3D Duplex and Carotid Artery Flow Dynamics for High Risk Patients

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Disclosures
No Conflicts

Co-PI NIH: CREST 2
PI NIH/CMS/Industry: CREST 2 Registry
PI NIH: Vascular Imaging Core Lab
PI VA Merit: Cognitive Impairment in Carotid Disease (ACCOP)
PI VA Merit: Exercise for thrombus resolution in DVT (EFFORT)
PI Osiris Inc.: Stem Cells in Vascular Disease

Study Objectives

Evaluate the reliability of a commercially available 3D DUS method of measuring deep vein thrombus volume

Measure the change over time of the thrombus volume

Results

Thrombus volume can be measured with high reliability

AlMuhanna et al J Vasc Tech 2011
Zhao et al J Vasc Surg 2014
Results

- Thrombus volume reduction can be detected over time

\[
\text{slope} = -0.04 \pm 0.01 \text{ cm}^3/\text{day}, \quad p = 0.003
\]

Limitations of commercial transducer

- Cannot capture targets larger than the commercial transducer length
- Design a new freehand 3D device and test its reliability in measuring target vessels

Study Objectives

- Assess the reliability of freehand 3D DUS carotid plaque imaging to measure
  - Carotid plaque volume
  - Tissue composition

Study Design

- Cross-sectional cohort study
- 10 patients (66±7 years old) with asymptomatic carotid stenosis ≥ 50%
- Performed 3D DUS imaging using a commercial transducer
- Outlines of the arterial wall and luminal surface performed on cross-sectional images

Results

- Carotid plaque volume can be measured reliably using a commercially available transducer

Study Design

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Results

3D Ultrasound

…… To quantify altered carotid flow dynamics

Computational Fluid Dynamics

Shear stresses and complex flow patterns affect disruptive forces on a plaque
- Wall Shear Stress (WSS): Tangential stress on wall
- Oscillatory shear index (OSI): Change in WSS direction
- Vorticity: Curl of velocity field
- Vortex core lines: Center of swirling flow

Study Objectives

- Create 3D renderings of the carotid artery bifurcation and test the use of flow complexity CFD measures as biomarkers for plaque instability
- Measure for different degrees of stenosis created in the same carotid artery geometry
  - WSS
  - OSI
  - Vortex core line length

Stenosis Increased in each artery

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Data Analysis

- Imaging
- Geometric Modeling
- Meshing
- Flow Analysis
Visual Results

Flow stream lines  Wall shear stress

55%  65%  75%  85%

Conclusions

- 3D DUS imaging reliably measures carotid plaque volume and tissue characteristics
- 3D DUS imaging with CFD analysis reliably measures WSS and flow complexity (vorticity)
- It allows serial measurement over time
- These are all potential markers for high-risk plaques