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Can FFR Be Reliably Calculated From Cardiac Computed Tomography Without Consideration of Collateral Flow?

The paper by Taylor et al. (1) on a new method for the calculation of fractional flow reserve (FFR) from cardiac computed tomography (CTA) images of the coronary arteries is elegant and interesting, with some striking pictures, and it offers the possibility of calculating this important quantity noninvasively. In particular, it may help to increase the effective sensitivity of CTA for evaluation of the potential significance of some stenotic lesions (e.g., for tandem or long lesions) whose hemodynamic significance may be underestimated by visual inspection alone.

However, the methods used seem to lack any consideration of the potential contribution of collateral flow from other coronary arteries to the net flow in the microcirculation downstream of a stenotic lesion. Such collateral flow is commonly found in the setting of ischemic heart disease (2), and it can even supply adequate flow to the myocardium in the setting of chronic total occlusions (3). The adequacy of this flow cannot be reliably assessed from angiographic images alone, even with conventional invasive angiography; this was one of the principal reasons for the introduction of the measurement of FFR (4). Thus, it seems likely that any modeling of the predicted pressure drop due to a given area of coronary artery stenosis seen on CTA will be prone to overestimation without consideration of the potential presence of collateral flow. This outcome, in fact, is suggested by the data on positive predictive values quoted in the paper by Taylor et al. (1), which was only 67% for the FFR calculated from CTA, which is not much different from the corresponding value of 61% for CTA stenosis alone. Because it is the positive predictive value of an assessment that is generally the most relevant consideration when using it to decide whether to intervene on a given identified arterial stenosis, this is a significant limitation of this new method. Although the presence of such collateral flow could, in principle, be incorporated into the modeling shown in the paper in Figure 5 (e.g., as an additional, parallel resistance between the aorta and the microcirculation), it is unclear how the value of the corresponding collateral vessel flow resistance could be estimated from CTA data alone.

Therefore, although this proposed new method is interesting, and it may help to increase the effective sensitivity of CTA for evaluation of the potential significance of some stenotic lesions, the lack of inclusion of the effects of collateral flow make it likely to overestimate the significance of arterial stenoses in many cases. This limitation will decrease its clinical reliability and utility.

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Reply

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We thank Dr. Axel for his interest in our paper (1) that describes the scientific basis underlying the calculation of fractional flow reserve (FFR) from coronary computed tomography angiography (FFR_{CTA}). Given the present high sensitivity of CTA to effectively exclude anatomically and physiologically significant coronary lesions, the calculation of FFR_{CTA} provides a novel method for improving the specificity of CTA to reduce false-positive interpretations of coronary stenoses that are either anatomically overestimated and/or lack hemodynamic significance.

Dr. Axel suggests that the calculation of FFR_{CTA} does not adequately consider the effects of coronary collateral flow, and he notes that the adequacy of flow within a stenotic vessel cannot be reliably determined from angiographic images in isolation. On the latter point, Dr. Axel is certainly correct, thus highlighting the need for a functional measure such as FFR to identify ischemia-causing lesions. On the former point, 2 additional ideas can clarify this issue: First, Pijls et al. (2) have demonstrated that epicardial, myocardial, and collateral flow are all taken into consideration when an FFR is measured during maximal arteriolar vasodilation, a concept that can be similarly applied to FFR_{CTA}. This finding is, in large part, because the resistance of both the myocardial capillary bed as well as the collateral circulation is constant as well as negligible, thus ensuring that the flow-dependent resistance across a stenosis also remains constant even when collateralization is present. Second, from the perspective of a clinician caring for patients with coronary artery disease, collateral flow develops as a compensatory anti-ischemic mechanism in response to only the most severe cases of coronary stenosis; thus, clinically significant collateral vessels do not develop until subtotal or total coronary occlusions are present (3). In a manner similar to invasive FFR, FFR_{CTA} is expected to be accurately applied to intermediate and severe stenoses for which the physiological significance of the coronary lesions remains uncertain, and not for normal coronary arteries or coronary arteries with total or subtotal occlusions.