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Restriction Training (BFR)? - Episode #1 ~~Cardiovascular System 2, Blood circulation with MCQs~~ ~~Circulatory System and Pathway of Blood Through the Heart~~

Lukáš Likavčan – Introduction to Comparative Planetology*Blood Flow Models A Comparative*

The two-compartment model has been widely known as a tool for kinetic urea modeling in hemodialysis. On the other hand the Regional Blood Flow (RBF) model, based on the flows transporting the marker toxin, seems to be another attractive solution. Both models correctly show the rebound effect and may be tuned to the experimental data.

Flow Based Two-Compartment Models - A Comparative ...

Two-Fluid Mathematical Models for Blood Flow in Stenosed Arteries: A Comparative Study D. S. Sankar and Ahmad Izani Md. Ismail School of Mathematical Sciences, University Science Malaysia, 11800 Penang, Malaysia Correspondence should be addressed to D. S. Sankar, sankar ds@yahoo.co.in

Two-Fluid Mathematical Models for Blood Flow in Stenosed ...

Blood flow models The unsteady entry blood flow in a 90ocurved tube is numerically and experimentally investigated by comparing the Newtonian and nonâ€“Newtonian blood models. For modelling purpose, non-Newtonian nature of blood flow is considered. Both numerical and experimental results are in good agreement.

Blood Flow in Human Arterial System-A Review - ScienceDirect
dimensional global models of blood circulation. We will explain the main ideas of this approach and will present some examples of its application. Keywords and phrases: blood rheology, shear thinning, viscoelasticity, dissipative particle dynamics, global circulation Mathematics Subject Classi cation: 92C35, 76A10, 76M12, 76Z05, 70-08, 35L40 1.

Methods of Blood Flow Modelling
We compare the predictive capability of two mathematical models for red blood cells (RBCs) focusing on blood flow in capillaries and arterioles. Both RBC models as well as their corresponding blood flows are based on the dissipative particle dynamics (DPD) method, a coarse-grained molecular dynamics approach.

Predicting dynamics and rheology of blood flow: A ...
We compare the predictive capability of two mathematical models for red blood cells (RBCs) focusing on blood flow in capillaries and arterioles. Both RBC models as well as their corresponding blood flows are based on the dissipative particle dynamics (DPD) method, a coarse-grained molecular dynamics approach.

Predicting dynamics and rheology of blood flow: A ...
Modeling of Non- Newtonian Fluid for Blood Flow in Stenosed Arteries; A

Comparative Study By Mohammed Musad University of Aden, Yemen Abstract - In this paper the mathematical model have been developed for the computation of pressure gradient, viscosity, yield stress and wall shear stress and the influence of stenosis in the

Modeling of Non- Newtonian Fluid for Blood Flow in ...

We compare results from numerical simulations of pulsatile blood flow in two patient-specific intracranial arterial networksusing one-dimensional (1D) and three-dimensional (3D) models. Specifically, we focus on the pressure and flowrate distribution at different segments of the network computed by the two models.

Modeling Blood Flow Circulation in Intracranial Arterial ...

3D computer model Wall shear stress distribution (CFD) Experimental Measurement & Modelling. The difficulties of direct measurement of blood flow in-vivo US MRI ... – The blood flow pattern in anuerysm – The pressure and stress to blood vessel wall – Evaluation of New device.

Fluid Dynamics of Blood Flow – Modelling & Simulation

Our work is intended to address how different blood properties and flow conditions within medical devices affect blood cell damage by developing different engineering models and flow systems to...

Fluid Dynamics Laboratory | FDA

In the present study, we evaluated the effect of non-Newtonian blood properties on hemodynamics in the idealized 90 ∘-bifurcation model, using Newtonian and non-Newtonian fluids and different flow rate ratios between the parent artery and its branch. The proposed Local viscosity model was employed for high-precision representation of blood ...

NEWTONIAN AND NON-NEWTONIAN BLOOD FLOW AT A 90 ...

