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A COMPUTATIONAL, TWO-DIMENSIONAL MODEL OF THE CORONARY VASCULATURE

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The blood supply to the heart muscle, via the coronary vasculature, is a crucial component of normal cardiac function. Several diseases, including coronary artery disease, myocardial ischemia, and coronary dissection can have a significant impact on the coronary vasculature and lead to an increase in morbidity and mortality. Detailed knowledge of the coronary vasculature structure is vital to understand and predict changes that occur in diseased states. Current clinical imaging techniques, such as computed tomography (CT), can be used to extract some vasculature geometry, but are limited to vessels above 1-2 millimeters in diameter, which excludes key components of the perfusion bed. The need to reconstruct detailed vasculature anatomy has driven significant research into the structure and arrangement of the coronary arteries beyond what can be captured in clinical imaging. Previous research examined coronary casts and derived equations that optimize pumping power, drag force, lumen volume, and lumen surface area. These equations can be used to predict coronary vessel geometry in terms of vessel radius, branching angle, and branch length. In this study, we implemented a rule-based algorithm from previously defined equations to create a two-dimensional model of the coronary vasculature to extend the coronary geometry beyond what is visible in medical images. We evaluated the accuracy of the algorithm by comparing the simulated coronary structures to reported human coronary structure parameters, including the symmetry ratio between daughter vessel radii and the total bifurcation angle.

The rule-based model produced a mean symmetry ratio of 0.67 ± 0.25 and a total bifurcation angle of $76.94^{\circ} \pm 3^{\circ}$ which are 25% and 10% higher than the values reported from human coronary data, respectively. Statistical analysis between our model and coronary cast data showed a statistically significant difference in both parameters ($p < 0.05$). Our analysis suggests that a rule-based approach does not produce a coronary structure that matches actual human coronaries. Despite these differences, we observed empiric similarities when comparing simulated and human coronary trees. With further modification, this model could allow us to better construct and analyze coronary vascular geometry and predict its effect on cardiovascular pathology.

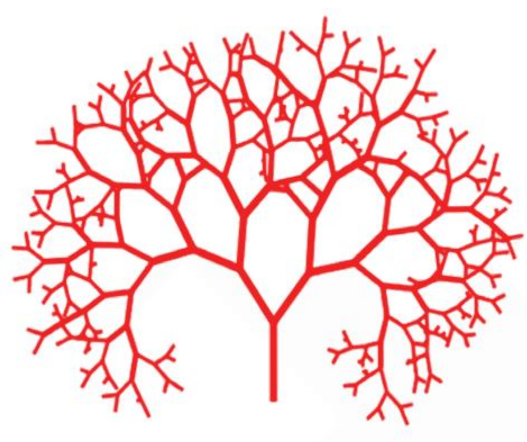

Figure 1. Sample of the two-dimensional coronary vascular model.