analysis, a quantity that cannot be directly measured in vivo and can only be determined numerically.

While the study is interesting and provides important results for further autograft remodeling research, there are some limitations that need to be highlighted. First, the pulmonary autograft geometries were obtained from magnetic resonance imaging in patients performed at 1 year after the Ross procedure. The autograft may have already remodeled by this time, and the wall stresses are indicative of remodeling and may not provide a causative link between the biomechanical state and graft remodeling. Second, the aortic valve was not included in the computational models, since the authors were focused mainly on wall stresses and had not investigated velocity distribution and flow characteristics. While reconstruction of the valve geometry and its coupling with the aorta is a complicated task, adding the aortic valve would have an impact on blood flow, likely to be significant. This in turn might also influence stress distribution along the aortic wall, thus leading to more realistic simulation results. In addition, patient-specific blood pressures were not accounted for. This is a little bit disappointing, especially since all the other aspects of the simulation protocol were patient-specific, including the material properties, rarely seen in computational studies of such a large volume.

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Commentary: An opportunity for a new look at the Ross autograft

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CENTRAL MESSAGE

This proof-of-concept study provides a novel modeling technique for analyzing Ross autograft wall stresses.

The famed Italian anatomist Antonio Valsalva is credited for discerning the relationship between eddying aortic sinus blood flow and leaflet closure in the early 1700s.[1] However, Leonardo da Vinci observed this phenomenon and even developed a functional glass model of the aortic root 2 centuries prior.[1,2] It is therefore remarkable that 500 years since Leonardo's death, we are provided with a novel technique for examining the form and function of the (neo-) aortic root.[3] The present study entailed a combination of patient-specific geometry and material properties to perform finite element analysis to estimate wall stress at each component of the Ross neoaortic root.[3] Aortic and

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pulmonary arterial tissues collected at the time of the Ross procedure and were subjected to ex vivo biaxial stretching to generate patient-specific material properties for modeling. Cardiac magnetic resonance imaging studies were obtained 1 year after surgery to reanalyze autograft wall stresses and dimensions.

The authors observed that wall stresses in all autograft regions were greater than in the native distal ascending aorta though without significant dilatation at 1 year of follow-up. Interestingly, peak first principal stresses were greatest at the sinotubular junction (STJ), especially when Dacron grafts were used to replace the ascending aorta, and areas of peak stresses did not correlate with areas of maximal diameter. More pockets of peak wall stresses were also seen in the STJ region. Less study attention was given to distensibility, although this was reduced at the STJ region when graft reinforcement was used. These results shed new light on the early biomechanical forces exerted upon the autograft neoaortic root. Importantly, the authors aim to follow this cohort longitudinally to generate longer term clinical correlations.

Important limitations of this study include a very small sample size and lack of baseline clinical data. It is a relatively older patient cohort with 12 of 16 patients (75%) aged 50 years or older. It is unclear how well systemic hypertension was managed particularly, as this can be an important contributor to late autograft dilatation and dysfunction. Clearly, the long-term associations of neoaortic root dimensions, wall stresses, and valve function will need to be followed.

These data may support the various strategies of supporting the Ross autograft to prevent late dilatation and valve dysfunction. Since 2000, our center has reinforced both the annulus and STJ during the Ross procedure when patient size permits (eg, older adolescent and adult patients) even when replacement of the ascending aorta is not performed.[4,5] This strategy has helped to mitigate late dilatation and valve incompetence with a 91% 15-year freedom from autograft reintervention.[4] Others have promoted incorporating the entire root within the sinus segment of a Valsalva graft so as to provide reinforcement of the entire autograft with similarly positive mid-term results.[6,7] This conceptually and even artistically work harkens back to the Renaissance Era of Leonardo. While the present work is unfinished in its current stage—as was the vast majority of Leonardo's ideas and projects—there is a hopeful future for completion and direct clinical impact.

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