Superficial wall stress: the long awaited comprehensive biomechanical parameter to objectify and quantify our intuition

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Received: 12 May 2018 / Accepted: 26 May 2018 / Published online: 6 June 2018
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Keywords Intracoronary biomechanics · Superficial wall stress · Coronary artery disease

Even the most enthusiastic advocates of intracoronary biomechanics will come to admit that this scientific discipline has failed hitherto to translate into practical correlates for the interventional cardiologist. Of course, this is a fascinating research field, enlightening relevant processes like atherogenesis, plaque vulnerability, restenosis or neointimal healing after stenting, but no single practical hint could ever be derived from the biomechanical theory for the interventionalist. Only oscillatory shear stress seemed to offer a rationale to avoid step-up/step-down scenarios when a stent was implanted [1], but neither the evidence was so overwhelming, nor this concept gained widespread acceptance among the interventional community. Still the role of biomechanical factors in atherogenesis and other vascular processes is consistent: shear stress (SS) is a potent stimulus for the endothelium that determines the plaque distribution within the vessel [2–7] and the thickness of neointima after stenting in bare metal stents [8], drug-eluting stents [9–11] and bioresorbable scaffolds [12, 13]. Strain has been associated to plaque vulnerability [14–19], instead, and is calculated by elastography and palpography, based on radiofrequency tracking in grey-scale intravascular ultrasound (IVUS) cross-sections. Strain measures the radial stress in the cross-section due to the changes in blood pressure, which is about four orders of magnitude higher than the absolute value of SS and depends on the tissue composition of the vessel wall: a lipidic plaque is more strained than a fibrous one, when submitted to the same blood pressure. Therefore, the spots of high strain might represent potentially vulnerable plaques. Nonetheless, even though some indirect clinical evidence could support the concept [18], strain has failed

to find a niche in the routine of the cathlab, because most of the vulnerable plaques, detected by whichever imaging method, remain indeed stable over time and only a few are substrate for future clinical events. In summary, most interventional operators have turned their back to the biomechanical fundamentals, ignoring them in their routine practice, and just appealing to them from time to time as if they were an arcane force that can explain (or be blamed for) any kind of weird or inconvenient finding.

This panorama could however change soon. Leaving SS aside and focusing on biomechanics of high magnitude, like strain, they have been based on cross-sectional analysis so far, which is an important limitation, because the coronary vessels are submitted to other vectors of mechanical stress (Fig. 1), which are elusive to a cross-sectional analysis. Besides the blood pressure, during the cardiac cycle the systo-diastolic motion stresses the coronary vessels in different ways: longitudinal compression/stretching, bending and twisting. The concept of plaque structural stress (PSS) is meant to integrate the strain of all these mechanical vectors, but in practice it is calculated by finite element analysis (FEA), entering the vessel geometry, the plaque composition of the vessel wall and different haemodynamic parameters into the equation [20–22]. Therefore, when calculated this way, PSS essentially neglects the vectors depending on the systo-diastolic motion and ends up estimating the strain dependent on the blood pressure, but following a different method of calculation (Fig. 1). In the current issue of Int J Cardiovasc Imaging, Wu et al. validate a novel biomechanical parameter, namely superficial wall stress (SWS), that integrates for the first time all the mechanical vectors of high magnitude stressing the vessel: blood pressure, stretching, bending and twisting [23]. It is hence quite close to the theoretical concept of PSS, but concentrating on the intimal surface of the vessel. The key difference is that the authors analyse the deformation of the luminogram in all the

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Fig. 1 Different mechanical vectors straining the coronary vessel and their relation to strain, plaque structural stress and superficial wall stress. *FEA* finite element analysis

abovementioned vectors, instead of solving complex equations in FEA [24, 25]. They need to know neither the plaque composition along the vessel nor any other haemodynamic parameters: all is implied in the final deformation over the cardiac cycle.

The potential for this novel parameter is sizeable. Firstly, because of its appealing simplicity: all the required information for such a comprehensive biomechanical assessment can be obtained by a simple coronary angiography. This enables the widespread application of SWS in all kind of clinical settings. The authors focus initially on the potential to detect vulnerable coronary spots, because SWS offers much more information than just strain, but SWS can have many more potential applications. Interventional cardiologists have intuitively avoided to stent regions submitted to high mechanical stress, like muscular bridging, or segments submitted to extreme bending or compression in systole. They tend to believe that coronary devices perform poorly under these circumstances, but their identification still relies on a subjective and intuitive evaluation of the coronary angiography. SWS can finally provide an objective and quantitative assessment of the stress due to stretching/compression, bending and twisting of each coronary segment, thus opening an interesting door to study the fatigue of coronary devices and to reduce the risk of stent or scaffold failure.

Last but not least, SWS is calculated with a similar approach to the one required to obtain quantitative flow ratio (QFR) [26, 27] and could be probably simplified in a near future. It could come soon the time when a coronary angiography could provide us with information about the physiologic relevance of a stenosis (QFR), while pointing out potential spots of plaque instability (SWS). For quite some time the perspective of coronary biomechanics was not so promising as it is now. The authors must be congratulated for having revolutionised coronary angiography, by squeezing the functional and biomechanical information that can be objectively derived from it. Whether SWS will finally succeed in translating into practical consequences for the interventional cardiologist is still a mystery, but the door is open and the path is clear.

Compliance with ethical standards

Conflict of interest The author has no conflict of interests to disclose.

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