EFFECT OF GEOMETRY AND MATERIAL CHARACTERISTICS ON STIFFNESS CHARACTERIZATION WITH SHEAR WAVE ELASTOGRAPHY: A NUMERICAL STUDY

A. Caenen[1], D. Shcherbakova[1], B. Verhegghe[1], C. Papadacci[2], M. Pernot[2], P. Segers[1], A. Swillens[1]
[1]Ghent University, Ghent, Belgium
[2]Institut Langevin, Paris, France

Abstract

Shear wave elastography (SWE) has received wide recognition as a reliable, quantitative tool for the diagnosis of breast cancer and liver fibrosis. To apply this technique to more challenging settings, such as the arterial wall for cardiovascular risk assessment, a thorough and extensive analysis of the induced shear wave (SW) propagation is necessary as the artery's thin wall and intricate material properties induce complex wave propagation phenomena. We used a finite element (FE) method to study the effect of these factors on SW propagation.

Keyword(s): biomechanics – medical imaging

1. INTRODUCTION

SWE is an ultrasonic (US) technique that assesses the mechanical properties of tissue by inducing SW's in the tissue via a focused high-energy US beam (acoustic radiation force or ARF). The propagation properties of these SW's are directly linked to the mechanical properties of the medium. This relationship is straightforward for bulky media, such as the breast and liver, but is complicated by dispersion and complex 3D SW propagation paths in arteries. To allow flexible investigation of the effect of geometry and material properties on SWE performance, we developed a 3D FE-modeling strategy [1] of which the numerical settings were validated and optimized according to SWE-experiments on a agar-gelatin phantom of 4.35mm thick.

2. MATERIALS AND METHODS

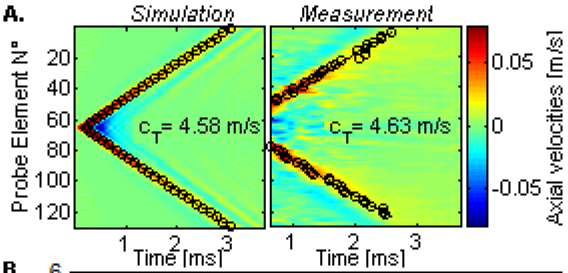
Our developed numerical framework models SW propagation in a rectangular slab with the FE-software Abaqus (Providence, USA) by imposing a realistic ARF, which is derived from the US simulation software Focus (Michigan, USA). The numerical results of our model were validated with a SWE-experiment performed on the agar-gelatin phantom with the Aixplorer system (SuperSonic Imaging, France). The phantom's material in this model was characterized based on uniaxial mechanical tensile tests (assumed density ρ=1000kg/m³). Validation was realized by comparing the obtained wave shapes, shear wave speed c and corresponding E-modulus (rough estimate via $E=3\rho c^2$). Next, this model was used to study the effect of varying thicknesses and material characteristics on SW propagation via the analysis of dispersion curves (SW phase velocity vs. frequency).

3. RESULTS AND DISCUSSION

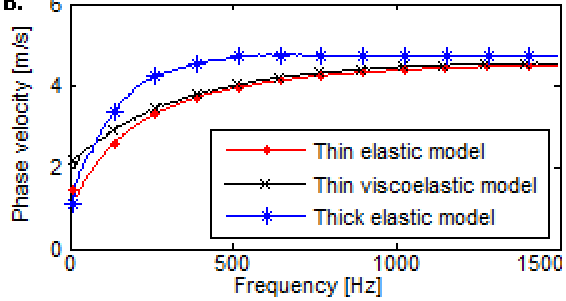
Fig. A depicts the SW speeds obtained for simulation and measurement, corresponding to E-moduli of respectively 62.9kPa (-8%) and 64.3kPa (-6%) compared to 68.1kPa for the mechanical tests. The dispersion curves are indicated in fig. B for varying thicknesses (20mm vs. 4.35mm) and material properties (elastic vs. viscoelastic), showing the isolated effect of these factors on dispersion, which can normally not be distinguished in in-vitro/in-vivo experiments.

Future research will apply the developed model to more advanced configurations, such as arteries and the heart.

A.



B.



References

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