Unidimensional Longitudinal Strain: A Simple Approach for the Assessment of Longitudinal Myocardial Deformation by Echocardiography

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Background: Impaired left ventricular (LV) longitudinal function (LF) is a known predictor of cardiac events in patients with heart failure, but two-dimensional strain imaging, the reference method to measure myocardial deformation, is not always feasible or available. Therefore, reliable and reproducible alternatives are needed. The aim of the present study was to evaluate unidimensional longitudinal strain (ULS) as a simple echocardiographic parameter for the assessment of LV LF.

Methods: Two hundred two patients with dilated cardiomyopathy who had their first presentation in the authors' cardiology department, as well as the same number of age- and gender-matched control subjects, were prospectively included in this study. ULS was compared with global longitudinal strain (GLS), the current gold standard for LV LF assessment by echocardiography. Uni- and multivariate Cox regression analyses were conducted to evaluate the prognostic value of ULS.

Results: LV LF was higher in the control group compared with patients: GLS −19.5 ± 1.7% versus −12.6 ± 4.8% and ULS −16.3 ± 1.5% versus −10.2 ± 3.9% ($P < .001$ for each). Correlation between ULS and GLS was excellent ($r = 0.94$), while Bland-Altman plots revealed lower values for ULS (bias −2.76%, limits of agreement ±3.31%). During a mean follow-up time of 39 months, the combined end point of cardiovascular death or hospitalization for acute cardiac decompensation was reached by 28 patients (13.9%). GLS (hazard ratio, 1.21; 95% CI, 1.10–1.34; $P < .001$) and ULS (hazard ratio, 1.24; 95% CI, 1.12–1.39; $P < .001$) had comparable prognostic impact on patient outcomes.

Conclusions: ULS might be an alternative echocardiographic method for the assessment of LV LF, with similar diagnostic and prognostic value compared with GLS. (J Am Soc Echocardiogr 2018;■:■-■.)

Keywords: Echocardiography, Strain, Longitudinal left ventricular function

Heart failure is a syndrome affecting about 1% to 2% of the population in the Western world and has evolved into a major health problem also in developing countries.[1,2] Its etiology is multifactorial and comprises coronary artery disease, abnormal loading conditions, arrhythmias, and cardiomyopathies.[3] Acute decompensation is a common finding in chronic heart failure and may indicate progressive deterioration of cardiac function, which subsequently can lead to hospitalization, a strong predictor of mortality in patients with heart failure.[4,5] Therefore, early detection of left ventricular (LV) systolic dysfunction is one of the main tasks of cardiac imaging.

The quantitative method most frequently used for grading systolic heart failure is the biplane assessment of ejection fraction (EF) by echocardiography, but this volumetry-based technique shows significant variability, examiner dependency, and limited intermodality agreement, especially compared with cardiac magnetic resonance imaging.[6,7] Furthermore, changes in cavity size do not entirely reflect the complexity of LV systolic function, which is much more determined by different components of myocardial deformation. On the basis of the complex arrangement of myocardial muscle layers,[8,9] contraction is multidimensional, including apicobasal torsion, longitudinal shortening, and radial thickening. Since Feigenbaum's first echocardiographic recordings of mitral annular motion in the late 1960s,[10] systolic LV longitudinal function (LF) in particular has gained increasing diagnostic importance and has shown superior prognostic value compared with LVEF.[11] One of the possible mechanisms may represent the fact that LV LF appears to be the main

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Conflicts of Interest: None.

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Abbreviations

AUC = Area under the curve

AV = Atrioventricular

DCM = Dilated cardiomyopathy

EF = Ejection fraction

GLS = Global longitudinal strain

LV = Left ventricular

LF = Longitudinal function

MAPSE = Mitral annular plane systolic excursion

MASV = Mitral annular systolic velocity

ULS = Unidimensional longitudinal strain

contributor to stroke volume generation.[12,13] Hence, techniques that enable assessment of LV LF are of great clinical relevance.

Strain imaging allows the direct measurement of myocardial deformation.[14] New implementations such as two-dimensional speckle-tracking analysis permit angle-independent assessments, but dependency on proprietary products or additional nonproprietary expensive software options limit common use, especially in developing countries. Therefore, we aimed to investigate a vendor-independent approach to evaluate global LF by echocardiography.

