Simulation of Endovascular Repair of Abdominal Aortic Aneurysms (AAA)

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1 Clinical background

- Strong correlations with hypertension, family history, smoking habit, sedentarity.

- 13\textsuperscript{th} cause of death in the USA in 2005 for Caucasians between 60 and 85 \cite{2}.

\cite{1} \url{http://www.nlm.nih.gov/medlineplus}
2 Treatments

Open surgery [3]

Endovascular repair (EVAR) [4]


3 Main complications due to EVAR

Endoleak

Occlusion

Example of highly tortuous iliac artery [5]

Simulation of Endovascular Repair of Abdominal Aortic Aneurysms

4 AAA geometry reconstruction from CT scans
5 AAA material properties (hyperelastic model)

6 Stent-graft modeling and experimental validation

<table>
<thead>
<tr>
<th></th>
<th>Imposed</th>
<th>Measured</th>
<th>Simulated</th>
<th>Difference (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-SG simple bending</td>
<td>F 0.30</td>
<td>D 79</td>
<td>D 78</td>
<td>1.27</td>
</tr>
<tr>
<td>B-SG simple bending</td>
<td>F 0.65</td>
<td>D 96</td>
<td>D 101.40</td>
<td>5.62</td>
</tr>
<tr>
<td>B-SG three-point bending</td>
<td>F 1.10</td>
<td>D 27</td>
<td>D 28.60</td>
<td>5.93</td>
</tr>
<tr>
<td>B-SG axial compression</td>
<td>D 12</td>
<td>F 0.74</td>
<td>F 0.75</td>
<td>1.35</td>
</tr>
<tr>
<td>B-SG transversal compression</td>
<td>D 12</td>
<td>F 0.62</td>
<td>F 0.60</td>
<td>3.23</td>
</tr>
</tbody>
</table>

Forces (N) and displacements (D) are in Newton and mm respectively.
7 Body stent-grafts from Cook Medical (TFFB models) implemented in a plug-in
8 Leg stent-grafts from Cook Medical (ZSLE models) implemented in a plug-in
9 Guidewire & catheter mechanical characterization

<table>
<thead>
<tr>
<th></th>
<th>Ø (mm)</th>
<th>E (kPa)</th>
<th>ν</th>
<th>ρ (kg mm⁻³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body outer catheter</td>
<td>6.85</td>
<td>5.740 × 10⁵</td>
<td>0.3</td>
<td>1.673 × 10⁻⁶</td>
</tr>
<tr>
<td>Leg outer catheter</td>
<td>5.22</td>
<td>1.093 × 10⁶</td>
<td>0.3</td>
<td>1.764 × 10⁻⁶</td>
</tr>
<tr>
<td>Inner catheter</td>
<td>1.25</td>
<td>1.930 × 10⁸</td>
<td>0.3</td>
<td>8.00 × 10⁻⁶</td>
</tr>
</tbody>
</table>
10 AAA pre-deformation due to catheter insertion

Typical real iliac deformation due to catheter insertion
11 Complete stent-graft deployment simulation (with blood pressure)
12 Prototype of graphic interface to program the simulation

**Note:** In this step, the input files defining the AAA geometry are entered along with the patient's blood pressure, and consequently, the zero pressure geometry is identified as well as the centerlines corresponding to its pressurized configuration.

**Patient Parameters**
- **ID:**
- **Directory:**
- **Diasstolic Pressure (mmHg):**
- **Systolic Pressure (mmHg):**

**AAA Input Files**
- **Points Data File:**
- **Facets Data File:**

**ILT Input Files**
- **Points Data File:**
- **Facets Data File:**

**Spine Input File**
- **Data File:**

**Controls Input File**
- **Data File:**

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**Notes:** Both the distal diameter and length must be entered for each stent-graft (body and legs).

**Warning:** For legs having a distal diameter above 13 mm, only the following working lengths are available: 39, 56, 74 and 90 mm.

- **Body Parameter**
- **Proximal Diameter (mm):**
- **Distal Diameter (mm):**
- **Body Short Length (mm):**
- **Official Working Length (mm):**
- **Angle Rotation About Z (in degrees):**

- **Left Leg Parameters**
- **Right Leg Parameters**
- **Distal Diameter (mm):**
- **Official Working Length (mm):**
- **Angle Rotation About Z (in degrees):**

**Warning:** All overlaps must be entered as integer numbers.

**Stent-Graft Relative Positions**
- **Distance From Left Renal Centerline To The Upper Body Graft (DI) (mm):**
- **Left Leg Inside Body Overlap (mm):**
- **Right Leg Inside Body Overlap (mm):**

**Warning:** The precedent step must be completed and the new centerlines data file must be renamed as **Patient_ID_Pressurized_and_Protected_3FG_Centerlines.dat** (as a convention).
13 Next steps with simulation

Modeling the pelvic bone as a rigid surface, like already done with the spine.

Modeling abdominal organs with a fluid material of equivalent density and stiffness, and the skin with a membrane.
Next steps with experimental validation (before clinical validations)

- First simple phantom made of polyurethane.
- PVA phantoms are currently tested, including a degraded PVA to simulate organs.

CAD model of a patient-specific AAA.
Thank you for your attention!

Any questions!?