Comparison of Allometric Scaling Patterns for Estimating Coronary Flow

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Background

The coronary arterial tree is a branching network of vessels that transports oxygenated blood to the heart muscle. Quantification of flow in the coronary tree is clinically challenging and is a critical parameter for the estimation of FFR_{CT}. For this reason, allometric scaling laws, which relate the size of an object to its anatomy or physiology, are used to estimate coronary flow. There are various morphological parameters in the human coronary artery tree suitable for this with left ventricular mass (LVM) commonly used. Comparison with other morphological parameters such as vessel volume and length has not been extensively studied. This works compares and investigates the feasibility of using alternative coronary morphological parameters for flow estimation.

Methods

A total of 20 coronary arteries from patients from the CREDENCE trial who underwent coronary computed tomography angiography (CCTA) and had also received invasive physiological assessment were analyzed for this study. Physiological assessment included resting and hyperemic distal (P_d) and aortic pressure (P_a). Three-dimensional reconstructions of the left ventricle and coronary tree from the CCTA images were performed. LVM, cumulative arterial length (L), cumulative vessel volume (V), and proximal vessel diameter (D) were measured. Mean computed coronary flow (Q) was determined using computational fluid dynamics by iteratively tuning the inflow until the simulation pressure drop ($\Delta p = P_a - P_d$) matched the invasively measured Δp. Allometric scaling patterns were assessed by fitting a power law ($Q=aY^b$) between computed coronary flow and four different morphological parameters (Y = LVM, L, V, and D).

Results

The strongest agreement with computed flow (Q) was found for LVM (R^2=0.3). Weaker agreements were found for cumulative centerline length (R^2=0.21) and cumulative vessel volume (R^2=0.11). Lowest agreement was seen for the proximal diameter (R^2=0.04).

Conclusion

In this exploratory study left ventricular mass was more strongly associated with resting coronary flow than CT-derived vessel volume, length, and diameter. This supports the use of LVM for estimating flow in FFR_{CT} studies.