Mini-Symposia Title:

Noninvasive fractional flow reserve from computed tomography coronary angiography: challenges and opportunities

Mini-Symposia Organizer Name & Affiliation:

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Mini-Symposia Speaker Name & Affiliation 3:

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Mini-Symposia Speaker Name & Affiliation 6:

Theme:

○ 01. Biomedical Signal Processing

○ 02. Biomedical Imaging and Image Processing

○ 03. Micro/ Nano-bioengineering; Cellular/ Tissue Engineering &

○ 04. Computational Systems & Synthetic Biology; Multiscale modeling

◉ 05. Cardiovascular and Respiratory Systems Engineering

○ 06. Neural and Rehabilitation Engineering

○ 07. Biomedical Sensors and Wearable Systems

○ 08. Biorobotics and Biomechanics

○ 09. Therapeutic & Diagnostic Systems and Technologies

○ 10. Biomedical & Health Informatics

○ 11. Biomedical Engineering Education and Society

○ 12. Translational Engineering for Healthcare Innovation and Commercialization

Mini-Symposia Synopsis— Max 2000 Characters

Computer modeling and simulation is emerging as a defined programme in the development of or regulatory evaluation of a medical product and medical intervention. The growth in science and technology has catalysed to develop the high-tech products. These advances require engineers capable of intimate interdisciplinary collaboration, particularly with physicians at each stage of research.

For example, the use of mathematical methods in medicine enjoyed its most signal successes in the application of invasive fractional flow reserve (FFR), and latterly non-invasive FFR derived from computed tomography (FFR-CT), for clinical decision-making in coronary artery disease management. FFR-CT, a parameter veritably constructed from imaging data and computational modelling, and has recently been demonstrated to be clinically useful for angina management in the PLATFORM trial.

We have invited several speakers from various disciplines (cardiology interventionist, radiologist, and scientist) to present their studies and perspective on the unmet clinical and engineering need. The symposium will cover topics ranging from clinical physiology guided PCI, physiologic and pathophysiologic regulation of coronary circulation, mathematical modeling of coronary flow simulation, CFD and non-CFD approach for CT-FFR, and clinical evidence of CT-FFR from meta-analysis.

FFR, iFR and qFR in catheterization lab: basic and clinical applications

Chi-Yang Chin, National Heart Centre Singapore

Abstract— The introduction of invasive physiology indices in the functional assessment of coronary artery disease has revolutionised the way clinical decisions are made whether or not to treat a coronary artery lesion by percutaneous coronary intervention (PCI). The fractional flow reserve (FFR) was introduced over 3 decades ago as a user friendly wire-based index using intra-arterial pressure gradients as a surrogate measurement for coronary blood flow.

Over the last 15 years, the number of trials involving FFR has increased exponentially with robust data consistently supporting the superiority of an FFR-guided versus angiography-guided approach to PCI. It follows that FFR now receives the top level of recommendation from many international Cardiology societies as a required step before PCI is performed in patients with stable coronary artery disease. More novel indices have since been developed, namely the wire-based resting indices including the instantaneous wave free ratio (iFR), which overcome some of the main limitations of FFR such as the need for a hyperaemic drug agent which increases procedure time and affects patient comfort. Yet more novel tools available for use in the cardiac catheterisation laboratory include non-wire-based indices such as the quantitative flow reserve (QFR), which utilises computational fluid dynamics to estimate changes in flow based on angiographic findings. In this paper, we discuss the pivotal trial data supporting the use of these physiologic indices and their rise in prominence from mere research devices to real-world clinical tools for decision making.

A vessel length method to compute coronary fractional flow reserve from computed tomography images

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Abstract— The fractional flow reserve (FFR) is an index to evaluate the functional severity of coronary stenosis. To obtain non-invasively the coronary FFR value, this method uses on-site simulation method based on the auto-segmentation of CT images and the vessel length-based model of the coronary vascular system. We exclude aortic part in the computational domain of the computational fluid dynamics model for efficient computation. The computed FFR (CT-FFR) was compared with clinically measured results for validations of this method. Simulation results show that the diagnostic accuracy, sensitivity, and specificity of non-invasive FFR on a per-vessel basis were 85.8%, 86.2%, and 85.5%, respectively, for CT-FFR ≤ 0.80.

Lattice Boltzmann approach for fractional flow reserve

Simone Melchionna, Franck Perot
Lexma Technology

Abstract— The Lattice Boltzmann method (LBM) is a method in computational fluid mechanics that is recognized to be particularly powerful to analyzing blood flow in complex arterial trees. Many of its characteristics concur to its success in the study of physiological flows, such as: mesh management, accuracy, parallel scalability and robustness. In addition, as a time-explicit approach, LBM bears the complete time evolution, which is particularly useful to analyze pulsatile flows and unsteady conditions. An even more important element is the possibility to include suspended red blood cells in the fluid flow, which provide a highly realistic response of blood different flow conditions. We will present a computational model based on a multiscale method and by utilizing combinations of fluid mechanics and cellular biomechanics. The approach stems from the concurrent motion of blood cells and plasma and is therefore able to reproduce blood rheology in a wide range of spatial scales. Simulations provide a wealth of information on the motion of blood cells and their structural and dynamical heterogeneities, with specific applications to measuring Fractional Flow Reserve (FFR) and instantaneous wave-free ratio (iFR).

Fast analytical methods for fractional flow reserve assessment in coronary artery disease

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Abstract— The gold standard for diagnostic assessment of ischemic coronary lesions is fractional flow reserve (FFR) which can only be measured through invasive coronary angiography (ICA). We developed two analytical models (AM1 and AM2) to calculate FFR non-invasively and efficiently. These analytical models were applied to two flow rates, one derived from computational fluid dynamics (CQ) and the other estimated from morphological data (EQ), to calculate FFR_{AM1CQ}, FFR_{AM1EQ}, FFR_{AM2CQ} and FFR_{AM2EQ}. The feasibility and diagnostic performance of these methods were performed in reference to invasively measured FFR as the gold standard in forty-nine patients (61 lesions). Processing of CTCA images provided 3D coronary tree models and morphological information. Subsequently, FFR_{AM1CQ}, FFR_{AM1EQ}, FFR_{AM2CQ} and FFR_{AM2EQ} were calculated. The results showed the bias (mean ± SD) relative to invasive FFR was 0.0039±0.069, -0.0036±0.090, 0.014±0.079 and 0.0035±0.10, respectively. Area (95% CI) under the receiver operating characteristic curve (AUC) for FFR_{AM1CQ}, FFR_{AM1EQ}, FFR_{AM2CQ} and FFR_{AM2EQ} was 0.88 (0.77, 0.95), 0.85 (0.73, 0.93), 0.85 (0.74, 0.93) and 0.82 (0.70, 0.91), respectively.