concomitant atrial filling (2,4,5). The outer (pericardial, all 4 chambers) total heart volume has only a small systolic decrease, corresponding to the radial decrease in epicardial ventricular size; is much smaller than left or right ventricular ejection fraction; and is 8% in humans (5). Longitudinal and radial contribution to stroke volume have been quantitated by measurements of all inflow and outflow to the heart (2,5) and showed a strong correlation between the absolute longitudinal function and the difference of inflow and outflow (r = 0.92).

In summary, the seeming difference in the degree of "longitudinal" versus "radial" contribution to left ventricular pumping is resolved by noting the differences between the physiological conceptual frameworks used. When focusing on the contribution of myocardial tissue displacement to pumping, using a geometrical model as in Stokke et al. (1), short-axis function must be dominant (due to Poisson ratio, limited epicardial displacement, and conservation of tissue volume). This approach, however, does not account for the degree by which longitudinal shortening per se through wall thickening contributes to circumferential shortening. When using an integrated whole-heart or AV reciprocating volume approach, longitudinal shortening of the entire ventricle and descent of the AV valve plane causes predominantly systolic atrial filling and concomitantly is the dominant contributor to stroke volume.

***Marcus Carlsson, MD, PhD**
Einar Heiberg, PhD
Ellen Ostenfeld, MD, PhD
Katarina Steding-Ehrenborg, PhD
Sándor J. Kovács, MD, PhD
Frank Flachskampf, MD, PhD
Håkan Arheden, MD, PhD

*Department of Clinical Physiology
Skane University Hospital
Lund University
221 85 Lund
Sweden
E-mail: marcus.carlsson@med.lu.se

https://doi.org/10.1016/j.jacc.2017.09.1156

Please note: Dr. Heiberg is the owner of Medviso AB. Dr. Arheden own shares in Imacor AB. All other authors have reported that they have no relationships relevant to the contents of this paper to disclose.

REFERENCES

1. Stokke TM, Hasselberg NE, Smedsrud MK, 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.

2. Carlsson M, Ugander M, Heiberg E, Arheden H. The quantitative relationship between longitudinal and radial function in left, right, and total heart pumping in humans. Am J Physiol Heart Circ Physiol 2007; 293:H636–44.

3. Stoylen A. Basic concepts in myocardial strain and strain rate. Available at: http://folk.ntnu.no/stoylen/strainrate/Myocardial_strain#circumferential_strain. Accessed September 20, 2017.

4. Smiseth OA, Thompson CR, Lohavanichbutr K, et al. The pulmonary venous systolic flow pulse—its origin and relationship to left atrial pressure. J Am Coll Cardiol 1999;34:802–9.

5. Carlsson M, Cain P, Holmqvist C, Stahlberg F, Lundback S, Arheden H. Total heart volume variation throughout the cardiac cycle in humans. Am J Physiol Heart Circ Physiol 2004;287:H243–50.

Myocardial Contraction Fraction

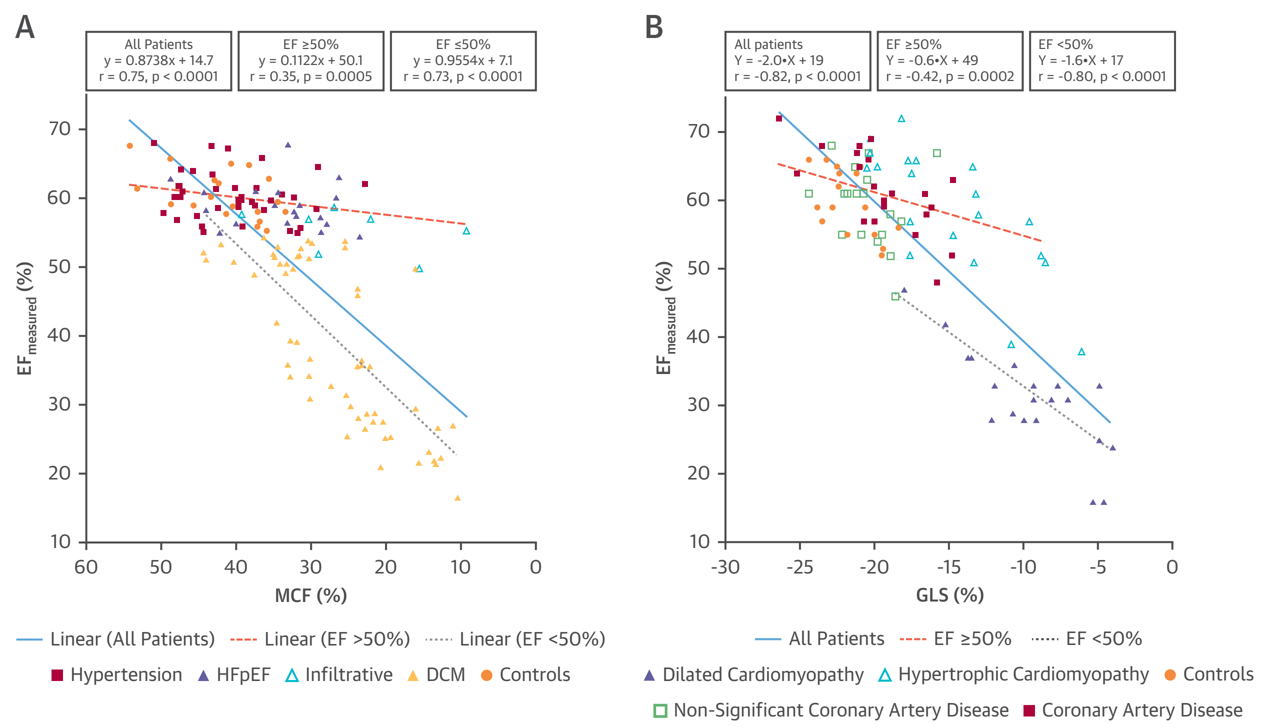
A Volumetric Measure of Myocardial Shortening Analogous to Strain

