Transient elastography at very high ultrasound frequencies

Steve Beuve, L. Chinchilla, Anthony Novell, J.-L. Gennisson

BioMaps, Université Paris-Saclay, CEA, CNRS, INSERM, Orsay, France

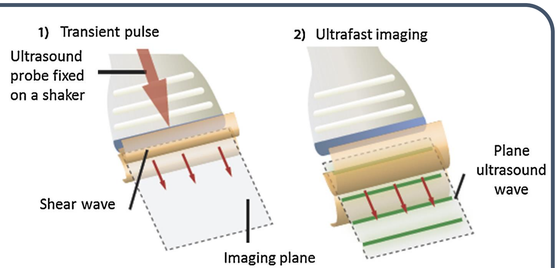
Emails: lenin.chinchilla-atencia@universite-paris-saclay.fr, jean-luc.gennisson@universite-paris-saclay.fr

Introduction

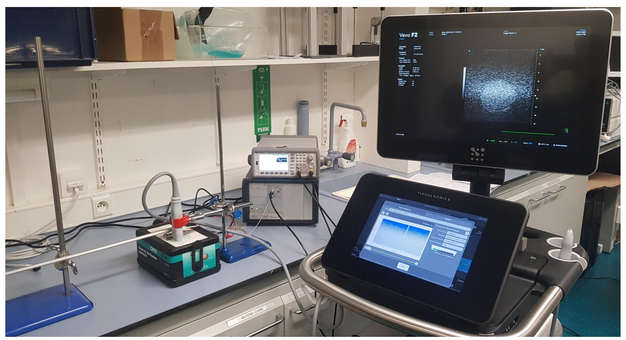
Elastography is a quantitative ultrasound (US) technique used to obtain soft tissue stiffness maps [1]. This technique is based on two key concepts: generating shear waves (SW) of which their speed is linked to stiffness and imaging the propagation of these SW with a high frame rate. This technique is routinely used in clinic by using the SW elastography (SWE) method where SW are commonly generated by acoustic radiation force at low-medium US frequency (between 3 and 15 MHz). At higher frequencies (HF) the energy deposit of the US beam is too low to create a force due to the low voltage applied on HF arrays. In this work, a mechanical vibrator, coupled to an ultrafast (UF) and US HF device (VevoF2, Fujifilm Visualsonics), is used to generate SW. It shows the capability of this device to catch propagation of SW, leading to strong improvement in the spatial resolution of stiffness maps at US frequencies higher than 15 MHz.

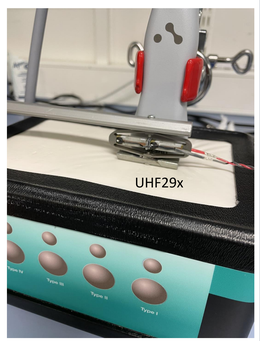
Methods

- Experiments were performed on a calibrated tissue mimicking phantom (CIRS). Shear waves were generate using an external mechanical vibrator (one-cycle sinusoidal from 300 to 600 Hz).



