Added value of hemodynamic forces for left ventricle function evaluation

Sara Monosilio, Massimo Mancone, and Viviana Maestrini*

Department of Clinical Internal, Anaesthesiological and Cardiovascular Sciences, Sapienza University of Rome, Rome, Italy

eBioMedicine 2023;87: 104409

Published Online 14 December 2022

https://doi.org/10.1016/j.ebiom.2022.104409

In the last few years, the study of left ventricular (LV) function has searched for alternatives to ejection fraction (EF). Myocardial deformation imaging and strain parameters have established as valid methods to quantify LV function, but they still present some limits. More recently, research has moved on regaining the old knowledge that behind the ventricular function there is a complex interaction between all the cardiac components and the blood flow that is driven by intraventricular pressure gradients (IVPG). IVPGs can be quantitatively expressed by hemodynamic forces (HDFs), the forces exchanged between the blood and the myocardium. LV HDFs are deeply connected to myocardial deformation and their magnitude and distribution have demonstrated to reflect cardiac function.[1] Advances from initial methods to compute HDFs have been made. Passing through studies conducted with echo-particle image velocimetry and 4D flow cardiac magnetic resonance (CMR),[2] HDFs can currently be estimated from simple echocardiographic cine-loops and CMR cine-images by applying a validated mathematical model.[3,4] They are emerging as a tool for LV function evaluation with the potential to be used in CV disease evaluation. Echocardiographic reference values have been provided,[5] and applications in common clinical scenarios are arising.[6–8]

The study by Backhaus and colleagues evaluated HDFs computed by CMR in a population of 34 patients with heart failure with preserved EF (HFpEF) compared to 34 patients with non-cardiac dyspnea (NCD).[9] They found a decrease in global LV longitudinal force in HFpEF patients due to an impairment of both systolic and late diastolic parameters. Systolic peak HDFs and diastolic deceleration/atrial thrust correlated with post-capillary wedge pressure (PCWP) measured by right heart catheterization (RHC) at rest and stress. Strain parameters obtained by CMR feature-tracking did not show significant differences between HFpEF and NCD patients. Finally, systolic peak HDFs showed greater accuracy in diagnosing HFpEF if compared with strain parameters and, along with systolic impulse, had a significant prognostic value. This results are in line with the first study on HDFs in HFpEF patients conducted by Lapinskas and colleagues.[10] Likewise the present study, they demonstrated that LV longitudinal force value, measured over the entire cardiac cycle using CMR cine-images, is the only impaired parameter in HFpEF patients compared to healthy volunteers. At the same time, strain values were not significantly different. A recent echocardiographic study by Airale et al. also found a significant difference in diastolic longitudinal force between patients with and without increased left ventricular filling pressures (based on PCWP values at RHC).[6] On the contrary, Arviddson et al. did not find differences in systolic and diastolic HDFs parameters obtained by 4D flow CMR between HFpEF patients and controls, and HDFs did not show a correlation with EF.[7]

Differences in findings among the available studies could be attributed mainly to two factors. Firstly, the HDFs evaluation has yet to be a standardized methodology, and as a result, different phases of the curve (reflecting different phases of the cardiac cycle) and parameters are considered. Thus, there is a need for more consistency between the variables assessed in different works. Secondly, it must be considered that HDFs evaluation is conducted with different techniques, with some studies based on echo-derived parameters and others on CMR (using cine or 4D flow images), and these differences could impact the results.

The most important finding of the present study is the prognostic implication of systolic HDFs parameters.

HDFs parameters were superior to other variables in predicting CV events (rehospitalization for heart failure at 24 months follow-up) in this population. This finding implies clinical consequences since it indicates that HDFs parameters could be more sensible than GLS in detecting LV functional alterations when ejection fraction is normal. Of note, it must be considered that the absence of differences in feature-tracking parameters could be related to the small number of enrolled subjects, as the authors reported. The limited cohort along with the relatively early stage of the disease and the lack of a control group of healthy subjects could also explain the absence of differences in diastolic HDFs between HFpEF diagnosed at rest and NCD patients.

DOI of original article: https://doi.org/10.1016/j.ebiom.2022.104334

*Corresponding author. Department of Clinical Internal, Anaesthesiological and Cardiovascular Sciences, Policlinico Umberto I Hospital, Sapienza University of Rome, Viale del Policlinico 155, 00100, Rome, Italy.

E-mail address: massimo.mancone@uniroma1.it (M. Mancone).

Despite differences between the available works in the literature, this study supports the increasing evidence that it is time to move beyond the simplified evaluation of LV function via LVEF and strain considering the complexity of ventricular mechanics. We have now the technology available to provide new parameters easily obtained by non-invasive imaging techniques, but wider studies are needed to further validate and standardize their application in clinical practice.

Contributors

All authors participate in literature search, writing and reviewing and editing of the manuscript.

Declaration of interests

The authors declare no conflict of interest.

References

1 Dal Ferro M, Stolfo D, De Paris V, et al. Cardiac fluid dynamics meets deformation imaging. *Cardiovasc Ultrasound*. 2018;16(1):1–10.
2 Arvidsson PM, Töger J, Carlsson M, et al. Left and right ventricular hemodynamic forces in healthy volunteers and elite athletes assessed with 4D flow magnetic resonance imaging. *Am J Physiol Hear Circ Physiol*. 2017;312(2):H314–H328.
3 Pedrizzetti G. On the computation of hemodynamic forces in the heart chambers. *J Biomech*. 2019;95:109323.
4 Pedrizzetti G, Arvidsson PM, Töger J, et al. On estimating intraventricular hemodynamic forces from endocardial dynamics: a comparative study with 4D flow MRI. *J Biomech*. 2017;60 (October):203–210.
5 Ferrara F, Capuano F, Cocchia R, et al. Reference ranges of left ventricular hemodynamic forces in healthy adults: a speckle-tracking echocardiographic study. *J Clin Med*. 2021;10(24): 1–15.
6 Airale L, Vallelonga F, Forni T, et al. A novel approach to left ventricular filling pressure assessment: the role of hemodynamic forces analysis. *Front Cardiovasc Med*. 2021;8(September):1–10.
7 Arvidsson PM, Nelsson A, Magnusson M, Smith JG, Carlsson M, Arheden H. Hemodynamic force analysis is not ready for clinical trials on HFpEF. *Sci Rep*. 2022;12(1):1–9.
8 Monosilio S, Filomena D, Luongo F, et al. Cardiac and vascular remodeling after 6 months of therapy with sacubitril/valsartan: mechanistic insights from advanced echocardiographic analysis. *Front Cardiovasc Med*. 2022;9.
9 Backaus S, Uzun H, Rösel S, et al. Hemodynamic force assessment by cardiovascular magnetic resonance in HFpEF: a case-control substudy from the HFpEF stress trial. *EBioMedicine*. 2022;86. https://doi.org/10.1016/j.ebiom.2022.104334.
10 Lapinskas T, Pedrizzetti G, Stoiber L, et al. The intraventricular hemodynamic forces estimated using routine CMR cine images: a new marker of the failing heart. *JACC Cardiovasc Imaging*. 2019;12(2):377–379.