It is concluded that the flow patterns of Newtonian and non-Newtonian blood models are similar, but the non-Newtonian nature of blood caused a significant increase in wall Shear Stress (WSS) patterns. It is very difficult to observe the quantitative information of hemodynamic profiles like flow parameters, wall pressure and WSS in vivo.

Non-Newtonian and Newtonian blood flow in human aorta: A ...

An effective model of blood flow in capillary beds. Acosta S(1), Penny DJ(2), Rusin CG(3). Author information: (1)Department of Pediatrics - Cardiology, Baylor College of Medicine, Houston TX, USA; Department of Pediatric Medicine - Cardiology, Texas Children's Hospital, Houston TX, USA.

An effective model of blood flow in capillary beds.

The aim of this study is to characterize the aortic blood flow in a silicone model of a

pathological aorta with ascending aneurysm, to analyze the differences in the blood flow pattern compared to a healthy aortic model, and to single out possible blood flow characteristics measurable using phase contrast magnetic resonance imaging (MRI) that could serve as indicators for aneurysm severity.

Blood flow patterns and pressure loss in the ascending ...

Comparative Epidermal Thickness and Number of Cell Layers from the Back of Nine Species. Monteiro-Riviere et al. Interspecies and interegional analysis of the comparative histological thickness & laser Doppler blood f low measurements at five cutaneous sites in nine species. Journal of Investigative Dermatology 95:582-586, 1990.

Introduction to the Comparative Anatomical Factors ...

In this paper a family of one-dimensional nonlinear systems which model the blood pulse propagation in compliant arteries is presented and investigated. They are obtained by averaging the Navier-Stokes equation on each section of an arterial vessel and using simplified models for the vessel compliance. Different differential operators arise depending on the simplifications made on the ...

One-dimensional models for blood flow in arteries ...

Comparative Study of Viscoelastic Arterial Wall Models in Nonlinear One-Dimensional Finite Element Simulations of Blood Flow. Journal of Biomechanical

Engineering, Vol. 133, Issue. 8, Journal of Biomechanical Engineering, Vol. 133, Issue. 8,

A wave propagation model of blood flow in large vessels ...
The results of our study indicated that pulsatile assist produced superior circulation in the kidney, and the microcirculation on the cell level was superior as well in early treatment of acute left heart failure. PMID: 9212968 [Indexed for MEDLINE] Publication Types: Comparative Study; MeSH terms. Animals; Blood Pressure/physiology* Blood Urea ...

Renal circulation and cellular metabolism during left ...
The model is validated by using clinically measured values of retinal blood flow and velocity. The model simulations for six theoretical patients with high, normal, and low BP (HBP-, NBP-, LBP-) and functional or absent AR (-wAR, -woAR) are compared with clinical data.

It is well known that blood vessels exhibit viscoelastic properties. Vessel wall viscoelasticity is an important source of physical damping and dissipation in the

cardiovascular system. There is a growing need to incorporate viscoelasticity of arteries in computational models of blood flow which are utilized for applications such as disease research, treatment planning and medical device evaluation. However, thus far the use of viscoelastic wall properties in blood flow modeling has been limited. As part of the present work, arterial wall viscoelasticity was incorporated into two computational models of blood flow: (1) a nonlinear one-dimensional (1-D) model and (2) a three-dimensional (3-D) fluid-solid interaction (FSI) model of blood flow. 1-D blood flow model: In blood flow simulations different viscoelastic wall models may produce significantly different flow, pressure and wall deformation solutions. To highlight these differences a novel comparative study of two viscoelastic wall models and an elastic model is presented in this work. The wall models were incorporated in a nonlinear 1-D model of blood flow, which was solved using a space-time finite element method. The comparative study involved the following applications: (i) Wave propagation in an idealized vessel with reflection-free outflow boundary condition; (ii) Carotid artery model with non-periodic boundary conditions; (iii) Subject-specific abdominal aorta model under rest and exercise conditions. 3-D FSI blood flow model: 3-D blood flow models enable physiologic simulations in complex, subject-specific anatomies. In the present work, a viscoelastic constitutive relationship for the arterial wall was incorporated in the 3-D Coupled Momentum Method for Fluid-Solid Interaction problems (CMM-FSI). Results in an idealized carotid artery stenosis geometry show that higher frequency components of flow rate, pressure and vessel wall motion