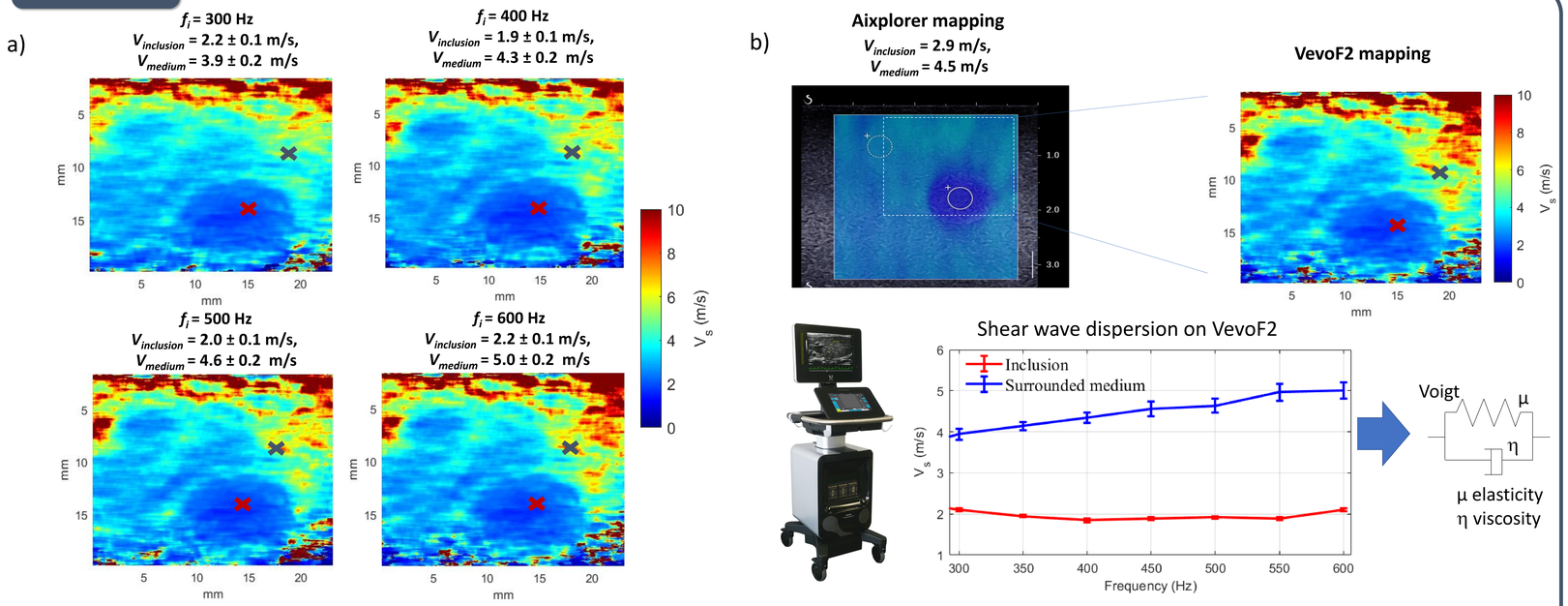
- The ultrafast ultrasound (US) device VevoF2 (Visualsonics Fujifilm) equipped with linear probes was used to perform the ultrafast US sequence in the frequency range 20 MHz to 40 MHz. The US sequence consisting of 3 angles (-5°, 0°, 5°) with a compounded framerate of 1896 Hz during 52 ms was used to track the shear waves.





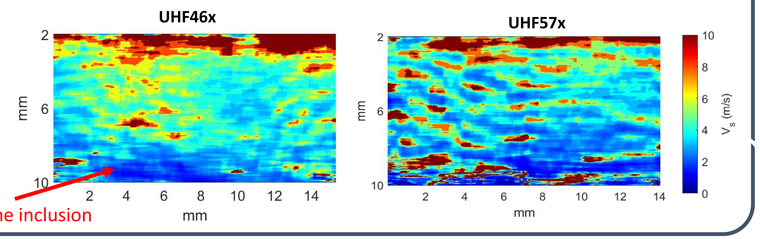
- Experiments were performed using three different ultrasound linear probes for the vevoF2 system: UHF29x, UHF46x, UHF57x. Velocity mappings were obtained by using the autocorrelation method. First, the autocorrelation between frames is computed, then, each autocorrelation frame is smoothed by using a filter consisting of a normalize square of 9 pixels. Finally, the Doppler velocity is computed from the argument of this filtered frames from which the shear wave velocity is obtained from the time of flight. Results were qualitatively compared with those obtained from the Supersonic Shear Imaging method (Aixplorer, Supersonic Imaging), using a linear probe (SL10-2, 6 MHz).

Results



Stiffness mapping obtained using an ultrasound frequency of 20 MHz. a) Examples of stiffness mapping for different vibration frequencies f_i b) Comparison between the stiffness maps obtained with the Aixplorer device and the VevoF2 device, as well as the dispersion curve obtained from the results of the VevoF2 system for the group velocity.

- Mean velocities of the dispersion curve for the medium and the inclusion are 2.1 ± 0.3 m/s and 4.4 ± 0.6 m/s respectively (ultrasound frequency of 20 MHz).
- Results of the shear wave dispersion shows that this phantom act as a Voigt model. Dispersion analysis allow to study stiffness of the medium as well as viscosity.
- Similar results were obtained at higher frequencies (30 MHz and 40 MHz) in the surrounded medium.



Discussion & Perspectives

Current challenges of the experiment

- For the higher frequencies (30 and 40 MHz) the results are strongly affected by noise, which may be mainly due to the limited driven energy of the probes for these frequencies.
- Shear waves were generated externally in the proposed strategy, which limits its application.
- Transient elastography with an external source was performed at US frequencies higher than 15 MHz.
- Special attention will be paid to finding out how to increase the SNR of the acquired signals and developed special advanced signal processing algorithms for this application.

- Although we must carefully consider the results since the methods (SWE vs vibrator) used are different, the feasibility of performing transient elastography at very high US frequencies has been demonstrated, thus providing higher spatial resolution for small biological soft tissues investigation.
- In future works, others technique to generate shear waves will be implemented and tested as: acoustic radiation force impulse or harmonic imaging by combining multiple transducers.

Acknowledgement: Authors would like to thanks Fujifilm Visualsonics engineers for interesting discussion about the VevoF2.

[1] Gennisson et al., DII, 2013