European Heart Journal - Cardiovascular Imaging (2021) **22**, 876–877
doi:10.1093/ehjci/jeab089

EDITORIAL

Strain identifies pseudo-normalized right ventricular function in tricuspid regurgitation

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Received 17 March 2021; editorial decision 18 March 2021; accepted 22 April 2021; online publish-ahead-of-print 20 June 2021

This editorial refers to 'Right ventricular systolic function in severe tricuspid regurgitation: prognostic relevance of longitudinal strain', by F. Ancona *et al.* pp. 868–875.

Ejection fraction (EF) has been the parameter of choice for evaluation of left ventricular (LV) function since the 1960s[1] and is proven useful for identification of heart failure patients who are likely to benefit from specific drugs and device therapies. There are, however, several limitations of left ventricular ejection fraction (LVEF) as a measure of LV contractile function as it has low sensitivity for detecting mild systolic dysfunction and has strong dependency on LV geometry. Furthermore, LVEF reflects predominantly LV circumferential contraction and is less sensitive to reduction in LV longitudinal contraction.[2] There is also a strong dependency on LV afterload, which is most marked in patients with impaired LV systolic function. Finally, in patients with severe mitral regurgitation, even a dysfunctional ventricle may have normal EF because it partly ejects into the left atrium as a low-pressure chamber.

When assessing right ventricular (RV) systolic function by right ventricular ejection fraction (RVEF) and other ejection phase indices, the limitations are in principle the same as for the LV. Furthermore, the RV has complex geometry and there is often suboptimal echocardiographic image quality, which represent additional challenges. In fact, RVEF is only accessible with cardiac magnetic resonance imaging or 3D echocardiography. RV fractional area change (FAC) is a simpler method only requiring acquisition of the apical four-chamber view, but is limited by uncertainty about RV geometry and only fair inter-observer variability.[3] In addition to visual assessment, the most widely used parameter of RV function in clinical practice is tricuspid annular peak systolic excursion (TAPSE),[4] but its correlation with RVEF is only modest.[5] Furthermore, as with peak tricuspid annulus velocity, TAPSE is angle dependent and influenced by overall heart motion.[3] There is currently no uniform consensus regarding what is best method, as reflected in the limitations and wide variability in methods in clinical use.[4] Hence, there is a need for better echocardiographic methods to assess RV function.

Over the last 20 years, myocardial strain has emerged as a more sensitive parameter of LV systolic function than LVEF and is currently gaining ground in clinical cardiology as both a supplement and substitute for LVEF. More recently, strain has also emerged as a promising parameter of RV systolic function, but comparing values from different vendors must be done with caution due to significant inter-vendor variability.[6] In 250 patients with severe tricuspid valve regurgitation, Ancona *et al.*[7] tested if RV dysfunction as determined by strain imaging could improve preoperative risk assessment. They found that RV strain analysis reclassified many patients with apparently normal systolic function by conventional parameters. Thus, about 50% of patients with normal values for either TAPSE, RVFAC, or peak tricuspid annulus systolic velocity, had reduced RV longitudinal strain measured in the RV free wall, and as a global parameter including both the RV free wall and the septum. Furthermore, they found that different levels of RV free wall strain were independent predictors of clinical RV failure and all-cause mortality in multivariate analysis. The authors should be acknowledged for the important findings, clearly demonstrating added prognostic value of RV strain measurements. Using RV strain measurements to improve timing of tricuspid valve intervention appears as an attractive approach, but clinical benefit remains to be determined. Moreover, results must be interpreted with caution due to the retrospective study design and relatively small sample size, with a substantial fraction of patients lost to follow-up and excluded, mainly for technical reasons.

As stated by Ancona and co-authors, the regurgitant volume represents an important limitation for most ejection phase indices, including strain. Therefore, the authors speculate if normal values for strain during such circumstances may be higher. Strain also is load-dependent, but apparently less so than the conventional ejection phase indices. Importantly, myocardial strain is a more direct measure of myocardial contractile function than the other parameters, which are

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more influenced by geometry, translational motion, and angle-problems with regard to direction of the ultrasound beam. To really overcome this problem, however, one should measure ventricular output separately. This may be done by pulsed-wave Doppler in the RV outflow tract, but is not regularly performed. Instead, LV stroke volume serves as a more feasible alternative. Potentially such measurement could be combined with mean pulmonary artery pressure to calculate right-sided cardiac power, which integrates volumetric output and afterload. Of note, left-sided cardiac power was recently shown to be a strong predictor of events in patients with normal LVEF.[8]

Incorporation of afterload is important for assessment of ventricular performance during certain circumstances and, in fact, RV function is substantially more afterload dependent than LV function.[9] As previously demonstrated, even moderate increments in systolic blood pressure may have important effects on strain.[10] Therefore, the use of strain has limitations especially when afterload is expected to be abnormal. This highlights the need for parameters taking blood pressure into account. In this regard, it was recently shown how TAPSE combined with pulmonary artery systolic pressure was superior combined to TAPSE alone for prediction of adverse outcome in patients with pulmonary embolism.[11] Approximately 10 years ago, our group introduced a method for non-invasive construction of LV pressure-strain loops thereby allowing assessment of the myocardial work index.[12] The method has shown promising results for several different applications.[13,14] Recently, Butcher *et al.*[15] demonstrated how this approach could be applied to the RV by constructing RV pressure-strain loops and calculating RV myocardial work. Furthermore, they elegantly demonstrated how RV work may have benefits over RV strain.

