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Data Article

Dataset on blood flow and instantaneous wave-free ratio in normal and stenosed coronary arteries

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A B S T R A C T

Instantaneous wave-free ratio (iFR) has been proposed as a hemodynamic parameter that can reliably reflect the blood flow in stenosed coronary arteries. Currently, there are few investigations on the quantitative analysis of iFR in the patients regarding the variation of microcirculatory resistance (MR). The data aim to provide geometric (cross-section area of branches) and hemodynamic (flow rate and iFR of branches) parameters of normal and stenosed coronary arteries derived from CFD simulation. The CFD simulation was performed on the three-dimensional artery models reconstructed from computed tomography (CT) images of four subjects. The hemodynamic parameters were obtained in six situations of MR to simulate coronary microvascular dysfunction (CMD). This dataset could be used as the reference to estimate the iFR and flow rate in patients with CMD and steno-

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sis in coronary arteries. The geometric parameters could be used in the modelling of coronary arteries.

Specifications Table

Subject	Cardiology and Cardiovascular Medicine
Specific subject area	Computational fluid dynamics simulation of blood flow in coronary arteries
Type of data	Table (xlsx format)
How data were acquired	The instrument for Computed Tomography (CT) image collection: Siemens Somatom Definition 64-slice dual-source CT scanner (SOMATOM Force; Siemens Healthcare, Forchheim, Germany). Software for 3-dimensional reconstruction: MIMICS 18.0 (materialise N.V., Belgium). Software for geometry amendment: Geomagic Studio 12.0 (3D Systems, Rock Hill, South Carolina, USA). Software for the computation of mesh, simulation of blood flow, and evaluation of hemodynamic characteristics of the arterial models: ANSYS 15.0 software package (ANSYS, Inc., Canonsburg, PA) including ICEM and CFX.
Data format	Raw, analyzed, descriptive
Parameters for data collection	Age (year), Sex, Number of left coronary artery branches, Cross-section area of inlet and outlet branches of a left coronary artery, Diameter severity (DS) of stenosis, Area severity (AS) of stenosis, Flow rate (m^3/s), Instantaneous wave-free ratio (iFR)
Description of data collection	Age and Sex were derived from clinical recordings. The number of left coronary artery branches, Cross-section area of inlet and outlet branches of the left coronary artery, AS and DS of stenosis, flow rate, and iFR were measured from the CFD simulation results derived by ANSYS CFX.
Data source location	Coventry University, Coventry, UK
Data accessibility	Data is attached with this article (Tables 1, 2,and 3)
Related research article	H. Liu, S. Ou, P. Liu, Y. Xu, Y. Gong, L. Xia, X. Leng, T.W.H Leung, L. Shi, D. Zheng, Effect of microcirculation resistance on coronary blood flow and instantaneous wave-free ratio: a computational study, Comput. Meth. Prog. Bio. In Press

Value of the data

- Currently, there is a lack of data on the CFD simulation of iFR in coronary arteries with CMD. This data could provide a reference for related studies on iFR estimation in the patients with CMD.
- This data could be helpful for clinicians to estimate flow rate and iFR in patients with CMD and stenosis in coronary arteries, and the researchers focusing on computational modelling of coronary arteries.
- This data could be used as the reference to estimate the iFR and flow rate in patients with similar severity of stenosis, with or without CMD. The geometric parameters (number and cross-section area of left coronary artery branches, severity of stenosis) could be used in the modelling of coronary arteries.

Data description

The dataset presented in this article describes the geometric and hemodynamic parameters in coronary arteries. Cases 1 and 3 are with mild and severe stenosis, respectively. Case 2 and

4 are normal controls for cases 1 and 3. Cases 1 and 2 have six outlet branches. Cases 3 and 4 have 11 outlet branches. The flow rate and iFR values were calculated in six different situations of microcirculatory resistance (MR).

- The “hyperemia” situation was simulated by applying the normal value of hyperemic MR at the outlet branches.
- The “resting” situation was simulated by multiplying normal hyperemic MR values of all outlets by 8/3.
- In the “h-one-1.5″ situation, the mild MR increase (multiplying normal hyperemic MR by 1.5) was applied to branch 1 which is the stenotic branch or its counterpart in corresponding normal model.
- In the “h-branches-1.5″ situation, mild MR increase (multiplying normal hyperemic MR by 1.5) was applied to the stenotic branch and all its cognate branches, or their counterparts in corresponding normal cases (branches 1, 2, and 3).
- The severe MR increase (“h-one-2″ and “h-branches-2″, multiplying normal hyperemic MR by 2) was simulated similarly as in “h-one-1.5″ and “h-branches-1.5″.

