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Diagnostic Ultrasound Using Acoustic Radiation Force Elasticity Imaging

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Abstract:

Considerable research has been devoted to the development of ultrasound-based elasticity imaging techniques since the mid-1990s. These methods offer a completely new subset of tissue properties properties that are not achievable with conventional ultrasound methods that are imaged during the process of describing the mechanical characteristics of soft tissues. Previous research has connected pathological conditions to tissue elasticity. Elasticity imaging methods have the potential to be highly helpful in the diagnosis and/or monitoring of disease since they are able to image these features in vivo. This review focuses on ultrasound-based elasticity imaging techniques that generate an acoustic radiation force that causes tissue displacements. Tissue elasticity can be quantitatively or qualitatively measured non-invasively using these methods during routine

Keywords: Diagnostic Ultrasound, Acoustic Radiation.

Introduction

Pathological conditions have been associated with the elasticity or stiffness of soft tissues since the dawn of medicine. In comparison, abdominal swellings that are soft, painless, and yield when pressed with the finger are more likely to be chronic, according to Hippocrates, who noted in 400 B.C. that those that are "as are painful, hard, and large, indicate danger of speedy death" (Adams, 1891). Manual palpation remains a common tool in routine physical examinations to assess tissue health and track the course of disease. For instance, stiff masses found during routine breast exams are often an early indicator of breast cancer (Donegan WL, 2002). Although very useful for medical diagnosis, manual palpation techniques are relatively subjective and limited to superficial structures.

Current challenges and opportunities .

A. Biomechanics of Soft Tissue:

A. When a force is applied to a material body in its initial configuration, or reference, the resultant deformation is described by a strain, and a restoring stress that maintains equilibrium is connected to the deformation. An idealized material body is one that is infinitely divisible, where the location of each infinitely small volume inside the continuum body determines the deformation, strain, and stress. We call this continuum mechanics. A brief review of these concepts is provided in, wherein an arbitrary physically feasible loading is shown for a small, infinitesimal volume, along with the associated strain and restoring stress.

B. Force of Acoustic Radiation

Acoustic radiation force generation is the phenomenon that happens when an ultrasonic wave transfers momentum in an attenuating medium, where the pressure and particle velocity go out of phase. It should be mentioned that because soft tissues cannot tolerate shear stresses, they are better modeled as viscous fluids at ultrasonic frequencies (Ophir J, 2011). Therefore, the Nyborg and Eckart method is used here, where a linear viscous fluid model is used to derive an equation for the acoustic radiation force. This model, unlike the elastic model, can account for the noticeable loss of energy from the propagating wave. An incompressible material can be understood using the constitutive equation for a linear viscous fluid (Parker, 2011).

C. Tracking the Response to Deformation

To extract meaningful information from ARF methods, one must be able to precisely monitor the tissue motion brought about by the applied acoustic radiation force. Traditional pulse-echo ultrasonography allows for the monitoring of tissue motion both spatially and temporally. Typically, phase shift or cross-correlation based algorithms are used to estimate the displacement of tissue between signals obtained before the excitation (reference) and after the excitation (tracking).

1) Methods of Cross-Correlation:

To estimate blood flow velocities from radiofrequency (RF) data, the cross-correlation technique was developed (Wells PN, 2011). determines how similar the tracking signals are to a windowed length of reference data in terms of similarity. Often referred to as a time-delay estimation technique, it determines the time shift that results in the maximum cross-correlation value, thereby revealing when the two signals are most similar.

1) Phase Shift Methods:

Real-time imaging of 2-D color flow was made possible by a 1-D autocorrelation phase shift estimation method developed in 1985 (Kasai et al., 1993). (Loupas et al., 1995) developed the 2-D autocorrelation method, which has the potential to enhance performance. that accounts for variations in the center frequency of the received echo across different regions for each estimate of displacement. For the small displacements that ARF methods typically encounter, the 2-D autocorrelation method performs similarly to normalized-cross correlation with less computational effort (Pinton, 2006).

2) Sources of Bias and Jitter:

An estimator's bias and jitter show how well it can estimate tissue motion. first appeared in Walker et al. (1995). Assuming a flat power spectral density, the Cramer-Rao lower bound can be used to theoretically lower limit the jitter (σ) of correlation-based tracking algorithms for partially correlated speckle signals. Here, SNR (signal-to-noise ratio) is replaced by is the transducer center frequency, T by the correlation window length, B by the fractional bandwidth, and ρc by the correlation value between the signals (Lai, 1999).

Imaging Methods.

A. Quasi-static Methods:

In quasi-static techniques, a steady state tissue response can be obtained by applying the force excitation of acoustic radiation for a significant duration at a high pulse repetition frequency (PRF). Since tissue heating can be a problem at high PRF, quasi-static techniques have generally been applied to fluids, where the forces required to produce a detectable deformation are lower than in soft tissue.

1) Acoustic Streaming in Diagnostic Ultrasound Acoustic streaming is the fluid flow in a viscous fluid caused by an acoustic radiation force. Standard Doppler techniques can be used to calculate the velocity of the induced fluid flow (Nightingale et al. 2001). employed this method to differentiate between solid and fluid-filled lesions, or cysts, in breast tissue in a clinical setting.

2) Sonorheometry first Sonorheometry is a method (Viola et al., 2001) for assessing coagulation properties by monitoring the fluid/solid response of blood to a quasi-static acoustic radiation force excitation.

Transient Methods: By applying an impulse-like (short duration) acoustic radiation force excitation, one can monitor the transient deformation response of soft tissue and obtain information on elasticity. For more information on these methods, the reader is directed to the current (Palmeri et al, 2006). A single ultrasound transducer is used in

Acoustic Radiation Force Impulse (ARFI) imaging in order to both induce and monitor a deformation response (Nightingale, 2001).

Imaging Shear Wave Elasticity: They created a method for measuring tissue stiffness in 1998 that they named Shear Wave Elasticity Imaging (SWEI). They achieved this by using a high intensity focused ultrasound (HIFU) piston to create shear waves.

C. Harmonic Methods:

Unlike sonoelasticity, which employs a vibrator that is mechanical (Palmeri et al., 2011). In harmonic ARF methods, soft tissue is driven at frequencies typically between 20 and 100 kHz using multiple acoustic radiation force excitations. By altering the force's frequency of generation, a vibratory response related to the soft tissue's mechanical properties can be generated.

Recommendations:

It is necessary to establish elasticity metrics for these specific healthy and diseased tissues before exploring new clinical uses of elasticity imaging. This will likely require extensive research and efforts to standardize imaging protocols. In addition to teaching physicians how to interpret relative elasticity images and standardizing results across multiple systems, ARF imaging systems must consider other considerations when used in the clinical setting. For instance, in order to generate an acoustic radiation force strong enough to cause a measurably large displacement in soft tissues, ARF elasticity imaging techniques might be required.

Conclusion:

Before investigating novel clinical applications of elasticity imaging, elasticity metrics for these particular healthy and diseased tissues must be established. It will probably take a lot of study and work to standardize imaging protocols for this. Using ARF imaging systems in the clinical setting requires more than just teaching doctors how to interpret relative elasticity images and standardizing results across multiple systems. For example, ARF elasticity imaging techniques may be needed to produce an acoustic radiation force strong enough to cause a measurably large displacement in soft tissues.

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