Evaluation of Phantom Elasticity Estimates with *Fibroscan*

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Introduction. Transient elastography by means of mechanical vibration has been developed to assess the elasticity of the soft tissues in real time [1]. This method for measuring the shear velocity was introduced by Sandrin et al. [1]. The vibration controlled elastography was also described by the authors [2]. Azar et. al. reported implementation of a transient elastography system on a standard ultrasound scanner and verified it on elasticity phantom [3]. Cournane et al. [4] reviewed the quality control of ultrasound elastography. The need for further development of elastography phantoms [5], which would help ensure the performance of new elastography diagnostic approaches, is being emphasized. Today vibration-controlled transient elastography is clinically validated quantitative elastography technique and Fibroscan® (Echosens, France) is a device, which is considered to be the reference tool for liver stiffness measurement [2]. Fibroscan has a high (>90 %) diagnostic sensitivity in advanced (F > 3 METAVIR) liver fibrosis, meanwhile in the early stages of the disease the sensitivity is limited. The present study had two aims. At first we aimed to evaluate the repeatability and accuracy of Fibroscan elasticity estimates by varying assessment conditions. Our second aim was to determine if the Zerdine phantom is a suitable tool for Fibroscan performance verification. The paper presents our in-house experience ensuring the performance of Fibroscan elastography using commercial elasticity phantom.

Materials and methods. We evaluated Fibroscan Model 402 with its M-probe working on 3.5MHz ultrasound frequency. The Fibroscan® device provides A-mode and M-mode images which are used to find a liver portion suitable for the examination. The force applied by hand with the probe on the skin is controlled during the whole examination and must be comprised between 4 N and 8 N in order to trigger a stiffness measurement.

General purpose multi-tissue ultrasound phantom Model 040 is filled with Zerdine (CIRS, USA). The background material has defined acoustic properties. The properties of Zerdine are close to wave propagation parameters found in human liver (in room temperature). The gentle mechanical deformations, such like Fibroscan controlled vibration, are safe to apply on its surface. The background has a pass/fail criteria of 25 kPa ± 5 kPa when CIRS test for the modulus in the elasticity phantoms is applied. CIRS compression test stand has a repeatability error of ± 5%. The measurement bias between CIRS test method and the Fibroscan method was observed and described by

Oudry J. et al. [6]. Phantom consists of two zones of background material: 1) filled with Zerdine having attenuation coefficient of β=0.5dB/cmMHz and 2) filled with Zerdine having attenuation coefficient of β=0.7dB/cmMHz. The phantom has defined inclusions: 1) 1 mm diameter nailon monofilament wires distributed at regular intervals of 10 mm; 2) anechoic cists of 4 mm and 6 mm.

The mechanical fixation bench was prepared (see Fig. 1) for stable positioning of the Fibroscan probe respectively to the phantom with an option to change the applied probe pressure force and probe axis angle to the surface of the phantom. The linear position was adjusted with 5 μm resolution by using microsrew and calliper. The force was increased by moving probe towards the phantom and indicated on Fibroscan arbitrary scale from 1 to 4.

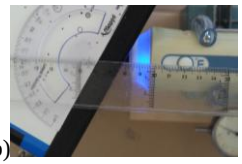
a)  b)  c) 

Fig. 1. Hardware setup (a) for evaluation of Fibroscan estimates dependence on: b) angle of probe-phantom alignment and c) probe pressure force.

The position changes were documented reading the micrometer gauge. At first we evaluated the dependence of phantom elasticity on probe pressure force of Fibroscan. The probe pressure force was controled by microscrew. Probe contact spot at the phantom surface was selected three times: 1) phantom zone where Zerdine β=0.7dB/cmMHz; 2) in phantom zone where Zerdine β=0.5dB/cmMHz; and 3) in zone where Zerdine β=0.7dB/cmMHz to evaluate repeatability. In the second stage we evaluated the dependence of phantom elasticity on Fibroscan probe action axis angle at three settings: 0 degrees (ideal direction of application or the probe axis perpendicular to phantom surface), 15 degrees and 25 degrees.

Results. The examples of Fibroscan analysis results are presented in photocopies (see Fig. 2). The elasticity estimates revealed dependence on phantom inclusions.

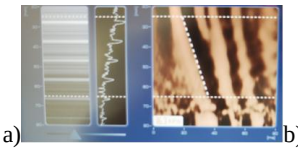
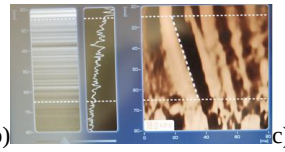
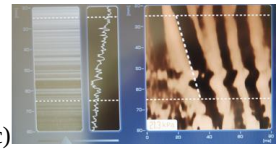
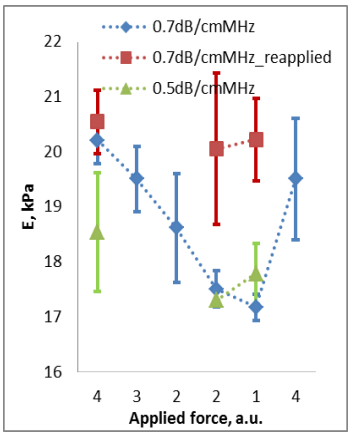
a)  b)  c) 

Fig. 2. Examples of Fibroscan diagrams, when with probe static pressue 2 a.u. the phantom area scanned is with: a) wire targets E=16.3 ± 0.9 kPa; b) anechoic 4mm cist E=18.0 ± 0.5 kPa; b) anechoic 6 mm cist E=21.3 ± 1.1 kPa (n=10).

