Oral Session III – Clinical Aspects, Hypertension and Diabetes

Chair: M Lorenza Muiesan, B Benczur
STRAIN DISCONTINUITIES IN CAROTID Atherosclerotic Plaques – A NOVEL MARKER FOR PLAQUE VULNERABILITY?

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Disclosures

No disclosures
Atherosclerotic Plaques
Atherosclerotic Plaques

• Causes 15-20% of ischemic strokes worldwide
Atherosclerotic Plaques

- Causes 15-20% of ischemic strokes worldwide
- Risk stratification relies on degree of stenosis and symptomatology
Atherosclerotic Plaques
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From Naghavi et al. 2003
Strain and plaques
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Strain and plaques

• Strain ($\varepsilon$) indicative for local mechanical stress ($\sigma$)
• Rupture of plaque occurs if local mechanical stress ($\sigma$) > material strength
• Rupture of plaque is pure biomechanical event
Aim of the study

- Develop new method for high resolution strain measurements
- Validate in Common Carotid Artery (CCA)
- Analyse strain in plaques in Internal Carotid Arteries (ICA)
Study set up

Population
- 22 patients
  - 17 with recent ischemic stroke or TIA
  - 5 asymptomatic

- 39 CCA’s and ICA’s were analyzed

Acquisition
- PICUS (ESAOTE Europe, Maastricht, The Netherlands) with 7.5 MHz linear array and 33 MHz RF acquisition.
Strain versus distension in CCA

• Distension:

\[ D = \frac{\Delta d}{d} \]
Strain versus distension in CCA

• Distension:
  \[ D = \frac{\Delta d}{d} \]

• Strain:
  \[ \varepsilon = \frac{\Delta l}{l} \]
Strain versus distension in CCA

- Distension:
  \[ D = \frac{\Delta d}{d} \]

- Strain:
  \[ \varepsilon = \frac{\Delta l}{l} \]

\[ D = -\varepsilon \]
Results: Strain versus distension in CCA

<table>
<thead>
<tr>
<th></th>
<th>Observer 1</th>
<th>Observer 2</th>
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</thead>
<tbody>
<tr>
<td>Mean strain ± SD (%)</td>
<td>-7.39 ± 2.61</td>
<td>-6.41 ± 2.56</td>
</tr>
<tr>
<td>Distension (%)</td>
<td>6.62 ± 2.68</td>
<td>6.03 ± 2.67</td>
</tr>
<tr>
<td>Correlation coefficient</td>
<td>0.69</td>
<td>0.68</td>
</tr>
<tr>
<td>strain versus distension</td>
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Results: Strain versus distension in CCA

![Graph showing the relationship between strain and distension in CCA](chart.png)

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$r \approx 0.7$
Method of analysis

- Identify ROIs
- Strain(t) (% at single position)
- Elevated strain regions
- Motion compensated strain rate
- Integrate strain rate over time
- Strain(t)
- Average diastolic to systolic strain all beats
- Strain map
- Identification of elevated strain regions
Results: Internal Carotid Artery strain characteristics

A. Homogeneous strain distribution

B. Narrow elongated region with deviating compressive strain

C. Narrow elongated region with deviating tensile strain

D. Narrow region with tensile strain
### Results: Internal Carotid Artery strain characteristics

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<tr>
<td>Total of ICA’s analyzed</td>
<td>N=39</td>
</tr>
<tr>
<td>Average strain</td>
<td>−0.1±1.2</td>
</tr>
<tr>
<td>High strain regions</td>
<td>N=26</td>
</tr>
<tr>
<td>Absolute strain (%)</td>
<td>12.6±6.5</td>
</tr>
<tr>
<td>Geometry</td>
<td></td>
</tr>
<tr>
<td>area (mm²)</td>
<td>4.7±2.2</td>
</tr>
<tr>
<td>width (mm)</td>
<td>0.7±0.3</td>
</tr>
<tr>
<td>length (mm)</td>
<td>11±5</td>
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Results: Internal Carotid Artery strain characteristics
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• 58% of deviating strain regions demarked the plaque-adventitia boundary
Results: Internal Carotid Artery strain characteristics

- 58% of deviating strain regions demarked the plaque-adventitia boundary

- Percentage of ICAs with >1 strain inhomogeneity increases with degree of stenosis (p = 0.03)
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- Percentage of ICAs with >1 strain inhomogeneity increases with degree of stenosis (p = 0.03)

- 86% of symptomatic ICAs had >1 strain inhomogeneity as compared to 56% of the other ICA’s.
Results: Internal Carotid Artery strain characteristics

- 58% of deviating strain regions demarked the plaque-adventitia boundary.
- Percentage of ICAs with >1 strain inhomogeneity increases with degree of stenosis (p = 0.03).
- 86% of symptomatic ICAs had >1 strain inhomogeneity as compared to 56% of the other ICA’s.
- Strain in deviating strain regions was higher at the symptomatic side compared to the asymptomatic side (p = 0.02). Average strain values were comparable.
Discussion

- Loss of correlation between strain and distension with ROI more distant from lumen

- Average thickness of strain inhomogeneity’s was only marginally bigger than the resolution
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• Loss of correlation between strain and distension with ROI more distant from lumen

• Average thickness of strain inhomogeneity’s was only marginally bigger than the resolution

• Future study should investigate causal relationship
Conclusion

• Successfully developed and validated a novel method to determine intraplaque inhomogeneity’s in strain distribution with high axial resolution.
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- Intraplaque strain inhomogeneity’s in ICA’s frequently demarcated the plaque-adventitia boundary.
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• Intraplaque strain inhomogeneity’s in ICA’s frequently demarcated the plaque-adventitia boundary.

• These strain inhomogeneity’s could be a promising marker for plaque vulnerability since they appear to be linked to recently symptomatic plaques.
Thank you for your attention