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Commentary: Are we there yet?

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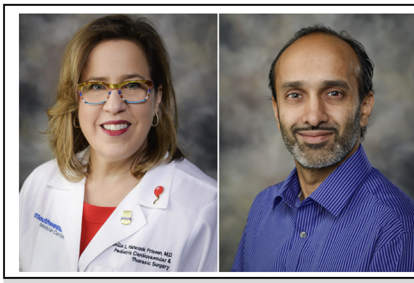

Camille L. Hancock Friesen, MD, and Tarique Hussain, MD, PhD

CENTRAL MESSAGE

Personalized medicine is coming closer to reality in congenital cardiac surgery as a result of computational modeling.

With progressively higher-resolution imaging, enhanced 3-dimensional reconstruction capabilities, and computational modeling of predicted flow characteristics, the level of sophistication in diagnosis and preoperative planning for many congenital cardiac pathologies has been greatly augmented in the current era.

Lo Rito and colleagues[1] present a pilot series of 5 cases of anomalous aortic origin of the right coronary artery (AAORCA) and 5 normal controls using computational modeling (ie, finite element analysis [FEA]) of computed tomography angiography data to determine whether simulated dynamic changes in coronary diameter during modeled loading conditions are consistent with coronary flow limitation. The model includes the known predictors of sudden death; that is, slit-like morphology of the coronary ostium, increased length of the intramural segment, and takeoff angle of the AAORCA. Using 25 measurements from each computed tomography angiography scan, the geometric model was personalized for each patient. Using structural FEA simulations, the investigators modeled 3 different aortic root pressures to simulate exercise (80, 120, and 180 mm Hg) and the coronary lumen characteristics were modeled at each of the loading conditions. The authors report reduced ability of the intramural segment of the AAORCA to expand at the various loading conditions.

The authors provide proof-of-concept that this type of modeling may have clinical relevance based on the ability to input human data into the models and to generate reproducible measurements that are clinically plausible; namely, the intramural segments of the AAORCA-modeled vessels exhibited lack of expansion not witnessed in the left coronary artery modeled vessels of the patients or controls. AAORCA is an entity that is poorly served by the empiric method of intervention and outcome given the low event rate and the unpredictable intervention rates.[2] Thus, computational modeling approaches like this are important.

There are a number of assumptions that must be made to conduct FEA in this setting. For instance, the aortic wall thickness is assumed to be uniform, but it is well recognized that the supracommissural aortic wall thickness is greater than the rest of the path of the intramural coronary and unroofing adequately at this point is an important determinant of outcome.[3] Also, the coronaries are modeled as a tube with uniform diameter and this is another assumption that does not reflect reality because coronaries are slightly irregular and taper from proximal to distal. Likewise, tissue characteristics are assumed to be identical between aortic and coronary walls but this is not clinically representative. Pathologically manifest anomalous coronaries are hypothesized to result from dynamic compromise of coronary flow, and this is much more complicated to model than fixed coronary obstruction. The influence of these limitations on the model's predictions is difficult to discern.

What is needed most for risk stratification in patients with AAORCA is indeed a functional assay to assess for dynamic compromise of coronary flow. The acid test for the technology presented by Lo Rito and colleagues[1] will be the accuracy of the simulation to predict lack of coronary expansion compared with values obtained during actual exercise.

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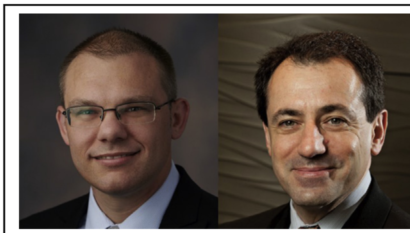
Commentary: Anomalous coronary arteries and car crash testing

Jacob R. Miller, MD, and Pirooz Eghtesady, MD, PhD



Jacob R. Miller, MD, and Pirooz Eghtesady, MD, PhD

CENTRAL MESSAGE

Structural finite element analysis allows for the dynamic evaluation of an anomalous coronary arteries. It may, eventually, help determine if surgical intervention is necessary.

An anomalous right coronary artery from the left coronary sinus (AAORCA) that is incidentally discovered, or even those with vague symptoms, continues to pose a conundrum.[1-3] Surgical outcomes, in terms of short-term survival, are excellent.[4] However, recent reports note worsening ventricular function, aortic valve function, or even death in a very small number of patients undergoing surgery for an anomalous coronary, even asymptomatic patients.[5] Therefore, a better understanding of who will benefit from surgical intervention is necessary to avoid surgery when the anatomy is unlikely to cause pathology. Currently, this decision is largely based on cross-sectional imaging. These current imaging modalities are insufficient, as they obtain static images and of the patient at rest. In this issue of the *Journal*, Lo Rito and colleagues[6] attempted to address these problems. Building off their earlier work using finite element analysis (FEA), recognizing that the aortic root and coronaries are dynamic, they created a model replicating the loading conditions associated with activity.[7]

FEA is used to evaluate the impact of a force on a complex structure. To do this, the structure is broken down into a finite number of elements. A simulation is run evaluating the strain on each element based on the force applied. When the elements are reassembled, the impact on the entire structure can be inferred. Commonly, it is used in the simulation of motor vehicle accidents. The car is broken down into multiple elements, each with different properties. The force of an impact on each element is evaluated, and they are reassembled and the damage to the automobile and its occupants determined.

Similarly, the authors divided the aortic root and coronaries (including their ostium and intramural course) into a finite number of elements. Using FEA simulations, the models were inflated at a baseline pressure and 2 greater pressure loads to simulate modest and strenuous activity. For each, the cross-sectional area of the coronaries was evaluated every 0.5 mm. This was performed for 10 patients, 5 controls and 5 with AAORCA. For patients with AAORCA, the model demonstrated that the normally arising left coronary appropriately increased in cross-

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