Evaluation of carotid elastic properties impairment in case of Bicuspid aortic valve

Guillaume GOUDOT
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Disclosure Statement of Financial Interest

I currently have, or have had over the last two years, an affiliation or financial interests or interests of any order with a company or I receive compensation or fees or research grants with a commercial company:

Speaker's name: Guillaume, Goudot, Paris

☑ Je n'ai pas de lien d'intérêt potentiel à déclarer
Evaluation in a population of patients with bicuspid aortic valve


| I. Introduction | II. Methods | III. Results | IV. Conclusion |
I. Introduction

II. Methods

III. Results

IV. Conclusion
Measuring arterial stiffness

I. Introduction

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Hooke’s law

Stress (σ) Pa (arterial pressure)

Elastic domain

Strain (ε) no unit (diameter variation)

Young modulus, Pa

Burton et al. Physiol rev. 1954
Segmental aortic stiffness in patients with bicuspid aortic valve compared with first-degree relatives

Guillaume Goudot, Tristan Mirault, Aude Rossi, Samuel Zarka, Juliette Albuisson, Paul Achouh, Mathieu Pernot, Emmanuel Messas

<table>
<thead>
<tr>
<th></th>
<th>BAV (n = 108)</th>
<th>Controls (n=148)</th>
<th>P values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arterial diameters (mm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aortic annulus</td>
<td>23.3±4.7</td>
<td>20.7±3.0</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Sinus of Valsalva</td>
<td>37.0±6.9</td>
<td>31.8±5.3</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Sinotubular junction</td>
<td>32.0±6.9</td>
<td>31.8±5.3</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Tubular aorta</td>
<td>39.7±8.6</td>
<td>30.2±5.4</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Aortic arch</td>
<td>28.8±6.5</td>
<td>26.0±5.4</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Abdominal aorta</td>
<td>19.3±5.2</td>
<td>18.5±3.5</td>
<td>0.162</td>
</tr>
<tr>
<td>Common carotid arteries</td>
<td>6.2±0.8</td>
<td>5.9±0.6</td>
<td>0.165</td>
</tr>
<tr>
<td>Stiffness index (no unit)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Sinus of Valsalva</td>
<td>17.0±10.9</td>
<td>8.9±6.1</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Tubular aorta</td>
<td>20.4±31.3</td>
<td>12.7±14.8</td>
<td>0.040</td>
</tr>
<tr>
<td>Aortic arch</td>
<td>13.8±19.1</td>
<td>7.5±8.9</td>
<td>0.080</td>
</tr>
</tbody>
</table>
Aortic elasticity indices by magnetic resonance predict progression of ascending aorta dilation

Giovanni Donato Aquaro¹ · Alessandra Briatico Vangosa² · Patrizia Toia³ · Andrea Barison¹ · Lamia Alt-All¹ · Massimo Midiri³ · Antonio Raffaele Cotroneo² · Michele Emdin¹ · Pierluigi Festa¹

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Fig. 6 Kaplan–Meier curves comparing the probability of progression-free survival from ascending aorta dilation between patients with a maximal rate of systolic distention (MRSD) value >6 and ≤6 in the entire population (left panel) and considering patients with tricuspid aortic valve (TAV) only (right panel).
Arterial stiffness measurement methods:

Arterial strain and distensibility

Pulse wave velocity

\[ Dist = \frac{2r}{hE} \]

\[ PWV = \sqrt{\frac{Eh}{2\rho r}} \]

E: Young modulus (Pa) ; h: wall thickness (m) ; r: arterial (m) ; ρ: blood viscosity (kg.m\(^{-3}\)) ; Dist: distensibility (Pa\(^{-1}\)) ; PWV: pulse wave velocity (m.s\(^{-1}\))
Pulse wave velocity with ultrafast ultrasound imaging

3. Couade M., Pernot M., Messas E. Ultrafast imaging of the arterial pulse wave. IRBM 2011
Common carotid artery of a BAV patient

Electrocardiogram

PWV 1

PWV 2

Tissue Doppler (mm.s⁻¹)

Z-axis (mm)

X-axis (mm)
Evaluation of arterial stiffening

\[ \Delta \text{PWV}_{PP} = (\text{PWV2} - \text{PWV1}) - (\text{PAS} - \text{PAD}) \]
Carotid stiffness change over the cardiac cycle by ultrafast ultrasound imaging in healthy volunteers and vascular Ehlers–Danlos syndrome

Tristan Mirault\textsuperscript{a,b,*}, Mathieu Pernot\textsuperscript{c,d,*}, Michael Frank\textsuperscript{b,e}, Mathieu Couade\textsuperscript{c,d}, Ralph Niarra\textsuperscript{e}, Michel Azizi\textsuperscript{e}, Joseph Emmerich\textsuperscript{a,b}, Xavier Jeunemaître\textsuperscript{b}, Mathias Fink\textsuperscript{c,d}, Mickaël Tanter\textsuperscript{c,d}, and Emmanuel Messas\textsuperscript{a,b}