are damped in the viscoelastic case. These results indicate that the dissipative nature of viscoelastic wall properties has an important impact in 3-D simulations of blood flow. Future work will include simulations of blood flow in patient-specific geometries such as aortic coarctation (a congenital disease) to assess the impact of wall viscoelasticity in clinically relevant scenarios. In the present work, arterial viscoelasticity has been incorporated in 1-D and 3-D computational models of blood flow. The biomechanical effects of wall viscoelasticity have been investigated through idealized and subject-specific blood flow simulations. These contributions are significant and suggest the potential importance of wall viscoelasticity in blood flow simulations for clinically relevant applications.

Atherosclerotic coronary artery disease continues to negatively impact the lives of millions worldwide. Computational fluid dynamics modeling of coronary blood flow has the potential to help improve clinical outcomes and aid in treatment planning. Significant advancements in coronary blood flow modeling in recent years have opened a wide range of applications such as assessing risk for disease progression or providing a platform for virtual surgery and treatment planning. To encourage the growth of this field and promote adoption of computational results in the clinic, it is crucial that these tools be made as automated as possible so they can be applied to large patient cohorts. In addition, the variability of computational results

with respect to uncertainties in the inputs and model must be better understood and systematically quantified. Addressing these concerns is the subject of this thesis. In the first part, a framework for automatically tuning the lumped parameter boundary conditions in simulations of coronary blood flow is developed and demonstrated. Specifying boundary conditions in complex computational models is not a trivial task, especially when the dimensionality of the input space is high and multiple constraints on the outputs need to be satisfied simultaneously. Specifically in the context of patient-specific coronary simulations, clinical data such as the blood pressure, cardiac output, and coronary flow waveforms must be simultaneously satisfied with a large set of input parameters that include lumped resistances, capacitances, and heart model parameters. A typical user can eventually gain expertise to modify the input parameters to satisfy targets, but this manual tuning is time-consuming and not easily reproduced. We thus formulate the automated tuning process as a Bayesian inverse problem in which the model parameters are treated as random variables, and optimal parameters are determined by finding the maximum of the posterior distribution of input parameters. We also perform sensitivity analysis on the input parameters to determine a subset of thirteen parameters that most influence the clinical targets. In the second part, we perform uncertainty quantification on patient-specific simulations of coronary artery bypass graft hemodynamics. Vein graft failure in patients with coronary bypass continues to be a major clinical issue with relatively little knowledge about the mechanisms for failure. Simulations have shown that

predicted quantities such as wall shear stress or wall strain can be useful in predicting vein graft failure, but adoption of such results in clinical practice is hindered due to the fact simulations can only produce deterministic results with no range of confidence. Uncertainty quantification provides a framework for quantifying the uncertainty in computational results, and we applied it to assess the variability in computed predictions of time-average wall shear stress and wall strain under uncertainty in the lumped parameter boundary conditions and vessel wall material properties. To achieve this aim efficiently, we develop a novel submodeling strategy for reducing the computational cost of the analysis. We also, for the first time, consider spatial variability in the graft wall material properties by using a random field description. We finally propagate these uncertainties forward using a newly developed multi-resolution approach. The results show that the time-averaged wall shear stress is relatively well estimated with confidence intervals about 35\% of the mean value, but the wall strain exhibited significantly more variability due to the large uncertainty in the material properties. In the third part, we perform a comparison of methods for modeling wall deformability in vascular blood flow simulations. Though sometimes neglected, wall deformability can have significant impacts on the computational results, affecting predictions of wall shear stress and precluding calculation of stresses and strains in the vessel wall. There are several methods proposed in the literature for modeling wall deformability, two of the most popular being the Arbitrary Lagrangian Eularian (ALE) and Couple Momentum Methods (CMM). Although both methods capture the essential

