



Descending aorta subject-specific one-dimensional model validated against *in vivo* data



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ABSTRACT

The aorta plays a major role in the cardiovascular system and its function and structure are primarily affected by aging, eating habits, life style and other cardiovascular risk factors, inducing increased stiffness which is associated with cardiovascular and cerebral morbi-mortality. Our objective was to develop and validate a robust subject-specific one-dimensional wave propagation numerical model of the descending aorta. This model with a cross-sectional area, velocity and pressure formulation is built using geometric and hemodynamic data measured on a specific person and is validated against *in vivo* data acquired on the same subject at three distinct anatomical locations along the thoracic aorta. We studied seven healthy volunteers, who underwent carotid applanation tonometry and aortic cardiovascular magnetic resonance (CMR). Responses of our model in terms of changes in central pressure waveform with arterial alterations were consistent with previously described physiological knowledge. Quantitative validation averaged over the three descending aortic locations and the seven subjects provided low rms errors (given in percentage of the maximal clinical value) between simulated and CMR data, i.e. area: $10 \pm 6\%$, velocity: $11 \pm 3\%$, flow rate: $9 \pm 3\%$. Finally, we also found low rms ($5 \pm 2\%$) when comparing simulated pressure in the proximal aortic location against tonometric carotid pressure curves. In conclusion, this simple model performs similar to more complex models of the entire systemic arterial tree at a fraction of the cost, and could be of major usefulness in the non-invasive and local estimation of proximal biomechanical and hemodynamic indices.

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1. Introduction

Both structural and functional alterations of large arteries, especially the aorta, occur with aging as well as with aggravating pathologic, genetic and environmental factors (Lakatta and Levy, 2003), resulting in arterial stiffening which has been associated with cardiovascular and cerebral morbi-mortality (Mitchell et al., 2010). One-dimensional (1D) computational fluid dynamics models, simulating parts or the entire systemic circulation, are widely used for studying arterial pressure and flow waves (Stergiopoulos

et al., 1992; Olufsen et al., 2000; Segers and Verdonck, 2000; Sherwin et al., 2003; Steele et al., 2003; Wang and Parker, 2004; Bessens et al., 2007; Matthys et al., 2007; Alastruey et al., 2008; Bessens et al., 2008; Raymond et al., 2009, 2011, 2012). Indeed, they can provide insights into wave propagation and reflection, allowing for a better characterization of the arterial system and its interactions with target organs. Despite their approximations and sensitivity to changes in arterial caliber and distensibility, as well as to peripheral wave reflections, 1D models are computationally attractive, compared to the more accurate three-dimensional models. Valid questions are whether 1D models may be easily adapted to a specific subject, i.e. which features and parameters must be precisely tuned? and how to quantitatively validate model predictions? To date, when available, validations of 1D models including the aorta were performed against either *in vitro* (Segers and Verdonck, 2000; Matthys et al., 2007; Huberts et al., 2012) or *in vivo* (Stergiopoulos et al., 1992; Olufsen et al., 2000; Steele et al., 2003; Raymond et al., 2009, 2011) data. Among these studies,

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Table of Contents Journal Of Biomechanics

1. Understanding the eBook Journal Of Biomechanics
 - The Rise of Digital Reading Journal Of Biomechanics
 - Advantages of eBooks Over Traditional Books
2. Identifying Journal Of Biomechanics
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Journal Of Biomechanics
 - User-Friendly Interface
4. Exploring eBook Recommendations from Journal Of Biomechanics
 - Personalized Recommendations
 - Journal Of Biomechanics User Reviews and Ratings
 - Journal Of Biomechanics and Bestseller Lists

5. Accessing Journal Of Biomechanics Free and Paid eBooks
 - Journal Of Biomechanics Public Domain eBooks
 - Journal Of Biomechanics eBook Subscription Services
 - Journal Of Biomechanics Budget-Friendly Options
6. Navigating Journal Of Biomechanics eBook Formats
 - ePub, PDF, MOBI, and More
 - Journal Of Biomechanics Compatibility with Devices
 - Journal Of Biomechanics Enhanced eBook Features
7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Journal Of Biomechanics
 - Highlighting and Note-Taking Journal Of Biomechanics
 - Interactive Elements Journal Of Biomechanics
8. Staying Engaged with Journal Of Biomechanics
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Journal Of Biomechanics
9. Balancing eBooks and Physical Books Journal Of Biomechanics
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Journal Of Biomechanics
10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
11. Cultivating a Reading Routine Journal Of Biomechanics
 - Setting Reading Goals Journal Of Biomechanics
 - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Journal Of Biomechanics
 - Fact-Checking eBook Content of Journal Of Biomechanics
 - Distinguishing Credible Sources
13. Promoting Lifelong Learning

- Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
14. Embracing eBook Trends
- Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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