminase (ALT), γ-glutamyl transpeptidase (GGT), alkaline phosphatase, total bilirubin, serum albumin, platelets count, and prothrombin time.

Statistical analysis

Descriptive statistics were compiled for clinical and laboratory characteristics of patients. In case of not-normally distributed quantitative variables, the results were expressed as median (min-max). Categorical variables are presented as frequencies and percentages. The Mann-Whitney test and Kruskal-Wallis test were used to assess the differences between the groups of lesions, as the situation required. The Spearman rank coefficient was used to test the correlation between study variables. The diagnostic performance of 2D-SWE among malignant and benign FLLs was assessed by receiver-operating-characteristic (ROC)-curves and the area under the ROC (AUROC) curve analysis.
All tests were two-sided with a significance value of \(\alpha=5\%\). Data analysis was performed with BiAS statistical package (BiAS for Windows, version 9.08, epsilon 2010, Frankfurt, Germany).

**RESULTS**

**Patients**

A total of 140 FLLs were evaluated in 140 patients during the recruitment period. 34 patients were excluded from the statistical analysis due to 2D-SWE measurement failure because of anatomic features: FLL location close to the capsule or to greater vessels, deep-seated >8cm, excessive tissue movement due to respiratory or cardiac motion. Other causes of failure were severe steatosis and obesity. The recruitment data is summarized in Fig. 2.

In the final analysis, 106 FLLs, successfully evaluated by 2D-SWE were included (Table I). There were patients with benign FLLs (n=42) including hemangioma (n=18), focal nodular hyperplasia (FNH) (n=18), adenoma (n=1), focal fatty sparring (FFS) (n=3), regenerative node (n=1), cholangiofibroma (n=1), and malignant FLLs (n=64) with HCC (n=16), CCC (n=7), and metastases (n=41). Table II shows the distribution of the included entities.

Of the 16 successful 2D-SWE acquisitions of HCCs, 14 occurred in cirrhotic, 1 in fibrotic, and 1 in a normal liver. The etiology of cirrhosis was alcoholic liver disease in 2, viral hepatitis in 7, primary biliary cirrhosis as well as NASH in 1, and cryptogenic in 3 patients.

**Reference method**

83/106 (78%) patients with FLL received a biopsy as the reference method (53 with malignant lesions, 30 with benign lesions). Patients without biopsy of FLL received in 7 cases CECT and CSEMRT, in 6 cases of metastases CECT and histologically proven primary elsewhere localized malignant tumour, in 5 cases CEMRT and US, in 4 cases CEUS and CECT or CEMRT and in 1 case of FNH only US and CEUS.

**B-mode ultrasound**

The mean depth and size of the benign FLLs was 38 (16-83) mm and 27 (10-87) mm, and of the malignant 45 (11-88) mm and 32 (11-118) mm; 58/106 (55%) FLLs were located in right liver lobe.

**2D-SWE**

The median (min-max) stiffness of all FLLs [28.6 (2.1-142.9) kPa] was significantly higher than that of the surrounding liver [9.9 (4.2-19.3) kPa] \((p<0.0001)\), whereas the surrounding liver in patients with HCC showed the highest stiffness with 18.1 kPa \((p<0.0001)\) in comparison to the surrounding liver of further subgroups. Fourteen out of 16 patients with HCC had liver cirrhosis. Using morphological imaging criteria 17 patients of the present cohort showed liver cirrhosis behind FLL with a median stiffness of 18.2 kPa vs. 8.9 kPa of patients without signs of liver cirrhosis. However, the FLL-stiffness of patients with liver cirrhosis showed no significant differences to FLL-stiffness of patients without ones \((p>0.20)\).

The elasticity in-between benign and malignant lesions obtained by the different ROI-placement (full size, peripheral or the stiffest area) in one FLL showed nearly the same significant differences. However, the level of cut-offs slightly differed. In detail, malignant FLLs had a significantly higher stiffness than benign FLLs measured in full size (36 (4.1-142.9) kPa vs. 16.4 (2.1-71.9) kPa; \(p<0.0001\)). ROC analysis for the differentiation between malignant and benign FLLs using stiffness values revealed an AUROC of 0.73 with an optimal cut-off of 20.7 kPa (sensitivity and specificity of 0.797 and 0.62; positive and negative predictive values of 0.67 and 0.76). The FLL stiffness measured in the periphery of the lesions showed the same difference \((p=0.00024)\) with AUROC of 0.74 and an optimal cut-off of 23.0 kPa (sensitivity and specificity of 0.67 and 0.72). Last, the measurement of the hardest area of lesions showed also a significant difference with \(p=0.0001\) and AUROC of 0.75 with an optimal cut-off of 37.6 (sensitivity and specificity of 0.61 and 0.84).