Journal of Hypertension 2015, 33:1890–1896

<table>
<thead>
<tr>
<th></th>
<th>Mean ± standard deviation</th>
<th>(P) value</th>
<th>(P^*) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(n = 37)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>PFV</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cfPWV (m/s)</td>
<td>7.9 ± 1.4</td>
<td>0.3508</td>
<td>0.0028</td>
</tr>
<tr>
<td>ufPWV early systole (m/s)</td>
<td>6.0 ± 1.5</td>
<td>0.0580</td>
<td>0.1069</td>
</tr>
<tr>
<td>ufPWV end systole (m/s)</td>
<td>6.7 ± 1.5</td>
<td>0.0759</td>
<td>0.0424</td>
</tr>
<tr>
<td>(\Delta PWV/PPc) (m/s per mmHg)</td>
<td>0.021 ± 0.046</td>
<td>0.0010</td>
<td>0.0035</td>
</tr>
<tr>
<td>(\Delta PWV/PPp) (m/s per mmHg)</td>
<td>0.014 ± 0.031</td>
<td>0.0018</td>
<td>0.0014</td>
</tr>
</tbody>
</table>
Objective

Evaluation of carotid stiffness in a series of BAV patients

• by ultrafast ultrasound

• in comparison to healthy relatives
Ultrafast ultrasound imaging

1. Bilateral evaluation of common carotid arteries:
2. Linear probe 15-4 MHz, 256 elements, SuperSonic Imagine©
3. 3 angles (-5; 0; 5) and were triggered by the QRS.

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Carotid diameter over the cardiac cycle

Diameter variation (%)

Arterial length (mm)

Tissue velocity

Time (ms)

PWV-1

PWV-2

Tissue acceleration

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Additional value of the wall shear stress measurement

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Wall shear stress measurement

Blood flow velocity

Map of Wall Shear Stress

Mean velocity in the carotid artery

Mean Wall shear stress in the carotid artery
## Results

<table>
<thead>
<tr>
<th></th>
<th>BAV patients N = 92</th>
<th>Controls N = 48</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (years)</strong></td>
<td>47.5 ± 16.6</td>
<td>42.6 ± 17.6</td>
<td>0.107</td>
</tr>
<tr>
<td><strong>Men</strong></td>
<td>62 (67)</td>
<td>18 (38)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Sinus of Valsalva Diameter (mm)</strong></td>
<td>35.3 ± 6.6</td>
<td>27.8 ± 5.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Tubular ascending aorta diameter (mm)</strong></td>
<td>36.6 ± 8.3</td>
<td>28.4 ± 4.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Mean carotid arterial diameter (mm)</strong></td>
<td>6.84 ± 0.82</td>
<td>6.56 ± 0.82</td>
<td>0.066</td>
</tr>
<tr>
<td><strong>DBP (mmHg)</strong></td>
<td>71.5 ± 10.7</td>
<td>69.8 ± 10.1</td>
<td>0.370</td>
</tr>
<tr>
<td><strong>SBP (mmHg)</strong></td>
<td>120.2 ± 16.3</td>
<td>117.6 ± 15.0</td>
<td>0.362</td>
</tr>
<tr>
<td><strong>PP (mmHg)</strong></td>
<td>48.6 ± 12.5</td>
<td>47.5 ± 10.8</td>
<td>0.616</td>
</tr>
<tr>
<td><strong>Heart rate (min⁻¹)</strong></td>
<td>68.0 ± 11.4</td>
<td>68.3 ± 14.0</td>
<td>0.917</td>
</tr>
</tbody>
</table>
Results: pulse wave velocity

No significant difference
Results: distensibility

Carotid distensibility of BAV patients and controls

- $R^2 = 0.164$
- $R^2 = 0.582$
- $P < 0.001$
- $P < 0.001$

$$P_{\text{ancova}} = 0.693$$

No significant difference
Results: delta-PWV

**Delta-PWV in BAV patients and controls**

- Aortic valve controls
- BAV

\[ R^2 = 0.155 \quad P < 0.001 \]

\[ R^2 = 0.461 \quad P < 0.001 \]

**DeltaPWV/PP in BAV patients and controls**

- Aortic valve controls
- BAV

\[ R^2 = 0.122 \quad P < 0.001 \]

\[ R^2 = 0.126 \quad P = 0.001 \]

\[ P_{\text{ancova}} = 0.727 \]

\[ P_{\text{ancova}} = 0.849 \]

**No significant difference**
Results of wall shear stress

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No significant difference

IV. Conclusion
This study confirms the absence of carotid involvement in BAV patients for:
- Stiffness
- Stiffness
- Wall shear stress

Ultrafast ultrasound imaging allow simultaneous measurements of the arterial stiffness parameters.

These indicators can converge, reinforcing the assessment of stiffness and stiffening.
Thank you