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● *Original Contribution*

AUTOMATIC ASSESSMENT OF SHEAR WAVE ELASTOGRAPHY QUALITY AND MEASUREMENT RELIABILITY IN THE LIVER

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Abstract—A strategy is proposed that accesses the quality of individual shear wave elastography (SWE) exams and the reliability of elasticity measurements in clinical practice. For that purpose, a confidence index based on temporal stability and SWE filling was defined to provide an automatic estimation of each scan quality: high (HG) or low (LG) grade. With this index, the intra-observer acquisition variability assessed by comparing consecutive scans of the same patient was 17% and 32% for HG and LG clips, respectively. The measurement quantification variability assessed by comparing the measurements of a radiologist with those of a trained operator and of two automatic measurements on a same clip averaged 13% and 22% for HG and LG exams, respectively. It was found that SWE measurements depend greatly on the quality of the acquired data. The proposed quality index (HG or LG) provides objective input on the accuracy and diagnostic reliability of SWE measurements. (E-mail: Claire.barakat@inserm.fr)

Key Words: **Elasticity imaging, Reliability, Reproducibility, Observer variability, Shear wave elastography, Quality criteria, Liver fibrosis.**

INTRODUCTION

Liver biopsy is currently considered the gold standard for the diagnosis, staging and monitoring of liver fibrosis (Afdhal and Nunes 2004). However, besides being an invasive procedure, liver biopsy can be inaccurate because of fibrotic liver tissue heterogeneity, leading to sampling errors and measurement variability (Bedossa et al. 1994; Muller et al. 2009). Thus, non-invasive, reproducible and reliable methods are greatly needed to overcome the limitations of liver biopsy.

Imaging techniques have been investigated for the diagnosis of liver fibrosis. Conventional imaging techniques such as magnetic resonance imaging, computed tomography and ultrasound imaging are useful for biopsy guidance, but are unable to diagnose early stages of fibrosis (Klatt et al. 2006). Because tissue stiffening seems to be a particularly relevant biomarker for the staging of liver fibrosis, new elasticity imaging techniques such as magnetic resonance elastography (Bensamoun et al. 2008; Klatt et al. 2006), ultrasound transient elastography (Fibroscan) (Castera 2009; Fraquelli et al. 2007; Sandrin et al. 2003) and acoustic radiation force impulse imaging have been developed (Fahey et al. 2008; Palmeri et al. 2008) using different methodologies. The supersonic shear wave elastography (SWE) technique (Bercoff et al. 2004; Tanter et al. 2008) was recently proposed. SWE is a 2-D real-time approach that combines the advantages of the remote palpation of acoustic radiation force impulse imaging and the ultrafast echographic imaging approach of transient elastography. SWE has been reported to be highly reproducible for breast masses (Cosgrove et al. 2012). Intra- and inter-observer reproducibility of SWE stiffness measurements in the liver has already been evaluated in several studies with healthy volunteers (Ferraioli et al. 2012b; Hudson et al. 2013), revealing the good accuracy of SWE measurements. Studies have also compared SWE with transient elastography in the assessment of liver fibrosis (Ferraioli et al. 2012a; Poynard et al. 2013).

The goal of this work was to study the conditions of reproducibility and reliability of SWE measurements in clinical practice and to propose recommendations on how to interpret SWE measurements.

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METHODS

Patient population

Patients who underwent a liver elastography exam in the radiology department at our hospital between February 2012 and December 2013 were prospectively included in the study without exclusion criteria such as etiology and body shape (body mass index, liver subcutaneous fat thickness, *etc*.). The protocol was approved by the institutional review board. Thirty-one patients (12 female, 19 male; mean age: 56 ± 14 y) were recruited for the study. Patients were addressed for liver examination for various reasons including hepatitis (12/31), liver damage after chemotherapy (5/31), liver transplant follow-up (6/31) and benign focal lesions (8/31). Informed consent was obtained from all patients.

Data acquisition

All exams were performed using the Aixplorer ultrasound system (SuperSonic Imagine, Aix-en-Provence, France) with a SuperCurved SC6-1 transducer. Patients fasted 6 h before the scheduled exam. Patients were placed in the supine position and were asked to hold their breath during the exam to minimize patient variables. The protocol consisted of recording three 10-s SWE video clips for each patient, with repositioning of the probe between acquisitions.

To evaluate the reproducibility and reliability of the SWE estimation, operator-dependent measurement stages were examined and studied separately. These steps include: (i) positioning the transducer between the patient's ribs, (ii) placing the insonation window, (iii) freezing a stable frame and (iv) selecting a region of interest (ROI) in which the average elasticity is calculated. The first two steps, placement of the transducer and insonation region on the right lobe of the liver, require the full expertise of the radiologist and are labeled "acquisition-dependent" steps. The last two steps, selecting a stable frame and a representative ROI, could possibly be carried out afterward by another operator or using an automatic algorithm, provided that the expert criteria for selecting a ROI can be explicitly expressed and reproduced. These steps are referred to as "quantification-dependent" steps. These two aspects (acquisition and quantification) are usually evaluated together. Because discrepancies can originate not only from the positioning of the probe, but also from the choice of the ROI, these steps were evaluated separately to estimate the contribution of each step to potential inaccuracies.

Elasticity measurements

Four different SWE measurements were obtained for each video clip. The first measurement (expert) was completed at the time of the exam by the radiologist considered as the expert operator. The measurement was performed by manually selecting a measurement frame (fixed frame) and a ROI using the system quantification tool (Q-box). The other three measurements were performed in post-processing in the laboratory by a second operator (M.L., technologist with 2 y of experience in reading SWE images) as well as by using automatic algorithms. This second operator was trained by the expert radiologist in frame and ROI placement: The most homogeneous and stable frame was chosen, and an elliptical ROI was positioned in the most homogeneous area, away from borders, vessels and possible artifacts such as areas of increased stiffness caused by physiologic phenomena or transducer placement or pressure. The mean elasticity in that ROI provided the trained operator (TO) measurement. Third, the most stable frame and ROI in the clip were automatically selected on the basis of temporal and spatial homogeneity criteria. For that purpose, laboratory-made software (AAE standing for Automatic Analysis of Elasticity maps) was used to automatically extract the frame that revealed the most similarities with previous and subsequent frames. The most representative ROI inside that frame was then automatically determined by extracting a region as large as possible with a standard deviation as small as possible among all the possible ROIs. The mean elasticity computed inside the selected ROI corresponded to the best frame (BF) measurement. Fourth, the video clip mean frame was computed and a measurement (MF) was performed in a representative ROI automatically selected from that mean frame using the AAE algorithm as well.

Data quality indexes

Preliminary studies in our laboratory (Labit et al. 2013) suggested that the SWE variability of an exam is higher for hard than for soft livers. This is due mostly to the fact that fibrotic livers are not homogeneous, and thus, consecutive measurements in different parts of the liver lead to different elasticity values. On the basis of these preliminary findings, we tried to find parameters descriptive of the data that would provide estimates of the reliability and accuracy of a given SWE measurement in a non-healthy liver. Ideally, these parameters must be as independent as possible of liver hardness, which is the parameter that must be estimated. We defined three parameters representative of video clip quality (two parameters directly related to the quality of the video clip and one related to the spatial homogeneity of the frame investigated), and we evaluated SWE measurement accuracy in subpopulations of exams obtained by splitting the general population according to these parameters. First, by use of the laboratory-made software, the temporal stability of the clip was evaluated