Stokke et al. (1) showed that despite reduced longitudinal and circumferential strain, ejection fraction is maintained by geometric factors, which prompted the editorialists to note, "although strain is emerging as the more optimal marker for LV systolic function, there seems to be no way to replace LVEF at this time, no matter how inaccurate it may be" (2). We would suggest that the myocardial contraction fraction (MCF) (3) fulfills the editorialists' suggestion for indexing left ventricular function to geometric parameters.

MCF, the ratio of stroke volume to myocardial volume, is a volumetric measure of myocardial shortening that is independent of chamber size and geometry, can distinguish physiological from pathological hypertrophy (3), is highly correlated with global longitudinal strain (4), and has shown prognostic significance in a variety of studies with various imaging techniques. As a measure of myocardial shortening, stroke volume is most appropriately assessed relative to the myocardial volume, because it is the myocardium that shortens. MCF is a measure of the amount by which the myocardium contracts during systole relative to total myocardial volume, although the myocardium itself has not undergone a reduction in volume. As with left ventricular ejection fraction, MCF is a unitless ratiometric with normal values similar to ejection fraction, thereby facilitating its clinical adoption.

In a cohort of patients with varying cardiac pathology, MCF, measured with freehand 3-dimensional echocardiography (3), had a very similar relationship to what was reported by Stokke et al. (1) (**Figure 1**), further supporting its potential clinical utility. We respectfully submit that MCF should be explored further to advance our understanding of this seemingly powerful, yet simple, metric.

FIGURE 1 **Correlation Between MCF, GLS, and EF**



(A) Correlation of myocardial contraction fraction (MCF) with ejection fraction (EF) by using freehand 3-dimensional echocardiography. There were 20 control subjects, 39 subjects with hypertension, 59 subjects with dilated cardiomyopathy (DCM), 8 subjects with infiltrative diseases, and 24 subjects with heart failure with preserved ejection fraction (HFpEF). **(B)** The regression analysis reveals a markedly weaker correlation between EF and MCF in the patient group with EF ≥50% compared with the group with EF <50%, similar to what was reported by Stokke, et al. (1) for global longitudinal strain (GLS).

Stephen D. Matthews, MD
Jonah Rubin, MD
Laura P. Cohen, MD, MPP
***Mathew S. Maurer, MD**

*Clinical Cardiovascular Research Laboratory for the Elderly
Columbia University Medical Center
Allen Hospital of NewYork-Presbyterian
5141 Broadway
3 Field West, Room 035
New York, New York 10034
E-mail: msm10@cumc.columbia.edu

https://doi.org/10.1016/j.jacc.2017.09.1157

Please note: Dr. Maurer is funded by a K24 Award from the National Institute on Aging (AG036778-07). All other authors have reported that they have no relationships relevant to the contents of this paper to disclose.

REFERENCES

1. Stokke TM, Hasselberg NE, Smedsrud MK, 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.

2. Januzzi JL Jr., Chandrashekhar Y. Strain echocardiography: the new gold standard for imaging ventricular function? J Am Coll Cardiol 2017; 70:955–7.

3. King DL, El-Khoury Coffin L, Maurer MS. Myocardial contraction fraction: a volumetric index of myocardial shortening by freehand three-dimensional echocardiography. J Am Coll Cardiol 2002;40:325–9.

4. Milani P, Dispenzieri A, Gertz MA, et al. In patients with light-chain (AL) amyloidosis myocardial contraction fraction (MCF) is a simple, but powerful prognostic measure that can be calculated from a standard echocardiogram (ECHO) (abstr). Blood 2015;126:1774.

Complexities in Modeling the Relationship Between Longitudinal Strain and Ejection Fraction

Stokke et al. (1) have performed a combined echocardiographic and mathematical modeling study to investigate the relationship between left ventricular (LV) ejection fraction (EF), global longitudinal strain (GLS), and global circumferential strain (GCS). On the basis of modeling using an equation for EF that included both GLS and GCS as independent variables, and that was validated against echocardiographic EF