The Good, the Bad, and the Ugly of Using Left Ventricular Longitudinal Myocardial Deformation by Speckle-Tracking Echocardiography to Assess Patients After an Acute Myocardial Infarction

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Timely reperfusion, effective mechanical recanalization of the obstructed coronary arteries, and aggressive antiplatelet therapy have dramatically improved the prognosis of patients with acute ST-segment–elevation myocardial infarction (STEMI).[1] Although no study has formally examined temporal trends in the prevalence of moderate to severe left ventricular (LV) systolic dysfunction after STEMI, it is likely that modern management of STEMI may have increased the proportion of patients who survive with only modest impairment of LV systolic function. However, not all survivors of a STEMI with normal or only modestly reduced LV ejection fractions have either a preserved systolic function or a favorable prognosis. Thus, a measure of systolic function in the setting of preserved LV ejection fraction that identifies high-risk STEMI patients could potentially be applied to identify those patients who may benefit from closer clinical monitoring, more aggressive management, and could be selected for future randomized studies testing new therapies.

See Article by Joyce et al

In this issue of the *Circulation: Cardiovascular Imaging*, Joyce et al[2] report about a large cohort of patients with first STEMI treated with primary percutaneous coronary intervention who were followed for 5.2 years to assess the effects of myocardial function and body size (namely body mass index [BMI]) on outcome defined as all-cause mortality. Interestingly, despite similar mild reduction in LV ejection fraction (46±9%, 48±9%, and 47±9%, respectively) in normal/underweight (BMI<25 kg/m^2), overweight (25 kg/m^2≤BMI<30 kg/m^2), and obese (BMI≥30 kg/m^2) STEMI patients, they found that LV global longitudinal strain (GLS) was also reduced in normal and overweight patients (−15.0±4.2),[3] but obese patients had a significantly more impaired LV GLS (−13.7±3.8%). This was observed despite similar infarct characteristics across the BMI groups. Moreover, LV GLS was significantly more impaired in patients with the highest BMI regardless of the presence of reduced or preserved LV ejection fraction, underscoring the relative inadequacy of LV ejection fraction to determine contractile abnormalities in this population. Conversely, survival was worse in lower BMI patients despite having less impaired LV systolic function than higher BMI patients. The study is interesting because it adds evidence about the need of a more sensitive marker than LV ejection fraction to assess LV function in STEMI patients managed with state-of-the-art treatment, and also because it shows that other factors (eg, patient body size) in addition to infarct size may affect LV GLS after STEMI. Notably, the relationship between BMI and LV GLS was also reported by Wong et al[4] in overweight and obese, but otherwise healthy subjects.

The Good

Speckle-tracking deformation imaging can provide a quantitative measure of myocardial function independent of LV ejection fraction which is a chamber function index and, as a such, more affected by loading conditions.[5] To date, research and clinical applications of speckle-tracking deformation imaging have focused on the assessment of LV GLS reflecting the function of subendocardial longitudinally oriented myocardial fibers, which are particularly sensitive to ischemia and increased wall stress.[5] LV GLS has been shown to correlate with infarct size,[6,7] and previous studies have shown that LV GLS adds prognostic value in patients with high-risk myocardial infarction and STEMI over the entire spectrum of systolic function.[8–12] Moreover, the presence of regional differences in electric properties may cause heterogeneity of myocardial contraction that can be measured as mechanical dispersion.[13] Measurements of mechanical dispersion and LV GLS in postmyocardial infarction patients have been reported to add important information about the risk of arrhythmia beyond LV ejection fraction.[13] In patients with a preserved or slightly reduced LV ejection fraction, mechanical dispersion >70 ms identified postmyocardial infarction patients with an increased risk of life-threatening arrhythmias.

The Bad

Widespread clinical application of speckle-tracking deformation imaging has been hampered by the fact that strain values are heavily influenced by both technical- and patient-specific factors.

