Acoustic radiation force impulse (ARFI): a review of an useful technique to assess liver stiffness

Poster No.: C-2166
Congress: ECR 2013
Type: Educational Exhibit
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Keywords: Tissue characterisation, Diagnostic procedure, Ultrasound, Elastography, Liver, Abdomen
DOI: 10.1594/ecr2013/C-2166

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Learning objectives

To describe the basis of ARFI, a new ultrasound technique in the evaluation of tissue stiffness.

To show the numerous advantages of this ultrasound-elastography method.

Images for this section:

Fig. 1: Normal ARFI evaluation
Background

1. WHY WAS THIS TECHNIQUE DEVELOPED?

Worldwide the prevalence of chronic liver diseases is increasing, due to viral hepatitis as well as due to alcoholic (ASH) and non alcoholic steatohepatitis (NASH). The prognosis of chronic hepatopathies is based on the severity of fibrosis but there is evidence that fibrosis is not the only determinant of liver stiffness: inflammation, cholestasis and congestion also interferes with stiffness measurements [1]. In patients with chronic liver disease (Fig. 2 on page 5) precise staging of fibrosis is not only necessary for the estimation of prognosis but it is also an important parameter when determining appropriate treatment decisions.

Since liver biopsy is considered the gold standard for hepatological evaluation, non-invasive methods are nowadays been developed to detect quantitatively the degree of tissue elasticity as:

1. Transitient elastography (TE) (Fibroscan®)
2. Sonoelastography (Hitachi RT-E), Acoustic Radiation Force Impulse (ARFI) on Siemens Acuson S2000 and Shear wave Elastography (on the Aixplorer System)

2. HOW DOES THIS TECHNIQUE WORK?

ARFI imaging involves targeting an anatomic region to be interrogated for elastic properties using a region of interest cursor while performing real time B mode imaging. ARFI images have spatial resolution comparable to that of B-mode, often with greater contrast.

The probe generates a pressure wave that propagates into the liver. Tissues are mechanically excited using short-duration (262 microseconds) acoustic pulses with a fixed transmit frequency of 2,67 MHz to generate localized tissue displacements. The displacements result in shear wave propagation away from the region of excitation in a defined anatomical location. Virtual touch tissue quantification measures shear wave speed to provide a fast and accurate numerical measurement related to tissue stiffness. The data obtained is displayed on the screen: Vc (velocity of the shear wave in m/sec) through the region of interest. The more elastic the tissue, the greater degree of displacement it undergoes.
3. ARFI CORRELATION AND STIFFNESS

There is significant positive correlation between median velocity (Vc) measured by using ARFI sonoelastography, severity of liver fibrosis following the (METAVIR score Fig. 3 on page 5) and US Mode B imaging Fig. 4 on page 6 and Fig. 5 on page 7 [2].

In a practical sense, this allows a quantitative assessment in patients with chronic liver disease as the shear wave propagation velocity is proportional to the square root of tissue elasticity. Therefore, the stiffer the liver, the higher the recorded shear wave velocity.

4. COMPARISON AND RELATIONSHIP WITH TRANSIENT ELASTOGRAPHY

The main drawback of the TE is that, unlike ARFI imaging, the apparatus is not integrated into a conventional ultrasound system and only produces an M-mode image for localization. It precludes the operator from determining the presence of any adjacent biliary of vascular structures, ascites (valid ARFI values on ascites Fig. 6 on page 8) or severe steatosis (valid ARFI values on steatosis: Fig. 7 on page 9) that may interfere with the accuracy of measurement. That is the reason why 10% of the studies performed by Fibroscan are invalid. Virtual touch tissue imaging application implements ARFI for evaluation of deep tissues (from 0.5 cm to 8 cm depth), not accessible to superficial compression elastography techniques.

In preliminary studies ARFI provides similar results to Transitent Elastography (Fibroscan) [1].

Recent studies have shown that MRI elastography is superior to TE for staging of liver fibrosis, but MRI elastography is more costly and requires a longer examination time than sonography [3].

5. OTHER APPLICATIONS OF THIS TECHNIQUE.

- ARFI elastography of sinusoidal obstructive syndrome (venoocclusive disease) [4].
- In vivo guidance and assessment of liver radiofrequency ablation with acoustic radiation force elastography as well as for the monitoring of radiofrequency ablation [5].
- The relationship between tissue stiffness and pathology may also apply to the kidney. Long term graft loss is typically associated with chronic rejection and fibrosis. The onset of renal fibrosis may cause an increase in the
elasticity of the organ. Initial results suggest that elasticity imaging (ARFI) may be useful in detecting fibrosis and assessing overall graft health [6].

