Investigating Venous Elasticity As A Biomarker In Lower Extremity Veins Using Shear-Wave Elastography And Force Controlled Ultrasound

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Veith Symposium
November 19-23, 2019

Elastography

- Elastography is a non-invasive medical imaging modality for assessing the elastic mechanical properties of soft tissue, both quantitatively and qualitatively
- Based on the principle that pathological tissues are stiffer than normal tissues
- Elastography determines the tissue’s stiffness, or resistance to applied forces, by measuring a ratio of stress to strain (force/displacement): the amount of deformation of an object given an external force
- Called the Young’s modulus expressed in units of pressure
- Strain elastography (force controlled) and shear wave elastography

Young’s Modulus ($E=\sigma/\varepsilon$)

- $\sigma$ (stress) force per unit area (kPa)
- $\varepsilon$ (strain) deformation (length2/length1)
- Measure of stiffness of a solid
- Or conversely the elasticity of a material

Force Sweep and Shear Wave

- Force controlled ultrasound can perform a smooth linear force sweep to model tissue as a simple spring and calculate the Young’s modulus (elasticity) in kPa
  - Manual compression force (stress) causes the deformation
- Shear wave elastography assesses tissue elasticity based on a linear isotropic mechanical model by measuring transmission speed of a shear wave, manual compression not required
  - Acoustic radiation force (ARF) provides the deformation force
- This technique has been applied to measure muscle and tendon tissue elastic properties, liver fibrosis, arterial elasticity, venous thrombosis age, and venous insufficiency

Nothing to Disclose
No Conflicts of Interest
Force Controlled US & SWEI

Goals:
- Obtain venous stiffness/elasticity
- Obtain venous pressure
- Learn how vascular disease affects these measurements
- Employ shear wave elastography (SWE)

Calf GSV Shear Wave Elastography

Thigh Great Saphenous Vein

Femoral Vein

US elastography of acute and chronic DVT
- Unprovoked 1st DVT fem-pop
- Acute (w/in 3 d of sx) and chronic >3 mo old
- 149 patients (63.9±13.6 yo, M:F 73:76)
- Compression US for dx, and blinded examiner performing the UE
- Elasticity index (unitless) relative strain value

SWE Stiffness

Red Stiff
Green Moderate
Blue Soft

Elasticity Index

0 Hardest
3 Intermediate
6 Softest

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EI Acute Femoral 5.09 ±0.38
Popliteal 4.96 ±0.47
(P = 0.15)
P < 0.0001

EI Chronic Femoral 2.46 ±0.66
Popliteal 2.48 ±0.59
(P = 0.81)

Experience of Using Shear Wave Elastography Imaging in Superficial Venous Insufficiency of the Lower Extremity

- 138 symptomatic CVI (C2-C6, limbs 257) and 51 normal controls (limbs 102)
- F:M 62%/58%, mean±sd age 43±13 yrs
- In CVI patients all primary disease, no arterial insufficiency/DVT/SVT
- No prior surgical/endoavascular venous interventions
- SWE of GSV and perivenous tissue and SSV

Thoughts and Perspective
- Elastography-based imaging techniques enable non-invasive assessments of tissue stiffness in response to an applied mechanical force, by detecting differences in the biomechanical properties of normal and diseased tissues
- Possible applications to distinguish residual DVT vs. recurrent DVT
- Thrombus age and affecting treatment duration or type of treatment
- Predicting complete thrombus resolution
- Predicting PTS
- Predicting CVI and progression of CVD