Intervendor variability of strain values[14] has been partially addressed by the work of the European Association

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of Cardiovascular Imaging/American Society of Echocardiography/Industry Task Force to standardize deformation imaging[15] that managed to reduce the intervendor variability of 2-dimensional longitudinal strain.[16,17] Technical factors that may affect LV GLS values are mainly related to image quality and temporal resolution, selection of the region of interest, choice of LV segmentation model, quality of tracking, and identification of the end-systolic frame.[18] Recommendations on how to standardize most of these factors have been published.[15]

Demographic factors, such as reduction in myocardial deformation with aging and higher strain values in men than in women,[19] should be taken into account when interpreting strain values. The work of Joyce et al[2] highlights BMI among the factors to consider when interpreting LV GLS values. Finally, image acquisition plays also a pivotal role in strain assessment, and foreshortened apical views may result in inaccurate LV GLS measurements.

The Ugly

In patients with acute myocardial infarction, accurate and reproducible assessment of regional myocardial function is essential for early detection of ischemic injury and for the delineation of myocardial viability which helps guide patient management and potentially prevention of serious complications, such as LV remodeling, arrhythmias, and sudden cardiac death. LV segmental longitudinal strain measurements have been reported to detect the presence and extent of ischemia and distinguish between viable and nonviable segments.[20–24] However, a recent study by Mirea et al[25] performed in standardized conditions showed that the averaged absolute difference between repeated measurements of different regional longitudinal parameters ranged from 2.5% to 5.0%. Despite the fact that the lower end of this range might be still considered acceptable under certain conditions, the higher end constitutes an average relative error in the range of 25% which makes the regional strain measurement unsuited for clinical use. Moreover, a significant intervendor variability in regional strain values was also detected.[25]

There are reasons that may help explain the difference in performance between GLS and regional longitudinal strain in patients after myocardial infarction. To assess LV GLS, algorithms can apply a priori knowledge of LV shape and motion (eg, they assume that the apex is relatively fixed, and the mitral valve plane moves toward the apex). The measured extent of myocardial deformation can be averaged over a large area which makes the results more robust and reproducible. However, the only source of information to measure regional longitudinal strain is the local tracking of the speckles. Moreover, smoothness constraints in time and space must be limited to remain sensitive to regional abnormalities. Finally, good compensation of regional image artifacts (eg, reverberations, apical clutters) and a clear definition of the timing of strain measurements become pivotal for the correct interpretation of the abnormal strain patterns in pathology which requires at least the distinction among peak, end-systolic, and postsystolic strain values.

Conclusions

Semiautomated measurement of LV GLS is significantly associated with mortality, heart failure admission, and risk of life-threatening arrhythmias in survivors of acute myocardial infraction over the entire spectrum of LV ejection fraction. However, GLS values are heavily influenced by technical- and patient-specific factors that should be considered when interpreting strain values. At present, regional strain values are affected by large test/retest variability and suboptimal intervendor reproducibility that makes them unsuited for routine clinical use.

Disclosures

None.

