Shear modulus and incompressibility imaging using quasi-static elastography

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I. INTRODUCTION

Breast cancer is one of the most common cancers, representing 25% of all new cancers and 13% of all cancer related deaths in Canadian women [1]. Early detection before treatment of breast cancer is paramount as survival rates decrease significantly over time. Some of the most common diagnostic and screening procedures include breast MRI, mammography, and manual examination. These methods are either too costly or have difficulty detecting or differentiating malignant tumors from benign ones without a follow-up biopsy. One technique that has shown a potential to minimize the number of biopsy cases is ultrasound elastography (USE), which images the breast stiffness which is known to be substantially different for normal and pathological tissue [2].

Currently, the images produced by USE tend to be of low quality, plagued by noise and distortions due to the nature of ultrasound, inconsistent mechanical stimulation by the operator, and other inconsistencies in acquisition or tissue structure. We have developed new real-time techniques aimed at improving the data quality by enforcing known physical properties [3]. This work aims at developing a method by which the Young's modulus, shear modulus, and Poisson's ratio are simultaneously reconstructed.

II. PROPOSED METHODS

The reconstruction algorithms follow an iterative technique that includes stress calculation based on Hooke's law where both axial and lateral strains are utilized for the Young's Modulus reconstruction. The resulting stress fields were then used to calculate the shear modulus by taking the ratio between the shear stress and experimentally measured shear strain field. The Poisson's ratio was then calculated using the relationship between the shear modulus and young's modulus. These techniques were validated on an in-silico phantom study of a cancerous lesion with a highly incompressible periphery. Then, the method was tested on clinical data of cancerous breast lesions.

III. RESULTS

Measured by their high signal-to-noise ratio and contrast-to-noise ratio, the results of both in-silico and clinical cases show that, the reconstructed images of Young's modulus, shear modulus and Poisson's ratio are of high quality. Each image shows some unique features that can be used as cancer biological signatures. For example, while the Young's modulus measures tissue stiffness the shear modulus can be used to assess bonding between adjacent types of tissue. The latter shows a difference in shear modulus at the outline of benign or malignant lesions despite similar Young's Moduli.

IV. CONCLUSION

The investigation shows promising capability of the proposed algorithms to produce high quality images of tissue Young's modulus, shear modulus and Poisson's ratio that showed complementary features that can be fused for accurate breast cancer diagnosis. Further investigation is necessary to measure the method's sensitivity and specificity.

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