The estimated phantom elasticity was 16.3kPa when the nailon monofilament wires were distributed on scanning line, meanwhile when Fibroscan generated

shear wave travelled through anechoic cists of 4 mm and 6 mm, the estimated elasticities were 18.0 kPa and 21.3 kPa respectively. Relations presented in Fig.3 show Fibroscan measured elasticity (E, kPa) mean and standard deviation (n=10 repetitive measurements) varying from (a) probe static pressure, (b) probe axis angle to the surface. Fibroscan probe on β=0.7dB/cmMHz zone with static pressure 2 a.u. was appied two times in different places on phantom surface. Total number of Fibroscan valid measures was 150 (3 invalid measures) or so called success rate was 98%.

a)



b)

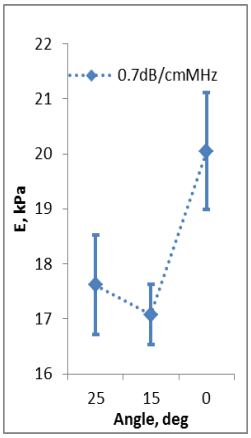


Fig. 3. Experimental evaluation results: a) elasticity vs probe static pressure on phantom surface; b) elasticity vs probe axis angle to the normal of phantom surface.

When position stable probe-phantom setup (the same place of mechanical contact with phantom surface, the same zone in phantom, pressure force into phantom, direction perpendicular to phantom surface) was used, the maximal standard error was 1.5 kPa. Applying mechanical fixation and defined levels of static pressure into phantom (levels 1, 2, 3 and 4 indicated by Fibroscan402) we found the correlation of changes in estimates: when pressure into phantom increases from 1 to 4 level, elasticity estimate also increases by up to 3 kPa (in the range from 17 kPa up to 20 kPa). Application of mechanical fixation and defined error (0-25 degrees) in direction, revealed correlation of changes in estimates: elasticity decreases by 3 kPa (in range from 20 kPa down to 17 kPa).

Discussions and conclusion. It is important to ensure fixation of Fibroscan probe for mechanical contact by hand, preserving probe axis angle and probe static pressure onto the phantom simultaneously thus showing that the Fibroscan based elasticity assessment depends on operator experience. Therefore we propose mechanical fixation of probe on surface of phantom during performance evaluation. However in case of mechanical fixation elasticity estimates are always smaller, when compared with manual fixation.

We performed few experiments with hand-held probe and obtained 25 kPa maximal estimate which is closer to the expected value. Meanwhile in the fixation stage estimates were ≤22 kPa.

The determined changes (up to 3 kPa) and spread (up to 1.5 kPa) in elasticity estimates, which were obtained by varying the force and angle, could not be called negligible. In advanced fibrosis (F≥3), the established clinical differences between the METAVIR fibrosis stages exceeds the 3 kPa and could not significantly influence the correct diagnosis, meanwhile in the early (F1: 6.1 kPa and F2: 7.1 kPa) stages method error could be meaningful [7].

The elasticity phantom could be used for the assessment of relative elasticity values (e.g. elasticity assessment in the regions with the inclusions) for long-term repetitive performance verification, meanwhile the assessment of absolute elasticity values remains inconclusive.

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Today vibration-controlled transient elastography is clinically validated quantitative elastography technique and device, Fibroscan® (Echosens, France), has emerged as the reference tool for liver stiffness measurement. There has been stressed the need for the further development of elastography phantoms to ensure the performance of new elastography diagnostic approaches. In this presentation we are aiming to obtain in-house experience ensuring the performance of Fibroscan elastography using elasticity phantom. We evaluated Fibroscan Model 402 with its M-probe working on 3.5MHz ultrasound frequency. We proposed mechanical fixation stage and evaluated elasticity phantom in dependence of probe static pressure and action angle on phantom surface. Elasticity of used CIRS Model 040 phantom was 25 kPa ± 5 kPa. Our obtained elasticity estimates are in the range 17-21 kPa with maximal standard deviation ± 1.5 kPa. The elasticity phantom could be used for the assessment of relative elasticity values (e.g. elasticity assessment in the regions with the inclusions) for long term repetitive performance verification, meanwile the assessment of absolute elasticity values remains inconclusive.