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Commentary: The vortex and the ring

Tomasz A. Timek, MD, PhD

Modern magnetic resonance imaging (MRI) is providing a window to the hemodynamic intricacies of cardiac flow patterns and simultaneously elucidating previously uncharted physiologic territory. Ascending aortic flow imaging has been illuminating in exploring the link between bicuspid aortic valves and aneurysms of the ascending aorta,¹ and ventricular chamber flow characterization is adding to our understanding of normal² and pathologic³ cardiac function. In the current issue of the *Journal*, Morichi and colleagues⁴ go a step beyond and use 4-dimensional MRI to assess the influence of mitral annular prostheses on left ventricular flow patterns after mitral repair for degenerative disease. The authors report that mitral repair with smaller annuloplasty rings significantly altered left ventricular flow patterns with complete rings also perturbing aortic root flow. Although the influence of these differential flow characteristics on repair durability and clinical outcomes is yet unknown, preservation of physiologic cardiac flow ought to offer a hemodynamic advantage in the long term. The presented findings add new pieces to the complexity of the mitral puzzle and spur renewed interest in previous mechanistic studies.

The flow patterns in healthy volunteers revealed formation of vortexes under the anterior and posterior leaflets in early diastole with subsequent enlargement of the anterior vortex displacing the anterior leaflet toward the valve. This flow-induced leaflet motion acts to pre-position the valve for competent and efficient closure before rise of ventricular pressure. The vivid images provided by the authors corroborate the findings of Tsakiris and colleagues,⁵ who more than 4 decades ago postulated facilitated valve closure with “eddy currents” under the leaflets. In the current study,

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Disclosures: The author reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

Received for publication May 2, 2020; revisions received May 2, 2020; accepted for publication May 4, 2020; available ahead of print May 15, 2020.

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J Thorac Cardiovasc Surg 2022;163:961-2

0022-5223/\$36.00

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<http://dx.doi.org/10.1016/j.jtcvs.2020.05.014>

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CENTRAL MESSAGE

Small and complete mitral annuloplasty prostheses perturb physiologic cardiac flow patterns after repair of degenerative mitral regurgitation.

both partial and complete annular prostheses abolished the vortex-induced displacement of the anterior leaflet in mid-diastole and hence perturbed normal physiologic flow patterns. These findings from healthy volunteers also add clarity to the complex mechanisms of mitral valve closure. Diastolic vortexes and atrially mediated annular reduction⁶ work in tandem to approximate the valve leaflets in late diastole for subsequent sealing by rising systolic pressure to achieving timely and competent valve closure. The interaction between the aortic root and the mitral annulus also deserves renewed attention in light of the results at hand. Previous experimental work has shown that the mitral and aortic annuli change size during the cardiac cycle in reciprocal manner that is not strictly mediated by the aorto-mitral curtain.⁷ To this end, incomplete mitral annuloplasty prostheses have been shown to better preserve anterior annular flexion than complete rings,⁸ thus perhaps better facilitating normal aortic root dynamics. Demonstration of near-physiologic aortic flow patterns with mitral bands but not rings in the current study substantiates these suggestive data of the past. However, the results of this advanced imaging analysis should be viewed through a lens of important limitations, as it is difficult to separate whether leaflet or annular techniques were responsible for the altered flow patterns. Artificial chordae with differential tension and posterior leaflet resective techniques may perturb normal leaflet motion and disturb physiologic vortex formation irrespective of the annular prosthesis used. Perhaps patients with functional mitral regurgitation repaired with an

annuloplasty prosthesis alone would have been a better substrate for this study. Indeed, in healthy sheep implanted with annuloplasty rings only,⁹ the MRI flow patterns were substantially different from those presented herein.

The 4-dimensional MRI flow patterns reported in the presented patients offer a unique glimpse into the physiologic subtleties of degenerative mitral valve repair that goes beyond the usual gross assessment of valvular insufficiency. Other investigators¹⁰ have shown that even with successful restoration of valvular competence, the technical nuances of mitral repair may lead to distant morbidity. The current report adds impetus for further refinement of surgical technique. Advanced imaging techniques may be the new bellwether of not only competent but also physiologic mitral valve repair.

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Commentary: Four-dimensional left ventricular flow imaging after surgical valve reconstruction—pretty pictures or marker of repair quality?

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From Hippocrates and Vesalius to Ibn al-Nafis and William Harvey, the controversy of blood flow in medicine and philosophy has persisted for centuries. While

Abnormal blood flow dynamics in a patient with degenerative mitral valve disease.

CENTRAL MESSAGE

Ventricular flow dynamics are disrupted by mitral valve disease and its surgical treatment. The clinical and prognostic impact of disrupted flow dynamics is yet to be determined.

Leonardo DaVinci's description of vortex and laminar flow¹ should have bridged the chasm between rationalists and empiricists, it took 450 years before his hypotheses were corroborated in the laboratory by Brian Bellhouse and colleagues in Oxford in the 1960s, using dyes with

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Disclosures: The authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

Received for publication May 28, 2020; revisions received June 1, 2020; accepted for publication June 2, 2020; available ahead of print June 24, 2020.

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J Thorac Cardiovasc Surg 2022;163:962-3

0022-5223/\$36.00

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<http://dx.doi.org/10.1016/j.jtcvs.2020.06.014>