References

1. Schmidt M, Jacobsen JB, Lash TL, Bøtker HE, Sørensen HT. 25 year trends in first time hospitalisation for acute myocardial infarction, subsequent short and long term mortality, and the prognostic impact of sex and comorbidity: a Danish nationwide cohort study. *BMJ*. 2012;344:e356.
2. Joyce E, Hoogslag GE, Kamperidis V, Debonnaire P, Katsanos S, Mertens B, Marsan NA, Bax JJ, Delgado V. Relationship between myocardial function, body mass index, and outcome after ST-segment–elevation myocardial infarction. *Circ Cardiovasc Imaging*. 2017;10:e005670. doi: 10.1161/CIRCIMAGING.116.005670.
3. Joyce E, Hoogslag GE, Leong DP, Debonnaire P, Katsanos S, Boden H, Schalij MJ, Marsan NA, Bax JJ, Delgado V. Association between left ventricular global longitudinal strain and adverse left ventricular dilatation after ST-segment-elevation myocardial infarction. *Circ Cardiovasc Imaging*. 2014;7:74–81. doi: 10.1161/CIRCIMAGING.113.000982.
4. Wong CY, O'Moore-Sullivan T, Leano R, Byrne N, Beller E, Marwick TH. Alterations of left ventricular myocardial characteristics associated with obesity. *Circulation*. 2004;110:3081–3087. doi: 10.1161/01.CIR.0000147184.13872.0F.
5. Mor-Avi V, Lang RM, Badano LP, Belohlavek M, Cardim NM, Derumeaux G, Galderisi M, Marwick T, Nagueh SF, Sengupta PP, Sicari R, Smiseth OA, Smulevitz B, Takeuchi M, Thomas JD, Vannan M, Voigt JU, Zamorano JL. Current and evolving echocardiographic techniques for the quantitative evaluation of cardiac mechanics: ASE/EAE consensus statement on methodology and indications endorsed by the Japanese Society of Echocardiography. *J Am Soc Echocardiogr*. 2011;24:277–313. doi: 10.1016/j.echo.2011.01.015.
6. Gjesdal O, Helle-Valle T, Hopp E, Lunde K, Vartdal T, Aakhus S, Smith HJ, Ihlen H, Edvardsen T. Noninvasive separation of large, medium, and small myocardial infarcts in survivors of reperfused ST-elevation myocardial infarction: a comprehensive tissue Doppler and speckle-tracking echocardiography study. *Circ Cardiovasc Imaging*. 2008;1:189–196. doi: 10.1161/CIRCIMAGING.108.784900.
7. Munk K, Andersen NH, Nielsen SS, Bibby BM, Bøtker HE, Nielsen TT, Poulsen SH. Global longitudinal strain by speckle tracking for infarct size estimation. *Eur J Echocardiogr*. 2011;12:156–165. doi: 10.1093/ejechocard/jeq168.
8. Antoni ML, Mollema SA, Delgado V, Atary JZ, Borleffs CJ, Boersma E, Holman ER, van der Wall EE, Schalij MJ, Bax JJ. Prognostic importance of strain and strain rate after acute myocardial infarction. *Eur Heart J*. 2010;31:1640–1647. doi: 10.1093/eurheartj/ehq105.
9. Hung CL, Verma A, Uno H, Shin SH, Bourgoun M, Hassanein AH, McMurray JJ, Velazquez EJ, Kober L, Pfeffer MA, Solomon SD; VALIANT investigators. Longitudinal and circumferential strain rate, left ventricular remodeling, and prognosis after myocardial infarction. *J Am Coll Cardiol*. 2010;56:1812–1822. doi: 10.1016/j.jacc.2010.06.044.
10. Munk K, Andersen NH, Terkelsen CJ, Bibby BM, Johnsen SP, Bøtker HE, Nielsen TT, Poulsen SH. Global left ventricular longitudinal systolic strain for early risk assessment in patients with acute myocardial infarction treated with primary percutaneous intervention. *J Am Soc Echocardiogr*. 2012;25:644–651. doi: 10.1016/j.echo.2012.02.003.
11. Ersbøll M, Valeur N, Mogensen UM, Andersen MJ, Møller JE, Velazquez EJ, Hassager C, Søgaard P, Køber L. Prediction of all-cause mortality and heart failure admissions from global left ventricular longitudinal strain in patients with acute myocardial infarction and preserved left ventricular

