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Reply to Commentary: Can't flow down: More 4-dimensional flow magnetic resonance imaging studies are needed in congenital heart disease

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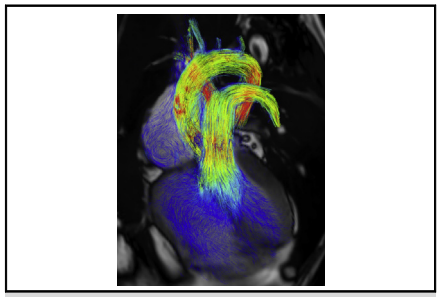

Whole-heart flow visualization of cardiac systole.

CENTRAL MESSAGE

Four-dimensional flow MRI studies in congenital heart disease are scarce, yet they might provide more information than current standard imaging techniques.

We thank Dr DeCampli for his thoughtful commentary[1] considering our study concerning quantitative left ventricular flow analysis in tetralogy of Fallot (TOF).[2] We agree with his conclusions regarding the ventricular interactions and the need for an early marker for pulmonary valve intervention. DeCampli's comments regarding the limitations of pooled correlative analysis are astute. This analysis is a limitation of our study due to the potential for clustering and confounding. That is why we provided the actual scatter plots to allow readers the opportunity for objective comparison and as a matter of transparency. Our rationale for the combined correlative analysis are 2-fold: to assess the potential relationship across the entire spectrum of participants and to increase the number of observations for meaningful analyses. The first argument was driven purely by the novelty of 4-dimensional flow magnetic resonance imaging markers where normative and disease progression markers are lacking in patients with congenital heart disease. Indeed, the observation that both groups tend to correlate differently suggests that interventricular interaction may be distinct in TOF patients compared with healthy controls. After considering De Campli's comments, we ran the Hotelling T^2 test and observed that the 2-group stratified correlations were statistically different ($P < .05$). However, we recognize that it is important to acknowledge the limitations of our small sample size where multivariable tests such as Hotelling's may be prone to errors.

Given the early stage of our investigation, we were careful not to draw definitive conclusions and causative correlations between right ventricular size and left ventricular flow hemodynamics. Early detection of left ventricular diastolic dysfunction has been more frequently suggested to be investigated by means of fluid–tissue interactions[3] and large scale vortex formations[4] with the premise that changes in the ventricular flow domain would be detectable sooner than early-stage tissue stiffening measured by conventional strain measuring. We continue to recruit patients with repaired TOF to acquire more magnetic resonance imaging-based flow hemodynamic parameters that will continue to inform our knowledge about the complex ventricular interactions in these patients. As we explore this problem further with patients who have more prominent right ventricular dilation, we expect that the relationship between right ventricular dilation and left ventricular flow hemodynamics will hold with improved statistical certainty. At the same time, we urge our colleagues and other investigators to pursue more 4-dimensional flow magnetic resonance imaging studies in patients with congenital heart disease to gain more large-scale, quantitative information. As highlighted previously: Keep those studies flowing.[5]

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