Table 1 listed the age (in years), sex, number of left coronary artery branches, the branch with stenosis, the diameter severity (DS) and area severity (AS) (in percentage) of the stenosis, and the cross-section area (in mm^2) of inlet and outlets. Table 2 and Table 3 listed the flow rate (in m^3/s) and iFR of each outlet branch derived in six different MR situations.

Experimental design, materials and methods

1. Materials

The imaging data were collected in the General Hospital of Guangzhou Military Command of PLA from 2015 to 2016 with approval from the local ethics committee which conforms with the declaration of Helsinki. Individuals were well informed with a consent form signed. The 64-slice dual-source CT scanning was performed by skilled clinicians to get the CT images.

2. Methods

2.1. Three-dimensional reconstruction of artery models

The three-dimensional (3-D) models of left coronary arteries were reconstructed from the CT images using the software MIMICS 18.0 (materialise N.V., Belgium). The 3-D geometric models started from the inlet of left main coronary artery (LMCA) on the aorta and extended to the distal branches of the left anterior descending artery (LAD) and left circumflex artery (LCX), with small branches (diameter<1 mm, or blurred structure) trimmed off. The geometry was smoothed with errors (self-intersections, spikes, small holes, etc.) amended in software Geomagic Studio 12.0 (3D Systems, Rock Hill, South Carolina, USA). Finally, the inlet and outlets were sectioned vertically to the local arterial centerlines. For each stenosis, the diameter severity (DS) and area severity (AS) were defined as $DS = 1 - \frac{\text{diameter at stenotic throat}}{\text{normal diameter}}$ and $AS = 1 - \frac{\text{cross} - \text{sectional area at stenotic throat}}{\text{normal cross} - \text{sectional area}}$.

2.2. CFD simulation

The geometric models were input into the software ANSYS ICEM-CFX 15.0 (ANSYS, Inc., Canonsburg, PA) for meshing and CFD simulation. Tetrahedron elements were used for meshing. The maximum element length was 0.25 mm globally and 0.1 mm at inlet and outlets to ensure the reliability of pressure and iFR values in the simulation [1]. The fluid domain was modelled using the incompressible, steady, and Newtonian Navier–Stokes equations. Non-Newtonian effect on pressure is negligible in the CFD simulation of stenosed coronary arteries [1]. Laminar flow assumption was used as in the existing study on CFD simulation of FFR in stenosed coronary arteries [2].

The diastolic aortic blood pressure of 80 mmHg was applied at the inlet of LMCA. *In* vivo measurement showed that the diastolic aortic blood pressure is 77.9 ± 12.9 mmHg (mean±SD) [3]. The non-slip and solid wall assumption was used. MR was applied as an outlet condition. The reference "hyperemia" situation was simulated by distributing the normal hyperemic MR value of left coronary artery to all outlet branches according to the modified Murray's law: $\frac{Q_1}{Q_2} = (\frac{D_1}{D_2})^{\frac{7}{3}}$, where Q1 and Q2 are the flow rates, while D1 and D2 are the diameters of two distal branches at a bifurcation [4]. The "resting" situation was simulated by multiplying normal hyperemic MR values of all outlets by 8/3, which is approximate to the average value in adults with FFR>0.5 [5]. In all CFD simulations, the convergence criterion was 1.0E-4.

2.3. Calculation of iFR

For each outlet branch, the flow rate was quantified as the area-averaged flow velocity on the cross-section of an outlet. The iFR was measured during the wave-free period in diastole as $iFR = \frac{P_d}{P_a}|_{\text{wave-free period}}$, where Pa and Pd are aortic and distal-to-stenosis pressures, simplified as the area-averaged pressure values of inlet and outlet.

Ethics statement

The data were collected with approval from the local ethics committee which conforms with the Code of Ethics of the World Medical Association (Declaration of Helsinki). Informed consent was obtained for experimentation with human subjects. The manuscript was prepared in line with the Recommendations for the Conduct, Reporting, Editing and Publication of Scholarly Work in Medical Journals.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships which have, or could be perceived to have, influenced the work reported in this article.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.dib.2020.106011.

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