



Is wall shear stress ready to become a prime-time clinical tool? — measurement of post-surgical patterns in patients undergoing aortic valve and thoracic aortic replacement using 4-dimensional flow magnetic resonance imaging

Matheus G. Carelli¹, Michael Seco^{1,2}, Paul G. Bannon^{1,2}, Stuart M. Grieve^{2,3,4}

¹Department of Cardiothoracic Surgery, Royal Prince Alfred Hospital, Camperdown, NSW 2050 Australia; ²Central Clinical School, Faculty of Medicine and Health, The University of Sydney, NSW 2050, Australia; ³Sydney Translational Imaging Laboratory, Heart Research Institute, Charles Perkins Centre, The University of Sydney, NSW 2006, Australia; ⁴Department of Radiology, Royal Prince Alfred Hospital, Camperdown, NSW 2050, Australia

Correspondence to: Matheus G. Carelli. Department of Cardiothoracic Surgery, Royal Prince Alfred Hospital, Camperdown, NSW 2050 Australia. Email: carelli.m@gmail.com.

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There is a significant need for new predictors of progressive dilation and dissection in aortic aneurysmal diseases, since the current paradigm of relying on aortic diameter is limited. Wall shear stress (WSS) is a known key pathological driver of aortic pathology and having insight into the post-operative changes in WSS is an important step toward meeting this need for more pathologically relevant metrics of risk (1).

The incidence of thoracic aortic aneurysms (TAA) is increasing—from 5.9 per 100,000 in 1980 to 10 per 100,000 in 1994 according to the CDC—and its complications can be lethal (2). Aortic dissection is a common complication of TAA (3,4), occurring when the hemodynamic forces exerted on the aneurysmal wall exceed the threshold holding the mural layers together, resulting in progressive separation of the layers (5).

It is known that a wide range of aortic pathologies have a negative effect on the flow dynamics in the proximal aorta, turning structured helical flow into a chaotic flow, generating high and low flow velocities. These changes in the flow characteristics are believed to increase the aortic dilatation rate and risk of dissection, however

the mechanism is not fully understood (6). These flow abnormalities are not currently reflected in decision-making algorithms, which primarily employ measurements of aortic size alone (7).

The predictive value of aortic diameter measurements, as the unanimous parameter for prediction of progressive dilation or major complications is quite poor, and therefore there is a need to identify better markers of risk. Given the role of hemodynamics in the pathophysiology of aortic dilatation, markers of risk should reflect factors associated with adverse impact on aortic flow dynamics.

The article by Bollache and colleagues (8) evaluated the postoperative changes in thoracic aortic WSS in a retrospective group of 33 TAA patients pre- and post-intervention. The data was collected using 4-dimensional flow magnetic resonance imaging (4D-flow MRI), which was then analysed to quantify the changes on WSS.

“At-risk” tissue was estimated using WSS through the use of a look-up method referring to a previously published atlas of normal individuals (9). In the absence of any validated metrics for WSS the authors used a definition of “at risk” as WSS outside of the 95% confidence interval

of this normal cohort (comprising 56 individuals without pathology). While this is an imperfect metric, this approach represents a sensible proxy in the absence of longitudinal data linking WSS directly to outcomes. There are several notable take home messages from this paper, however the most important message is that WSS measurement is now feasible, and that use in a clinical setting is a viable proposition.

The key specific finding was that tissue aortic valve replacement alone resulted in a decrease in WSS and in the at-risk tissue area, mostly via reduction of the high values previously seen in the ascending aorta and proximal arch. These results reflect population data showing the dominant influence of the aortic valve on WSS in the ascending aorta and arch (1). In contrast, aortic root replacement showed a broad-based pattern of increases in ascending aortic WSS distal to the graft. Only a small number of root and hemiarch replacements were studied, but the data support a modest increase in WSS distal to the graft. Surgical intervention to the aortic root may therefore have a greater impact on the abnormal forces felt by the vessel wall than distal interventions on the ascending aorta and hemiarch, as reduction of excessively high WSS is clearly a desirable outcome.

The study had limitations, including small sample size and variable follow-up time points, but the results are significant and provide a motivation for future larger studies. With advances in MRI technology, particularly improvement in the magnitude of “eddy currents” generated within the magnet during the 4D-flow studies will greatly improve the precision and reliability of WSS measurements generated from these data. The impact of WSS on aortic pathology is also complex—both low and high values are known to have deleterious effects, and the temporal pattern of WSS over the cardiac cycle is also important. These data demonstrate a focal reduction of WSS on the inner curvature of the aorta, a finding likely reflecting recirculating, disturbed flow which would likely have a direct effect on both the vessel wall and on circulating platelets.

The work by Bolleche and others demonstrates that WSS is now a reliable technique, capable of being deployed in a routine clinical setting (1,10,11). What is now needed are large, prospective longitudinal studies that link these observations to clinically relevant outcomes.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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