Model Flow Determination of Stroke Volume

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Introduction

- Education: Mechanical Engineering (BS, 2015) - University of Kentucky
- Research and Career Interests: Biomedical Engineering, Bioengineering, Aerospace Engineering
- Experience with NASA JSC CVL + UKY BME to evaluate countermeasures to cardiovascular deconditioning induced by prolonged exposure to spaceflight:
  1. AlterG
  2. Ames Human Performance Centrifuge
Orthostatic Intolerance
Inability to maintain blood pressure during upright posture

Earth’s Gravity (1G)
Normal Volume

Microgravity
Volume Shifts to Chest and Head

Adaptation to Microgravity
Volume is Low and Still Shifted to Chest and Head

Return to Earth’s Gravity
Volume is Low and Now Shifts from Head to Legs Possibility of Fainting!
Orthostatic Tolerance Test
Doppler ultrasound

- Measures aortic blood flow velocity and diameter of the aorta to calculate stroke volume

Drawbacks:

- Requires a trained operator and expensive specialized equipment
- Each measurement typically incorporates a small sample of beats
- Difficulty in imaging certain subjects
BeatScope Modelflow

- Continuous blood pressure waveform acquired using a finger cuff (finger plethysmography)
- Computes aortic flow pulsations from arterial pressure waveforms by simulating a model that incorporates assumptions of human morphology

Three-element model used to compute aortic flow as proposed by Wesseling et al. Zo, characteristic impedance of proximal aorta; Cw, windkessel compliance of arterial system; Rp, total systemic peripheral resistance; Q(t), blood flow; P(t) arterial pressure waveform; Pw(t), windkessel pressure
Objectives of Internship

- To conceive, develop, and conduct a human subject research protocol to evaluate the use of Modelflow estimation of stroke volume during a stand or tilt test.

- Retrospective analysis to determine if Modelflow can be applied to previously collected data.

- Determine the possibility of analyzing future data in situations in which ultrasound measurements of stroke volume may not be possible, such as field testing.
## Protocol

<table>
<thead>
<tr>
<th>Supine</th>
<th>Stand</th>
</tr>
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<tbody>
<tr>
<td>Baseline</td>
<td>Baseline</td>
</tr>
<tr>
<td>1 2 3 4 5</td>
<td>6 7 8 9 10 11 12 13</td>
</tr>
</tbody>
</table>

- **Dinamap**
- **Ultrasound**
- **FM**: Right Arm Extended At Heart Level
- **PP**: Left Arm Extended At Heart Level

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**Image:**
- A patient lying supine with monitoring equipment attached.
- A clinician observing the monitoring equipment in a hospital setting.
Results

![Graph showing stroke volume changes over time for Supine and Stand positions using different methods: Finometer, Portapres, and Ultrasound.]
Results
Results

Change in SV From Hand Down (ml)

-30  -20  -10   0

Raise PP  Raise FM

- Finometer
- Portapres
- Ultrasound

PORTAPRES
FINOMETER
Retrospective Analysis

![Graph showing stroke volume (ml) for supine and tilt positions using Finometer and Ultrasound methods.]

- Stroke Volume (ml)
  - Supine
  - Tilt

- Change in SV (ml)
  - Finometer
  - Ultrasound
Individual Data

![Graphs showing stroke volume (SV) over time points (Supine to Tilt) for Finometer and Ultrasound methods.](image-url)
Discussion

Drawbacks and Limitations

- Modelflow may not accurately report absolute values of stroke volume
- Modelflow may not accurately report changes in stroke volume between postures
- The algorithm used by Modelflow estimates body surface area and aortic diameter
- Reliability of Modelflow computation of SV is dependent on its ability to track arterial pressure

Future Direction

- Identifying factors that contribute to differences between modelflow and ultrasound estimates
- Evaluate alternative inputs to the modelflow algorithm
- Investigate positional changes in finger cuff blood pressure acquisition
Acknowledgements

Cardiovascular Lab
Steven Laurie, PhD
Michael Stenger, PhD
Steven Platts, PhD
Stuart Lee, MS
David Martin, MS
Tim Caine
Tim Matz, BA
Sondra Perez, MS
Chris Ribeiro, MS
Tiffany Phillips, MS

Space Life Sciences Summer Institute
Lauren Merkel, PhD

NASA Internship Coordinators
Missy Mathias
Diego Rodriguez
Citations