characteristics of wall deformability, they can produce different results and computational performance. This provides a rigorous comparison which will aid in the choice of deformable wall model. Additionally, we consider the concept of prestress. Because the geometry for a patient-specific simulation is extracted from medical image data of the \textit{in vivo} cardiovascular system, the vessel walls carry an internal stress which holds the geometry in equilibrium with hemodynamic pressures and viscous stresses. We implement prestress in both ALE and CMM contexts and confirm that it is necessary to avoid over-inflation of the anatomic domain. Although studied mostly within the context of coronary flow simulations, the methods and approaches outlined in this thesis are designed to be generally applicable across other domains in computational modeling, fluid dynamics, and biomechanics. Automated tuning is a general framework for assimilating multiple sources of target data to inform optimal input parameter values, and can broadly be applied in multiscale modeling. The methods for uncertainty quantification can be adapted to assess variability of simulations in other computational fluid mechanics and biomechanics contexts. The results from the wall deformability comparison can also be extended to apply to other contexts including other cardiovascular diseases, respiratory flow, and medical devices. In addition to providing insights into coronary flow simulations, this thesis aims to motivate the importance of tuning, uncertainty quantification, and model comparisons for other cardiovascular simulations and multiscale biological modeling more broadly.

Blood, the most significant biological fluids plays a very vital role in the human mechanism, in terms of supplying the required nutrients to different parts of the human body, removing waste products and defending the body against infection through the action of antibodies. Therefore, it is imperative that blood flow must be studied in great detail. Hemodynamic analysis of blood flow in vascular beds and prosthetic devices requires the rheological behavior of blood to be characterized through appropriate constitutive equations relating the stress to deformation and rate of deformation. Numerical simulations, although not very accurate, provide an excellent alternative around this difficulty. As part of the preliminary studies, the Newtonian model of blood was assumed, and wall shear stresses have been plotted at certain critical points. Profiles of wall shear stress were then compared with the experimental results of Ku and Giddens. A numerical investigation of blood flow in stenosed carotid artery of the human body is presented in this thesis. Using a three-dimensional computational model of the stenosis, simulations were performed to capture the Non-Newtonian behavior of blood. The flow is considered as being pulsatile, with appropriate realistic boundary conditions. A shear thinning model (Carreau's) and a visco-elastic model (Yeleswarapu's Olydroyd-B model) have been employed to predict wall shear stress for the case of a healthy carotid artery and two cases of stenosed carotid artery models (50% and 90% stenosed carotid artery). From these simulation results, it was observed that wall shear

stresses predicted by the models at certain critical points are different. Recirculation zones, flow separation and associated negative wall shear stress were observed in certain cases. The electronic version of this dissertation is accessible from http://hdl.handle.net/1969.1/151909

The systemic circulation has a large number of vessels; therefore, 3-D simulation of pulse-wave propagation in the entire cardiovascular system is difficult and computationally expensive. Zero-Dimensional (Zero-D) and One-Dimensional (1-D) models are simplified representations of the cardiovascular network; they can be coupled as supplements to regional 3-D models for closed-loop multi-scale studies or be simulated as self-sufficient representations of the blood-flow network. Unlike Zero-D models, 1-D models can provide linear space-wise information for the vessels. However, Zero-D models can prove to be more useful in particular cases; as flexibility in adjusting parameters facilitate in tailoring the model to specific needs. A prevalent reservation regarding the Zero-D models has been the inconsistency of parameter adjustment. A primary objective of this work is to build a closed loop cardiovascular model with a consistent, easily replicable methodology so that the model (1) can be adopted in multi-scale studies and (2) can provide a quick clinical tool for patient-specific studies. Fifty-five large arteries were represented individually and the rest of the cardiovascular network was lumped into several equivalent components. This way, arbitrary parameter adjustments have been restricted to the microcirculation and venous sections only.

