Editorial

Wall shear stress: the challenges of a rising imaging marker in current clinical practice

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Wall shear stress (WSS) is the tangential frictional force that occurs at the interface of flowing blood and the endothelial surface of a vessel. It impacts endothelial cell behavior with repercussions on the vascular smooth muscle cells and the entire vascular wall (1,2). Many pathophysiological phenomena are thought to be partly mediated by changes in WSS, such as the development of atherosclerotic plaques (3), aneurysmal growth (4,5), or the risk of dissection (6). Therefore, the identification of WSS *in vivo*, leveraging innovative imaging methods, is particularly exciting as it is a causal factor rather than a simple risk indicator. The thoracic aorta is of particular interest for evaluating WSS variations. The flows and biomechanical constraints are highly complex here due to the influence of the aortic valve, the curvatures, and the offspring of peripheral vessels. Surgical procedures on the aortic valve and thoracic aorta greatly affect these parameters with limited ability to assess them thoroughly and evaluate the short and long-term consequences. The article by Osswald *et al*. published in a recent issue of *Journal of Thoracic Disease* reports WSS alterations in the case of a distal stent graft-induced new entry (dSINE) after frozen elephant trunk (FET) procedures (7). Complete aortic arch replacement with the addition of a FET is a surgical technique providing the ability to safely treat dissections involving the descending thoracic aorta in a staged approach, but it is associated with its own set of possible complications, notably the deterioration of the aortic wall properties in the areas adjacent to the free edge of the stent graft (8). The authors measured WSS obtained from computational fluid dynamics (CFD) using computed tomography angiography (CTA). They were particularly interested in the distal landing zone, a frequent location of dSINE. The use of WSS is particularly pertinent here, as the largely reshaped blood flow-wall interaction is at the forefront of wall remodeling and the potential complications that may arise thereafter.

The extension of this research includes a prospective analysis of WSS with a pre-established methodology that may allow better targeting of patients at risk. By monitoring changes in WSS over time, clinicians may be able to predict the progression of cardiovascular disease and identify patients at a higher risk of adverse outcomes. However, several challenges are encountered in moving WSS analysis into the clinical routine. First, accurate and reproducible measurements should be obtained, as much as possible, with direct quantification of flow, rather than by simulation from anatomical data. CFD is a particularly ingenious technique for estimating WSS, using CTA or magnetic resonance imaging (MRI), but is limited to simulation alone. Direct WSS quantification is made possible today by MRI in 4D flow technology, ultrasound, the Doppler effect, or echo particle image velocimetry (9). The descending aorta

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is, however, a major challenge for external non-invasive ultrasonic approaches, and 4D MRI remains the most promising technique for evaluating stents in the descending aorta. Nevertheless, in the near future, transesophageal echocardiography (TEE) may also guide these procedures as an intraoperative tool, like many interventional cardiac procedures, such as trans-catheter valve replacement. TEE has the potential to obtain intraoperative aortic WSS measurements using vector Doppler mode (10), and has a high resolution due to the proximity of the probe, now with 3D imaging, conditions that would provide live support for optimal stent positioning.

The second difficulty to overcome is creating a biomarker based on spatially and temporally defined WSS data. As shown in the article's figures by Osswald *et al.*, WSS distribution is highly complex and greatly variates over the cardiac cycle (7). Thus, choosing one WSS value per assessment area presupposes the operator's choice of the area to be delimited, leading to a variation in the measurements. Moreover, selecting either maximum WSS values over the cardiac cycle or time-averaged WSS, as most often done, disregards the role of the oscillatory shear index, a parameter with seemingly significant effects on arterial wall remodeling (11).

In conclusion, WSS is a developing tool of increasing interest. The joint technological advances of computed tomography, MRI, and ultrasound should lead to reliable and reproducible measurements of the descending aorta. Yet, there remains a need to use mapping for measurement standardization, aiming to evolve it into a real prognostic tool to optimize patients care.

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