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## Response to Letter Regarding Article, “Bicuspid Aortic Cusp Fusion Morphology Alters Aortic Three-Dimensional Outflow Patterns, Wall Shear Stress, and Expression of Aortopathy”

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We thank Hope and colleagues for their interesting and pertinent letter on our recent study in patients with bicuspid aortic valve (BAV), in which the relationship between bicuspid aortic valve morphology, the resulting flow patterns, and the aortopathy phenotype was examined.<sup>1</sup>

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**Disclosures**

None.

To confirm their initial comment, indeed, the ascending aortic flow displacement parameter was not normalized to the individual vessel diameter. We agree with Hope et al that flow displacement should ideally be normalized by the lumen diameter to account for interindividual differences in aortic geometry. Nonetheless, aortic diameters in the aorta size control group and the BAV patient groups in our study cohort were similar (4.1 versus 4.0 cm, respectively). Thus, the process of normalization did not affect the results or conclusions.

We thank Hope and colleagues for pointing out this important difference because the clear communication of measurement and naming conventions is paramount to the portability and translation of results across multiple institutions. This applies not just to flow displacement but to a number of the new hemodynamic biomarkers being investigated, including valve angle, flow angle, and wall shear stress. Although our study showed that flow displacement was most sensitive to detect differences in aortopathy phenotype, previous studies have provided evidence that other metrics of altered aortic hemodynamics can provide important additional information. For example, recent work by Meierhofer et al,<sup>2</sup> Bissell et al,<sup>3</sup> and Barker et al<sup>4</sup> has demonstrated the potential of wall shear stress to quantify the impact of altered flow patterns on shear forces acting on the aortic wall. However, assessment of wall shear stress can be technically challenging, and care has to be taken to accurately describe the underlying methodology to ensure the reproducibility of the technique across clinical settings. It is only with this effort that large-scale recruitment will be possible to identify new risk factors for aortopathy risk in the individual BAV patient.

As stated in their letter, large, prospective, multicenter studies are necessary to assess the diagnostic value of hemodynamic biomarkers in the normal-sized aorta of young BAV patients before the onset of aortic dilatation and development of aortopathy. Indeed, as previously reported,<sup>4,5</sup> even “normal” BAV patients can demonstrate altered flow patterns and abnormal wall shear stress along the ascending aorta. According to traditional measures, these patients can demonstrate “normal” flow past an unobstructed bicuspid leaflet, but subtle differences in shear forces at the downstream wall can be present as a result of the mere presence of a conjoined leaflet. It may perhaps be these subtle differences that provide the key to understanding the heterogeneity of aortopathy expression and, in combination with other metrics and demographic factors, may help to develop a novel risk score for the onset of aortopathy in the individual BAV patient. It goes without saying that to fully test this hypothesis, large-scale, multidisciplinary, and multicenter efforts are required, for which the clear and consistent communication of results is of utmost importance.

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