Shear Wave elastography in liver: correlation with clinical indexes and quality analysis

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Aims and objectives

Non invasive liver stiffness evaluation using US elastography has been recently introduced in clinical practice as an alternative to histology for assessing the degree of liver fibrosis in patients with risk factors for liver disease such as chronic hepatitis B or hepatitis C infection, cirrhosis, alcohol consumption and obesity. Moreover, in these patients, the degree of liver fibrosis is significantly related to the risk of hepatocellular carcinoma (HCC) occurrence (1,2).

US elastography is a simple, non invasive and inexpensive technology and already widely and routinely used in specialized centers for the diagnosis, staging and monitoring of liver fibrosis. ShearWave elastography (SWE) (SuperSonic Imagine, France) is a new method using a 2-D real time technology which provides color maps of absolute elasticity and quantitative estimation of liver shear modulus reported in kilopascals. It combines the advantages of the remote palpation of the liver by the acoustic radiation force and the real time echographic imaging of transient elastography.

To date, and according to EFSUMB recommendations, SWE can be used to assess the severity of liver fibrosis in patients with chronic viral hepatitis, especially with hepatitis C (3,4). To the best of our knowledge, only one study evaluated SWE reproducibility and showed that liver elasticity assessment using SWE was an intra and inter observer reproducible method but the performances were lower in non experienced operator (5). To our knowledge, the influence of patients physical factors on liver stiffness measurements using US elastography have been reported in few studies with various results (6,7).

The aim of our study was to evaluate the feasibility of SWE technology in liver stiffness measurements in routine practice by studying the influence of patients clinical indexes on SWE data quality.
Methods and materials

This study was approved by our institutional review board.

70 patients (47 men, 23 women, mean age: 53.9 yr; range 22-91 yr) have been prospectively included in a single center study. These patients were referred for abdominal ultrasound with normal as well as pathological conditions of liver: 49 patients with known chronic liver disease, 21 without known liver disease.

US examinations were performed by two experienced operators in liver elastography.

Clinical indexes:

Patient morphotype and body shape were determined as follow:

- Body Mass index: calculated from weight and height using the NIH calculator (National Institutes of Health). BMI categories were defined as follow: underweight ≤ 18.5; normal weight = 18.5-24.9; overweight=25-29.9; obesity= BMI of 30 or greater
- Skin-to-liver thickness: length measured from the skin to liver capsule (mm)

Pathological conditions of liver were associated with:

- Liver heterogeneity: evaluated by US operator at the time of examination using four grade scales (from 0: homogeneous to 3: strongly heterogeneous)
- Degree of elasticity: average value of 3 measurements of elasticity expressed in kilopascals in selected frames

Shearwave elastography acquisition:

SWE was performed using a conventional ultrasound probe during a standard intercostal examination of the right lobe of the liver.

For each patient the SWE acquisitions were performed as follow and repeated with an abdominal (convex) probe (1-6 Mhz) as well as with a linear probe (10 Mhz):

- an average value of 3 SWE measurements (kilopascals) was calculated after selection of 3 different frames at the time of examination and the manual determination of a Region Of interest (ROI) by the operator
- a SWE video clip (10 seconds) was additionally recorded
SWE quality parameters:

Three qualitative parameters were extracted from SWE video clips (10 seconds) using a homemade automatic algorithm:

- **Temporal Variability (TV)**: averaged frame to frame, pixel to pixel differences. This parameter reflects the stability of the elasticity measurements from frame to frame along the clip.
- **Percentage of Non Filling (PNF)**: percentage of non colored pixels into the whole SWE box. This parameter reflects the propagation of shear waves.
- **Spatial Variability (SV)**: standard deviation of the elasticity values into the whole SWE box in an automatically selected frame. This parameter reflects the spatial homogeneity of the elasticity values.

**Analysis**

Elasticity values and quality parameters were compared to clinical indexes as well as probes performances were compared and correlation coefficients \((r)\) were calculated.
Results

Clinical indexes:

- Liver structure on B-mode US imaging was described as homogeneous (grade 0 and 1) in 41 patients (58.6%) and heterogeneous (grade 2 and 3) in 25 (41.4%).
- Patients Body Mass Index were: 31 normal weight (44.3%), 26 overweight (37.2%), 10 obesity (14.3%), 3 underweight (4.2%)
- Skin-to-liver thickness: mean 17.68 mm; range 9-44 mm

Performances of linear and abdominal probes in elasticity measurements (average values on selected frames):

- At the time of examination, the convex probe failed to provide elasticity measurements in 12 patients (17%) because no consistent frame could be selected by the operator for SWE measurements (insufficient colored pixels filling): 7 of 12 (58.3%) were patients with BMI > 25 (i.e. overweight or obesity)
- The linear probe failed to provide elasticity measurements in only 2 cases (0.03%).
- The degree of heterogeneity on US imaging was more correlated with the degree of liver stiffness when using the convex probe than when using the linear probe: r = 0.45 and r = 0.19 respectively (Fig 1)
- Linear and abdominal probes showed poor correlation in elasticity measurements: (r=0.22) (Fig 2)

Influence of pathological conditions of liver on SWE data quality (abdominal probe)

- Liver stiffness (ie average elasticity value of 3 selected frames) was correlated with the Spatial Variability data (SV) [r= 0.65] but not with TV [r= 0.02] and PNF [r=0.19] (Fig 3)
- Liver structure on B-mode US imaging (grade 0 to 3) was not correlated with any SWE data quality [r \leq 0.2]

Influence of patient morphotype and body shape on SWE data quality (abdominal probe)

- Skin-to-liver thickness showed moderate correlation with Spatial variability (SV) (r= 0.43), poor correlation with Percentage of Non Filling (PNF) (r=0.27) and no correlation with Temporal Variability (TV) (r= 0.03) (Fig 4)
- Body Mass Index showed moderate correlation with Spatial Variability data (r= 0.47) (Fig 5), but not with PNF and TV data: r = 0.18 and r = 0.10 respectively.
Fig 6 summarizes our results.
Fig. 1

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Fig. 4

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Fig. 5

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Fig. 6: Correlation coefficients ($r$) between clinical indexes and SWE quality data.

<table>
<thead>
<tr>
<th></th>
<th>Liver stiffness (kPa)</th>
<th>Liver heterogeneity on US (grade 0 to 3)</th>
<th>BMI</th>
<th>Skin-to-liver thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TV</td>
<td>0.02</td>
<td>-0.26</td>
<td>0.10</td>
<td>0.03</td>
</tr>
<tr>
<td>PNF</td>
<td>0.19</td>
<td>-0.01</td>
<td>0.18</td>
<td>0.27</td>
</tr>
<tr>
<td>SV</td>
<td>0.65</td>
<td>0.2</td>
<td>0.47</td>
<td>0.43</td>
</tr>
</tbody>
</table>

: Pathological conditions of liver  : Patients' morphotype and body shape

Fig. 6

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Fig. 7

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Fig. 9

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Fig. 10

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Conclusion

As already shown for BMI in the literature (7), our results showed that quality of SWE acquisitions is not significantly correlated with patient morphotype and pathological conditions of liver. No correlations were found between linear and abdominal probes results underlying the importance of using only the validated convex probe for liver stiffness assessment.
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