A comparison of reduced-order computational models for central blood pressure estimation


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1. Clinical superiority of CBP

CBP is a better cardiovascular risk indicator than brachial pressure.

2. CBP estimation: 0-D/1-D models

- We identified optimal methods for the estimation of haemodynamic parameters by testing them on a virtual (computed) cohort (n = 20).
- We accounted for two common clinical scenarios:
  - Scenario 1: A peripheral pressure waveform is available.
  - Scenario 2: Only diastolic and mean pressures are available.

  Virtual cohort: 20 healthy subjects
  - 20 subjects generated from a 1-D model of the systemic arteries.
  - Individual cardiovascular parameter variations from the clinical literature for healthy humans.

- We estimated CBP on a clinical cohort (n = 9) using two-element (2-el) and three-element (3-el) Windkessel models and our 1-D aortic model.
- We compared CBP estimates against invasive CBP measurements.

Clinical cohort: 9 post-coarctation repair patients

- PC-MRI aortic flow and aortic geometry.
- Invasive CBP available for comparison.

3.1. Parameter estimation

- Optimal parameter estimation methods

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Formula</th>
<th>Scenario</th>
<th>Error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>End-systolic time, t_s</td>
<td>Maximum or x-axis, from Q</td>
<td>1, 2</td>
<td>0.0 ± 0.1</td>
</tr>
<tr>
<td>Outflow Pressure, P_out</td>
<td>Decay time method, t = t_s</td>
<td>1</td>
<td>8.3 ± 12.8</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>2</td>
<td>100.0 ± 0.0</td>
</tr>
<tr>
<td>Arterial Resistance, R_A</td>
<td>(7 - P_s)/(7 - P_a)</td>
<td>1</td>
<td>0.4 ± 0.1</td>
</tr>
<tr>
<td></td>
<td>(DBP + 0.4PP - P_m)/(7)</td>
<td>2</td>
<td>3.8 ± 0.9</td>
</tr>
<tr>
<td>Arterial Compliance, C_T</td>
<td>Decay time method, t = t_s</td>
<td>1</td>
<td>2.5 ± 2.1</td>
</tr>
<tr>
<td></td>
<td>DBP iterative method</td>
<td>2</td>
<td>6.4 ± 1.9</td>
</tr>
<tr>
<td>Pulse Wave Velocity, c</td>
<td>Least-squares: out-ends, from Q</td>
<td>1, 2</td>
<td>8.7 ± 3.9</td>
</tr>
<tr>
<td>Aortic Impedance, Z_o</td>
<td>0.05 R_A</td>
<td>2</td>
<td>26.9 ± 20.1</td>
</tr>
</tbody>
</table>

3.2. CBP estimation: 1-D vs 0-D models

- We have identified the best methods for individual cardiovascular parameter estimation in two clinical scenarios.
- Our 1-D aortic model provides more accurate and precise systolic and pulse CBP estimates compared to 0-D models.

4. Conclusions

- Increase the number of virtual subjects through simultaneous cardiovascular parameter variations.
- Apply optimal parameter estimation methods to calculate 0-D outflow boundary conditions of the 1-D aortic model.

5. Future work

- We identified optimal methods for the estimation of haemodynamic parameters by testing them on a virtual (computed) cohort (n = 20).
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