On Proper Use of Fluid Dynamics Conservation Laws in Defining the Contribution of Diastolic Vortex Ring to Left Ventricular Filling

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With much interest, we read the recent article by Martínez-Legazpi *et al.* (1), which suggests insights into the role of diastolic vortex formation in filling of the left ventricle (LV). We are delighted to see that fluid dynamics is increasing its presence in the clinical cardiology community and contributes to an improved understanding of cardiac function as underlined in the supplementing editorial (2).

The article by Martínez-Legazpi *et al.* (1) introduces a technique to evaluate the contribution of the LV vortex to diastolic filling using intra-ventricular velocity estimated by 2D color Doppler echocardiography. They aimed to quantify the percentage of diastolic filling volume related to the LV vortex and tried to distinguish between normal and abnormal LV function. Their method is based on the decomposition of the intra-ventricular velocity field into two components where one is the rotational flow, directly related to the presence of the LV vortex, and the other is irrotational; a mathematical approach known as *Stokes decomposition* widely applied in fluid dynamics.

Accordingly, Martínez-Legazpi *et al.* first isolated the LV vortex and subsequently tried to adjust the corresponding velocity to account for the presence of the LV wall and mitral leaflets. Based also on the communication that we had with some of the authors, we understood that the method initiates by computing the rotational velocity under the assumption that the LV wall is rigid, which should yield a zero volume for transmitral inflow. However, this results in an estimate a new transmitral inflow volume that is non-zero. Then the method iteratively repeats the same procedure that always results in an inflow volume that is different from the expansion volume, and this process continues until the solution converges to a value.

The major issue with this method is that once the LV wall is assumed to be rigid, and the ventricle is full of blood, it is physically impossible to result in a non-zero transmitral inflow volume. Similarly, when the LV wall expands, its volume increase cannot differ from the transmitral inflow volume. The fact that these volumes differ during the individual iterative steps represents a direct violation of the fundamental law of the conservation of mass and reveals an erroneous calculation in the method. This flaw invalidates the entire method and the subsequent results.

Moreover, according to the fluid dynamics conservation laws, the role of the LV vortex in diastolic filling volume cannot be evaluated merely by volumetric balances, but needs to be considered in conjunction with the corresponding momentum balances and intra-ventricular pressure gradients. The second misconception fallacy introduced by Martínez-Legazpi *et al.* stems from the decomposition of the pressure gradient into a rotational and an irrotational component. They did not consider the fact that every gradient field is a conservative field by definition; hence it has no rotational component. Therefore, the presented pressure decomposition presented in their analysis is rather improper for fluid dynamics, and should not be used for such a purpose.

In conclusion, this letter aims to bring attention to the misleading analyses reported by Martínez-Legazpi *et al*. (1) and the supporting editorial views on the article (2). Although the concerns raised here are highly technical and could have escaped during the normal review process, they do impact the validity of the reported method and results and consequently their clinical implications. We hope that this letter clarifies these technical, albeit fundamentally significant, points and prevents future misleading developments based on them.

REFERENCES

1. Martínez-Legazpi P, Bermejo J, Benito Y, et al. Contribution of the Diastolic Vortex Ring to Left Ventricular Filling. J Am Coll Cardiol 2014;64:1711-21.
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