In total, the time has come to improve and extend clinical assessment of RV function. The study by Ancona *et al.* is a great example of how strain imaging may be applied to identify RV dysfunction in patients with severe tricuspid regurgitation where the conventional parameters of RV function frequently are pseudo-normalized. Due to rather complex geometry and strong afterload dependency, we believe there is need for more than one parameter to quantify RV contractile function, and RV strain is likely to become one of the valuable measures. Importantly, however, new methods may also increase the risk of overdiagnosis and overtreatment and, thus, treatment decisions must always be rooted in robust clinical trials.

Conflict of interest: none declared.

References

1. Folse R, Braunwald E. Determination of fraction of left ventricular volume ejected per beat and of ventricular end-diastolic and residual volumes. Experimental and clinical observations with a precordial dilution technic. *Circulation* 1962;**25**:674–85.
2. Stokke TM, Hasselberg NE, Smedsrud MK, Sarvari SI, Haugaa KH, Smiseth OA *et al.* Geometry as a confounder when assessing ventricular systolic function: comparison between ejection fraction and strain. *J Am Coll Cardiol* 2017;**70**:942–54.
3. Lang RM, Badano LP, Mor-Avi V, Afilalo J, Armstrong A, Ernande L *et al.* Recommendations for cardiac chamber quantification by echocardiography in adults: an update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. *Eur Heart J Cardiovasc Imaging* 2015;**16**:233–70.
4. Schneider M, Aschauer S, Mascherbauer J, Ran H, Binder C, Lang I *et al.* Echocardiographic assessment of right ventricular function: current clinical practice. *Int J Cardiovasc Imaging* 2019;**35**:49–56.
5. Pavlicek M, Wahl A, Rutz T, de Marchi SF, Hille R, Wustmann K *et al.* Right ventricular systolic function assessment: rank of echocardiographic methods vs. cardiac magnetic resonance imaging. *Eur J Echocardiogr* 2011;**12**:871–80.
6. Badano LP, Muraru D, Parati G, Haugaa K, Voigt JU. How to do right ventricular strain. *Eur Heart J Cardiovasc Imaging* 2020;**21**:825–7.
7. Ancona F, Melillo F, Calvo F, Attalla El Halabieh N, Stella S, Capogrosso C *et al.*. Right ventricular systolic function in severe tricuspid regurgitation: prognostic relevance of longitudinal strain. *Eur Heart J Cardiovasc Imaging* 2021;**22**: 868–75.
8. Anand V, Kane GC, Scott CG, Pislaru SV, Adigun RO, McCully RB *et al.* Prognostic value of peak stress cardiac power in patients with normal ejection fraction undergoing exercise stress echocardiography. *Eur Heart J* 2021;**42**:776–85.
9. MacNee W. Pathophysiology of cor pulmonale in chronic obstructive pulmonary disease. Part One. *Am J Respir Crit Care Med* 1994;**150**:833–52.
10. Aalen J, Storsten P, Remme EW, Sirnes PA, Gjesdal O, Larsen CK *et al.* Afterload hypersensitivity in patients with left bundle branch block. *JACC Cardiovasc Imaging* 2019;**12**:967–77.
11. Lyhne MD, Kabrhel C, Giordano N, Andersen A, Nielsen-Kudsk JE, Zheng H *et al.* The echocardiographic ratio tricuspid annular plane systolic excursion/pulmonary arterial systolic pressure predicts short-term adverse outcomes in acute pulmonary embolism. *Eur Heart J Cardiovasc Imaging* 2021;**22**:285–94.
12. Russell K, Eriksen M, Aaberge L, Wilhelmsen N, Skulstad H, Remme EW *et al.* A novel clinical method for quantification of regional left ventricular pressure-strain loop area: a non-invasive index of myocardial work. *Eur Heart J* 2012;**33**:724–33.
13. Boe E, Russell K, Eek C, Eriksen M, Remme EW, Smiseth OA *et al.* Non-invasive myocardial work index identifies acute coronary occlusion in patients with non-ST-segment elevation-acute coronary syndrome. *Eur Heart J Cardiovasc Imaging* 2015;**16**:1247–55.
14. Aalen JM, Donal E, Larsen CK, Duchenne J, Lederlin M, Cvijic M *et al.* Imaging predictors of response to cardiac resynchronization therapy: left ventricular work asymmetry by echocardiography and septal viability by cardiac magnetic resonance. *Eur Heart J* 2020;**41**:3813–23.
15. Butcher SC, Fortuni F, Montero-Cabezas JM, Abou R, El Mahdiui M, van der Bijl P *et al.* Right ventricular myocardial work: proof-of-concept for non-invasive assessment of right ventricular function. *Eur Heart J Cardiovasc Imaging* 2021;**22**: 142–52.