ejection fraction. *J Am Coll Cardiol*. 2013;61:2365–2373. doi: 10.1016/j.jacc.2013.02.061.
12. Meimoun P, Abouth S, Clerc J, Elmkies F, Martis S, Luycx-Bore A, Boulanger J. Usefulness of two-dimensional longitudinal strain pattern to predict left ventricular recovery and in-hospital complications after acute anterior myocardial infarction treated successfully by primary angioplasty. *J Am Soc Echocardiogr*. 2015;28:1366–1375. doi: 10.1016/j.echo.2015.07.022.
13. Haugaa KH, Smedsrud MK, Steen T, Kongsgaard E, Loennechen JP, Skjaerpe T, Voigt JU, Willems R, Smith G, Smiseth OA, Amlie JP, Edvardsen T. Mechanical dispersion assessed by myocardial strain in patients after myocardial infarction for risk prediction of ventricular arrhythmia. *JACC Cardiovasc Imaging*. 2010;3:247–256. doi: 10.1016/j.jcmg.2009.11.012.
14. Takigiku K, Takeuchi M, Izumi C, Yuda S, Sakata K, Ohte N, Tanabe K, Nakatani S; JUSTICE Investigators. Normal range of left ventricular 2-dimensional strain: Japanese Ultrasound Speckle Tracking of the Left Ventricle (JUSTICE) study. *Circ J*. 2012;76:2623–2632. doi: 10.1253/circj.CJ-12-0264.
15. Voigt JU, Pedrizzetti G, Lysyansky P, Marwick TH, Houle H, Baumann R, Pedri S, Ito Y, Abe Y, Metz S, Song JH, Hamilton J, Sengupta PP, Kolias TJ, d'Hooge J, Aurigemma GP, Thomas JD, Badano LP. Definitions for a common standard for 2D speckle tracking echocardiography: consensus document of the EACVI/ASE/Industry Task Force to standardize deformation imaging. *Eur Heart J Cardiovasc Imaging*. 2015;16:1–11. doi: 10.1093/ehjci/jeu184.
16. Farsalinos KE, Daraban AM, Ünlü S, Thomas JD, Badano LP, Voigt JU. Head-to-head comparison of global longitudinal strain measurements among nine different vendors: the EACVI/ASE Inter-Vendor Comparison Study. *J Am Soc Echocardiogr*. 2015;28:1171–1181, e2. doi: 10.1016/j.echo.2015.06.011.
17. Yang H, Marwick TH, Fukuda N, Oe H, Saito M, Thomas JD, Negishi K. Improvement in strain concordance between two major vendors after the strain standardization initiative. *J Am Soc Echocardiogr*. 2015;28:642.e7–648.e7. doi: 10.1016/j.echo.2014.12.009.
18. Collier P, Phelan D, Klein A. A test in context: myocardial strain measured by speckle-tracking echocardiography. *J Am Coll Cardiol*. 2017;69:1043–1056. doi: 10.1016/j.jacc.2016.12.012.
19. Kocabay G, Muraru D, Peluso D, Cucchini U, Mihaila S, Padayattil-Jose S, Gentian D, Iliceto S, Vinereanu D, Badano LP. Normal left ventricular mechanics by two-dimensional speckle-tracking echocardiography. Reference values in healthy adults. *Rev Esp Cardiol*. 2014;67:651–658. doi: 10.1016/j.rec.2013.12.009.
20. Jurcut R, Pappas CJ, Masci PG, Herbots L, Szulik M, Bogaert J, Van de Werf F, Desmet W, Rademakers F, Voigt JU, D'hooge J. Detection of regional myocardial dysfunction in patients with acute myocardial infarction using velocity vector imaging. *J Am Soc Echocardiogr*. 2008;21:879–886. doi: 10.1016/j.echo.2008.02.002.
21. Sjøli B, Ørn S, Grenne B, Ihlen H, Edvardsen T, Brunvand H. Diagnostic capability and reproducibility of strain by Doppler and by speckle tracking in patients with acute myocardial infarction. *JACC Cardiovasc Imaging*. 2009;2:24–33. doi: 10.1016/j.jcmg.2008.10.007.
22. Sun JP, Niu J, Chou D, Chuang HH, Wang K, Drinko J, Borowski A, Stewart WJ, Thomas JD. Alterations of regional myocardial function in a swine model of myocardial infarction assessed by echocardiographic 2-dimensional strain imaging. *J Am Soc Echocardiogr*. 2007;20:498–504. doi: 10.1016/j.echo.2006.10.029.
23. Winter R, Jussila R, Nowak J, Brodin LA. Speckle tracking echocardiography is a sensitive tool for the detection of myocardial ischemia: a pilot study from the catheterization laboratory during percutaneous coronary intervention. *J Am Soc Echocardiogr*. 2007;20:974–981. doi: 10.1016/j.echo.2007.01.029.
24. Aarsaether E, Rösner A, Straumbotn E, Busund R. Peak longitudinal strain most accurately reflects myocardial segmental viability following acute myocardial infarction - an experimental study in open-chest pigs. *Cardiovasc Ultrasound*. 2012;10:23. doi: 10.1186/1476-7120-10-23.
25. Mirea O, Pagourelias ED, Duchenne J, Bogaert J, Thomas JD, Badano LP, Voigt JU. Variability and reproducibility of segmental longitudinal strain measurements. a report from the EACVI-ASE strain standardization task force [published online ahead of print May 12, 2017]. *JACC Cardiovasc Imaging*. doi: 10.1016/j.jcmg.2017.01.027. http://www.sciencedirect.com/science/article/pii/S1936878X17303601.

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