The model was validated by comparing simulated hemodynamic properties with clinical measurements and simulations from a comparable 1-D model. The Zero-D simulations have been shown to be in excellent agreement with the 1-D predictions, despite their discrete nature in space being contrary to linearly continuous 1-D counterpart. An advantageous characteristic of the developed model is the retention of physiological definitions, especially for the arterial network. Therefore, the model can be conveniently modified for patient-specific simulations. The generality of the method and closed-loop nature of the model also allow to inquisitively study various mathematical assumptions in blood flow modeling and experimental techniques. As an example, a possible source of non-physiological wave reflections has been studied in this thesis. The developed Zero-D model was found to be quite sensitive to the diastolic function of the left ventricle (LV). Therefore, several aspects of the mathematical modeling of ventricular elastance and LV-aorta coupling have been investigated in terms of measured responses from a healthy heart. Moreover, a few conventional assumptions of Zero-D modeling have been studied and found to be quite accurate with respect to 1-D simulations. Finally, the scopes for future studies and suitability of the model to certain applications have been discussed.

This book contains original research papers presented at the International Conference on Mathematical Modelling and Scientific Computing, held at the Indian Institute of Technology Indore, India, on 19–21 July 2018. Organized into 30

chapters, the book presents the recent progress and the most advanced innovations, trends, and real-world challenges encountered and solutions embraced in the applications of mathematics and scientific computing. The book will be of interests to a wide variety of researchers, students and the practicing engineers working in diverse areas of science and engineering, ranging from applied and computational mathematics, vibration problem, computer science, and numerical optimization to physics, chemistry, biology, electrical, civil, mechanical, chemical, seismology, aerospace, and medical sciences. The aim of the conference is to bring together leading academicians, scientists, researchers, engineers, and industry partners from all over the globe to exchange and share their experiences and research results on various aspects of applied mathematics and scientific computation, like, differential equation, modeling, simulation, dynamical systems, numerical analysis, matrix theory, inverse problems, and solid and fluid mechanics, computational engineering.

Peripheral artery disease is a condition that is prevalent among the American population. It is caused by plaque buildup in arteries, known as atherosclerosis, other than those arteries in the heart and brain. While peripheral artery disease is not generally life threatening, complications from this disease can lead to intense pain, amputation and severe loss of quality of life. Most of the studies focusing on the lower limb arteries have been finite element studies looking at the bending effects on stents. These models are useful for stent design; however do not

encompass the effects that curvatures, bifurcations and bends have on the fluid mechanics of blood flow. This thesis creates several computational fluid dynamics models of the Superficial Femoral, Deep Femoral and the Popliteal Arteries in an attempt to evaluate diseases and conditions that may contribute to peripheral artery disease. This includes the varying positions that the artery many take on during ordinary leg movement, the effects of pulsating flow, the effects of stenosis and stents, as well as the effects of increased and decreased viscosity caused by variable hemotocrit count. The results of these models were examined using various graphs of the mass flow rates, velocity profiles, wall shearing stress and static pressures. It was shown that stead state simulations will underestimate wall shearing stress and that diabetic blood will nearly double the wall shearing stress experienced in the arteries. The curvatures in the arteries will create areas of increased and decreased wall shear stress, as well as generate recirculation zones. Higher hemotocrit count decreases the recirculation zones and lower hemotocrit count increases these zones. These areas of low wall shear stress have a greater chance of forming plaque buildup; whereas the increased areas of stress can cause aneurisms in the arteries and put additional strain on the stent implants, possibly contributing failure.

Comparative Cardiovascular Dynamics of Mammals offers never-before-published data on the structure and function of the circulatory systems of the different mammalian species. This text explores classic allometry, dimensional analysis, and

modern hemodynamics to establish similarity principles that provide a necessary and important step in understanding the natural common design and functional features of the cardiovascular systems of different mammals. Fluid and blood vessel mechanics, pulse transmission characteristics, cardiac energetics and mechanics, as well as heart-arterial system interaction are included in this essential reference. The sensitivity of parameters and similarity of principles in the diagnosis of cardiovascular diseases are also addressed. This book also describes the natural processes involved in the functional development of the mammalian cardiovascular system. By using modern methods to present recent findings on the similarities and differences of the mammalian cardiovascular system, the author provides an easily understood approach to this dynamic field of study.