- Acoustic radiation force impulse (ARFI) ultrasound imaging of pancreatic cystic lesions: it is potentially able to differentiate more complex (mucinous) from simple (serous) content in cystic lesions [7].
- ARFI is increasingly being studied in different clinical applications including tumoral conditions of the breast, liver, kidney, colon and rectum and the characterizing of atherosclerotic plaques as well.

Images for this section:

Fig. 2: Patient with chronic liver disease
FO = No fibrosis
F1 = Portal fibrosis without septa
F2 = Portal fibrosis and few septa
F3 = Numerous septa without cirrhosis
F4 = Cirrhosis
<table>
<thead>
<tr>
<th>ARFI VALUES ($V_s$)</th>
<th>TRANSIENT ELASTOGRAPHY (E)</th>
<th>FIBROSIS (HISTOLOGY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,0 m/s</td>
<td>3,0 KPa</td>
<td>F=0</td>
</tr>
<tr>
<td>1,6 m/s</td>
<td>7,7 KPa</td>
<td>F=2</td>
</tr>
<tr>
<td>3 m/s</td>
<td>27 KPa</td>
<td>F=4</td>
</tr>
</tbody>
</table>

Fig. 4
<table>
<thead>
<tr>
<th>ARFI</th>
<th>B - MODE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NORMAL</td>
</tr>
<tr>
<td>1,0 m/s</td>
<td>+</td>
</tr>
<tr>
<td>1,6 m/s</td>
<td>+</td>
</tr>
<tr>
<td>3 m/s</td>
<td>-</td>
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</tbody>
</table>

**Fig. 5**
Fig. 6: Cirrhosis and ascites. Valid ARFI value.
Fig. 7: Severe steatosis. Valid ARFI value.
Imaging findings OR Procedure details

1. We perform ARFI measurements by means of a Siemens Acuson S2000 ultrasound system (Erlangen, Germany).
2. Although we use convex probe transducer to evaluate the liver, linear probes can also be used to evaluate superficial organs (breast, vascular, muscles, testicle etc...)
3. Patients are examined in the supine position with the right arm in maximum abduction.
4. The transducer is located in a intercostal space on the right hepatic lobe. The effect of excessive tissue motion, such as secondary to cardiac pulsation can disrupt shear wave velocity readings; this is the reason why it is recommended to obtain measurements on the right hepatic lobe but not on the left hepatic lobe.
5. The operators are required not to apply any external transducer skin pressure while scanning and taking care of obtaining good contact.
6. Patient is asked to stop breathing for a moment in order to minimize the breathing motion. Fig. 8 on page 11
7. The system shows a mode B imaging. The operator selects the depth at which the liver elasticity is evaluated by placing a region of interest (ROI) measuring box of 10 mm long and 0,5 cm wide in the desired place. None of the measurements have to be taken within the vicinity of any visible vascular, focal lesions, biliary structures or near ligaments areas, targeting solely the liver parenchyma. Whenever the operator presses the update key one tissue quantification measurement is acquired. Fig. 9 on page 12
8. We perform several valid measurements (from 5 to 10), and a median value is then calculated. When no valid measurement could be acquired the software would return "X.XX" on the screen so the measurement has to be repeated.

Images for this section:
Fig. 8
Conclusion

There are many advantages in using this new technique:

1. It can be used in patients in whom valid measurements of liver stiffness by transient elastography could not be obtained, for instance in patients with ascites, due to the fact that the place of ARFI measurements can be chosen under direct US guidance. There is no objection to use it in obese patients with severe steatosis or postoperative.
2. It can be used in patients with small intercostals spaces.
3. ARFI is a reproducible method of liver stiffness quantification in segments V-VI and VII-VIII but not in segments II-III.
4. It requires short training period.
5. It is such low time consuming that might be performed in a routine sonographic examination.
6. It is inexpensive, safe and reliable and non-invasive method to evaluate patients with chronic liver disease in the assessment of liver fibrosis.
7. It is an ultrasound guided method. Measurements can be performed under software integrated into a conventional ultrasound machine.
8. There is strong correlation with fibrosis stage.
9. It is a diagnostic method that detects liver stiffness in a quantitative way.
10. ARFI differs from traditional ultrasonic elasticity imaging methods as it does not require compression of the transducer so it is less operator dependent.

References


**Personal Information**

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