Furthermore, a heterogeneity-quotient was defined as the ratio of elasticity of the stiffest area of lesion (2mm²) to elasticity

### Table I. Patients’ characteristics

<table>
<thead>
<tr>
<th></th>
<th>All patients (n=106)</th>
<th>Patients with benign lesions (n=42)</th>
<th>Patients with malignant lesions (n=64)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age, y</strong></td>
<td>58 (24-82)*</td>
<td>48.5 (24-82)*</td>
<td>65 (46-82)*</td>
<td></td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male gender, n(%)</td>
<td>50 (47%)</td>
<td>13 (31%)</td>
<td>37 (58%)</td>
<td></td>
</tr>
<tr>
<td><strong>BMI (kg/m²)</strong></td>
<td>24.22 (13-39)*</td>
<td>24.21 (17-32)*</td>
<td>24.22 (13-39)*</td>
<td></td>
</tr>
<tr>
<td><strong>Diameter of lesion (mm)</strong></td>
<td>26.85 (1-11.8)*</td>
<td>31</td>
<td>25</td>
<td>0.055</td>
</tr>
<tr>
<td><strong>Distance liver capsule-lesion (mm)</strong></td>
<td>19.7 (0-67)*</td>
<td>25.2</td>
<td>11</td>
<td>0.20</td>
</tr>
<tr>
<td><strong>Labor</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ALT (alanine aminotransferase; (U/L)</td>
<td>36 (14-167)*</td>
<td>29 (15-138)*</td>
<td>42 (14-167)*</td>
<td>0.012</td>
</tr>
<tr>
<td>AST (aspartate aminotransferase; (U/L)</td>
<td>30 (7-339)*</td>
<td>33.5 (7-339)*</td>
<td>30 (7-173)*</td>
<td>0.93</td>
</tr>
<tr>
<td>Gamma-glutamyl transferase (U/L)</td>
<td>101 (12-1789)*</td>
<td>45.5 (12-639)*</td>
<td>146 (12-1789)*</td>
<td>0.0001</td>
</tr>
<tr>
<td>Total bilirubin (mg/dl)</td>
<td>0.6 (0.1-8.4)*</td>
<td>0.6 (0.1-1.7)*</td>
<td>0.5 (0.1-8.4)*</td>
<td>0.77</td>
</tr>
<tr>
<td>Platelets count (/nl)</td>
<td>244 (79-539)*</td>
<td>238 (80-452)*</td>
<td>254 (79-539)*</td>
<td>0.86</td>
</tr>
</tbody>
</table>

* median value (range)
of lesion in “full size”. Using this approach, the differentiation of malignant and benign FLLs was also feasible (p = 0.011). But the quotient did not allow for differentiation between the subgroups of malignant or benign FLLs.

Table II and Figure 3 summarize 2D-SWE results measured in full size for each evaluated FLL entity.

Among malignant FLLs, CCC was the stiffest entity with significantly higher stiffness as compared to HCCs (p=0.033) and metastases (p=0.0079). No significant difference in elasticity was observed between HCCs and metastases (Table II). Because of the small volume of subgroups among metastatic FLLs, we abstained from further statistical sub analysis. ROC analysis for the differentiation between CCCs vs. metastatic FLLs or HCCs using the stiffness values showed AUROCs of 0.81 and 0.79 with an optimal cut-off of 45.5 kPa and 61.3 kPa (sensitivity and specificity of 0.73 and 0.86 (CCCs vs. metastasis) and 0.81 and 0.71 (CCCs vs. HCCs (Fig. 4)). The positive and negative predictive values for HCC were 0.93 and 0.67.

No significant difference could be observed in elasticity values between the different benign FLLs, neither in FNH vs. hemangioma nor in FNH vs. non-FNH (p>0.20).

Furthermore, there was no correlation between size of FLL and median stiffness of FLL with an exception of CCC (Spearman’s coefficient rho= 0.86, p=0.014).

While analysing laboratory parameters and median stiffness GGT, APT and ALT displayed a positive correlation with rho=0.3 (p=0.002), rho=0.24 (p=0.018), and rho =0.24 (p=0.02).

Table II. Distribution of successful and failed acquisitions with the medians and SD of the lesion stiffness in kPa

