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SEARCHING FOR A PHYSIOLOGICALLY MEANINGFUL PARAMETER FOR AORTIC BIOMECHANICS—IS ENERGY LOSS THE WAY?

To the Editor:

We read with interest the article by Nightingale and colleagues, who introduced 2 biomechanical parameters, low strain tangential modulus (LTM) and onset stress of the transition zone (TZo), for assessing ascending aortic aneurysms. It is critically important that parameters measuring aortic biomechanics (1) can be measured in the physiologic range and therefore translate clinically, (2) correlate with failure properties as these are the true metrics of interest, and (3) correlate with underlying aortic wall microstructure.

Fulfilling these criteria sets up the biomechanical parameters for noninvasive in vivo testing that can segregate patients at low and high risk of aortic complications (Figure 1). We were enthusiastic that the authors were tackling some of these issues but are left with many questions.

WHICH PARAMETERS ARE MORE PHYSIOLOGIC?

LTM and TZo were measured assuming that physiologic loading of the ascending aorta ranges from zero stress to the early phase in the transition zone (Figure 1, D, in Nightingale and colleagues). However, the aorta is always under non-zero stress due to blood pressure and its ring configuration. This is immediately intuitive to surgeons. When starting stress and variable maximum stress are accounted for, we cannot assume that only the early linear region is important. Further, the aorta is strained unequally along different axes, and this was not considered.

Energy loss, which we introduced in 2014, was used by the authors as a main comparator biomechanical property. Contrary to what the authors mentioned, energy loss has been tested under both supraphysiological and physiological displacement/loads. Notably, we showed that energy loss is relatively insensitive to a wide range of loading conditions, including strain rate, starting and maximum strain, and strain ratios. This is exciting, as it supports

FIGURE 1. Necessary elements for a successful aortic biomechanics marker.
the robustness of energy loss to be measured in vivo for clinical translation.

**ENERGY LOSS CORRELATES WELL WITH MULTIPLE AORTIC WALL FAILURE CRITERIA**

The authors evaluated each biomarker against rupture strength. Energy loss correlated better than LTM and TZo in the circumferential direction; data were more limited in the axial direction making conclusions less clear. Previously, energy loss was shown to also correlate strongly with delamination strength, which measures the forces to peel apart the aortic wall as occurs during aortic dissection. Therefore, rupture strength is the second failure criteria that energy loss correlates well with.

**ENERGY LOSS CORRELATES WELL WITH UNDERLYING MICROSTRUCTURE**

We demonstrated correlations with elastin and collagen in our previous studies on energy loss. The current study showed that, across several domains, correlations with microstructural components were stronger with energy loss than with either LTM and TZo.

**ENERGY LOSS SEPARATES AT-RISK TISSUE FROM NORMAL CONTROLS**

One of the limitations listed in this paper was the lack of healthy controls. Previous studies with healthy controls may be useful. Our previous work demonstrated that energy loss can distinguish between patients with normal aortas, aneurysms, and acute aortic dissection.

This interesting paper hits the nail on the head on important criteria necessary for development of successful aortic biomechanics parameters. Energy loss appears to fulfill these criteria. We also look forward to future studies on LTM and TZo exploring these parameters in more detail.

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