<table>
<thead>
<tr>
<th>Group</th>
<th>Successful</th>
<th>Failed</th>
<th>Median (range) (kPa) (within lesion)</th>
<th>SD (range) (kPa) (within lesion)</th>
<th>Median (range) (kPa) (surrounding liver)</th>
<th>Heterogeneity-Quotient* ±SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benign lesions</td>
<td>42</td>
<td>7</td>
<td>16.4 (2.1-71.9)</td>
<td>5.73 (0.5-32.1)</td>
<td>8.15 (3.85-37.1)</td>
<td>1.66±0.6</td>
</tr>
<tr>
<td>FNH</td>
<td>18</td>
<td>0</td>
<td>16.55 (2.1-69.7)</td>
<td>7.05 (0.9-19.6)</td>
<td>7.8 (4.8-37.1)</td>
<td>1.70±0.6</td>
</tr>
<tr>
<td>Haemangioma</td>
<td>18</td>
<td>3</td>
<td>16.35 (5.4-71.9)</td>
<td>5.5 (0.5-20.5)</td>
<td>8.5 (3.9-18.4)</td>
<td>1.62±0.3</td>
</tr>
<tr>
<td>FFS</td>
<td>3</td>
<td>0</td>
<td>9.8 (3.5-30.4)</td>
<td>2.4 (1.4-10.3)</td>
<td>8.2 (5.1-9.6)</td>
<td>1.46±0.9</td>
</tr>
<tr>
<td>Adenoma</td>
<td>1</td>
<td>0</td>
<td>8.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regenerative node</td>
<td>1</td>
<td>3</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hepatopathia</td>
<td>0</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cholangiofibroma</td>
<td>1</td>
<td>0</td>
<td>29</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Malignant lesions</td>
<td>64</td>
<td>27</td>
<td>36 (4.1-142.9)</td>
<td>13.15 (2.4-73.65)</td>
<td>10.8 (3.0-45.6)</td>
<td>1.87±0.7</td>
</tr>
<tr>
<td>HCC</td>
<td>16</td>
<td>12</td>
<td>44.8 (15.8-97)</td>
<td>11.5 (3.5-34.6)</td>
<td>18.1 (3.0-34.1)</td>
<td>1.57±0.7</td>
</tr>
<tr>
<td>CCC</td>
<td>7</td>
<td>4</td>
<td>70.7 (28.3-110.5)</td>
<td>30.9 (9.9-66.7)</td>
<td>11.3 (4.2-19.3)</td>
<td>1.96±0.5</td>
</tr>
<tr>
<td>Metastasis</td>
<td>41</td>
<td>11</td>
<td>29.5 (4.1-142.9)</td>
<td>13.1 (2.4-73.7)</td>
<td>8.8 (4.9-45.6)</td>
<td>1.87±0.8</td>
</tr>
<tr>
<td>- colorectal adenocarcinomas (n=10)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- NET (carcinoid) (n=7)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- bronchial carcinomas (n=6)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- pancreatic carcinoma (n=5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- breast cancer (n=3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- malignant melanoma (n=3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- urothelium cancer (n=2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- endometrium carcinoma (n=1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- prostate cancer (n=1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- CUP (n=1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- anal cancer (n=1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- gastric carcinomas (AEG) (n=1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* heterogeneity quotient: (elasticity of the stiffest area of lesion (2mm²)) : ( elasticity of lesion in “full size”)
DISCUSSION

Elastography techniques are widely performed for imaging-based virtual organ palpation, and they remain safe, cost-efficient, and immediately available. pSWE integrated in conventional US systems provides additional information during surveillance ultrasound examinations.

The aim of the present study was to evaluate the diagnostic contribution of 2D-SWE for the differentiation of benign and malignant FLLs.

Numerous studies have addressed the diagnostic benefit of the pSWE using ARFI [19-38]. Subsequently, a meta-analysis showed significant differences in tissue-stiffness between benign and malignant FLLs [17]. However, the ROI of ARFI covers a fixed area of 5x10mm. As a result spatial resolution is low, potential inhomogeneity of FLLs is neglected and inter-examiner reliability of its placement within a lesion may be affected [19].

Only a few pilot studies have evaluated the most recent diagnostic elastography imaging system – 2D-SWE – for stiffness investigation of FLLs [27-31]. It provides quantitative elasticity maps in real time with a spatial resolution of one micrometre [20]. The circular ROI is operator-adjustable. However, most studies did not give precise information on the choice or ROI placement.

Significant differences in tissue stiffness between malignant and benign FLLs could be observed in the present study: benign FLLs appeared softer than the malignant ones. These results are consistent with a recently published study by Guibal et al. [27] investigating a comparable patient population using 2D-SWE as well as with a meta-analysis of measurement of FLL stiffness using ARFI [17].

We further analysed the optimal placement of the ROI to differentiate FLLs, which is a strength of the present study and has not been evaluated previously. As liquids preclude the propagation of transversal shear waves nectric proportions of the lesions were spared. The different ROIs in full FLL size, peripheral, or in the area of highest stiffness showed comparable differences of stiffness between benign and malignant FLLs with increasing cut-offs (20.7, 23 and 34.5 kPa). Remarkable increasing specificity (0.62, 0.72 and 0.87) and consecutively decreasing sensitivity (0.79, 0.67 and 0.56) could be shown respectively.

Regrettably, due to the heterogeneity of stiffness within benign and malignant lesion types, the simple diagnostic differentiation is not applicable. In 2014 Zhang et al. [18] showed that the combined examination by CEUS and ARFI in 170 solid liver lesions had a greater accuracy than CEUS alone (p<0.05). Therefore, the use of 2D-SWE might provide useful information complementing contrast-enhanced images, especially for the differentiation of HCCs and CCCs.

As pathognomonically expected [39] and already identified in other studies, the stiffest of all lesion types was CCC [70.7 (28.3-110.5)]. There was also a significant difference in stiffness compared to other malignant FLLs, especially HCC in agreement with results of previous studies [19, 27]. The stiffness value is nearly the same as published by Guibal et al. [27]. Ronot et al. [28] measured lower stiffness (34 kPa), but the size of lesions was smaller as well (19mm vs. 35mm).

Differentiation between HCC and CCC using MRI, CT, and CEUS can occasionally be difficult [40]. Therefore, CEUS has been dropped from the diagnostic techniques for HCC in the AASLD-Guideline 2011 [41]. By using the calculated cut-off 61.3 kPa for the differentiation of HCC and CCC only 3 of 16 HCC showed a higher stiffness. Hence, knowledge of lesion stiffness appears indeed to be helpful.

With 45 kPa, HCC was the stiffest lesion next to CCC. In contrast to the results of Guibal et al. [27] there was a significant difference with lower stiffness of the surrounding liver in contrast to HCC (p=0.002). In terms of similarities, most HCCs (14/17) occurred in cirrhotic livers, but the stiffness of cirrhotic livers was lower in our patients (18 vs. 26 kPa), and the stiffness of HCC higher (45 vs. 15 kPa) [27]. There was no correlation between size and stiffness. The stiffness of metastatic liver lesions was within the range of previous observations. However, patients with metastatic liver lesions showed a wide spectrum of origin.

The stiffest benign FLL appeared to be regenerative nodes (20 kPa; n=1) and cholangiofibroma (28 kPa; n=1), followed by FNH (17 kPa) and hemangioma (16 kPa). No significant difference could be observed in-between the groups. This could be due to the low number of patients with named entities. In our observations, the median stiffness of FNHs [16.6 (2.1-69.7)] appeared to be lower than in Guibal et al. [33 kPa] or Ronot et al. [33.3 kPa] [27, 28]. The wide range and relatively smaller size of observed FNHs is notable (33mm vs. 61mm by Ronot et al.) [28]. In return, there was no correlation between stiffness and size in the whole cohort nor in FNHs alone (Spearman's rho; correlation coefficient 0.29, p=0.11 and 0.12, p=0.65). The measured stiffness of hemangioma is comparable to results from other authors [27, 28].

A limitation of the present study is the inclusion of patients with various clinical diagnoses. Also patients with metastases of different origin (39%) are presented. Therefore, our data does not represent the general prevalence of incidental liver lesions and our conclusions and cut-offs cannot be applied to the general population of incidental liver lesions.

Secondly, the number of excluded 2D-SWE acquisitions, caused by the inability to obtain an accurate stiffness measurement and high claims in image quality, is quite high with 24% (14% Guibal et al.; 9% Ronot et al.) [27, 28]. The primary causes of failure were subcapsular or deep (>8cm) location of FLLs, major steatosis and the proximity to vessels. It is well known that increasing transducer compression during measurement is correlated with increasing shear wave speed. Structural boundaries [42] and tissue motion arise artifacts and maximum frame rates limit spatial resolution in shear wave images. Application-specific algorithms, standardization of imaging protocols and calibration standards have to be established [14]. Therefore, comparison of stiffness measurement failure to other studies remains difficult.

We reviewed the elastogram quality by a further evaluator, since quality criteria and stability index were not available on the machine at the time of study performance. Recently updated software versions of Supersonic include a Stability Index which assesses elastogram stability over time. This allows improvement of valid and reliable SWE acquisitions in future studies.
CONCLUSION

2D-SWE provides further information for characterization of FLLs and may be useful at least for differentiation of CCCs and HCCs. Distinguishing between benign and malignant lesions still remains a complex challenge for imaging-based techniques, and in case of strong doubt, liver biopsy remains the reference method. Large multicentre studies are awaited before elastography can be recommended for clinical practice for differentiation of FLLs. In addition, the diagnostic accuracy of combined interpretation of elastography and further imaging-based contrast-enhanced techniques is of notable interest.

Conflicts of interest: None of the authors have financial or conflicts of interest concerning this manuscript or received financial support.

Authors’ contribution: All authors participated in the study concept and design, acquisition of data, analysis and interpretation of data, and critical revision of the manuscript for important intellectual content; in addition, the authors L.G., D.F., M.F.R., and D.B. have drafted the manuscript and the statistical analysis.

REFERENCES


J Gastrointestin Liver Dis, September 2017 Vol. 26 No 3: 283-290