METHODS

Study Population

Adult patients with systolic heart failure who had their initial visit in our cardiology department were recruited between January 2009 and December 2015. Patients were invited to participate in this study if significant coronary artery disease could be excluded by left heart catheterization and cardiomyopathy was suspected. Information on demographics, case history, and laboratory results were collected, and a comprehensive echocardiographic examination was performed in every patient. Because our focus was on patients with dilated cardiomyopathy (DCM), patients with signs of LV hypertrophy due to hypertensive heart disease, hypertrophic cardiomyopathy, or storage disorders were excluded. The final patient population consisted of 202 individuals. Follow-up data were retrieved from digital clinical records and/or telephone interviews with patients, relatives, or family doctors. An age- and gender-matched control group of equal size was obtained from ongoing recruitment of prospectively comprehensively characterized healthy adult individuals across all ages and sexes.

The present study was carried out after approval by the ethics committee of the University of Heidelberg in concordance with the Declaration of Helsinki and with informed consent from all participants.

Echocardiography

Echocardiographic examinations were conducted using a commercially available ultrasound machine (Vivid E9 BT 11; GE Vingmed Ultrasound, Horten, Norway) using a 1.5- to 4.6-MHz phased-array probe (M5S-D). Three consecutive heart cycles were acquired for each two-dimensional image, with a sampling rate of 55 to 60 frames/sec. Special care was taken to avoid apical foreshortening during acquisition of the apical image planes. Offline analysis was conducted according to the recommendation of the American Society of Echocardiography and the European Association of Cardiovascular Imaging[15] using commercially available software (EchoPAC version 110.1.1 BT 11; GE Vingmed Ultrasound). Global longitudinal strain (GLS) measurements were performed on two-dimensional B-mode images of the apical two-, three-, and four-chamber views using the embedded Automated Function Imaging tool. Aortic valve closure was used to define end-systole. Mitral annular plane systolic excursion (MAPSE) and mitral annular systolic velocity (MASV), two other established LF parameters, derived from M-mode and color tissue Doppler records of the lateral mitral annulus in the four-chamber view, respectively.

Unidimensional Longitudinal Strain. This parameter for the assessment of LV LF is based on mitral annular plane excursion, the displacement of the LV base toward the apex during systole. In analogy to two- and three-dimensional techniques, we call this method "unidimensional longitudinal strain" (ULS) because it uses simple long-axis length measurements on B-mode grayscale images to calculate an equivalent of GLS.

ULS measurements were conducted on the same apical two-, three- and four-chamber views as used for GLS analysis. End-systole and end-diastole were defined visually as the time points of smallest and largest LV cavity size during the cardiac cycle, respectively. Longitudinal dimensions of the left ventricle were measured in a straight line from apex to base (Figures 1A and 1B). The epicardium served as an apical marker and the mitral annular plane, defined as the border between the LV myocardium and the fibrous part of mitral annulus, as a basal marker. For anteroseptal segments, we used the transition between muscular and membranous septum. According to the six longitudinal sections of the left ventricle, six diastolic and six systolic measurements were acquired. The final calculation of ULS is based on the Lagrange strain formula as follows: (end-systolic length − end-diastolic length)/end-diastolic length × 100.[16] All resulting values were than averaged to obtain the global ULS of the whole left ventricle expressed as a percentage.

Statistical Analysis

SPSS version 22 (IBM, Armonk, New York) was used for statistical analysis. Continuous values are reported as mean ± SD or as median (interquartile range) in case of skewed distribution, and categorical variables are expressed as number (percentage). Significance of continuous values was tested using Student's t test for normally distributed data; otherwise the Wilcoxon signed rank test for paired observations (patients vs control subjects) or the Mann-Whitney-Wilcoxon test for unpaired observations (patients with or without events) was used. Categorical variables were compared using χ^2 or McNemar tests as appropriate. P values $< .05$ were considered to indicate statistical significance. Pearson's correlation coefficients between the LV LF parameters were calculated, and agreement of ULS with GLS was analyzed using Bland-Altman plots. Receiver operating characteristic analyses were conducted to test the ability of different LV LF parameters to discriminate patients with DCM from healthy subjects and then again to discriminate patients with DCM with from those without cardiac events. Optimal cutoff values were calculated using Youden statistics. A combined end point included cardiovascular death[17] and cardiac decompensation with need for hospitalization. Kaplan-Meier curves and log-rank tests were used to display the occurrence of cardiac events over time. Hazard ratios were calculated using univariate Cox regression to investigate the impact of clinical, laboratory, and echocardiographic parameters on patient outcomes. On the basis of the results of the univariate regression analysis, different multivariate models were built including parameters with P values $< .05$. To identify independent prognostic variables, stepwise backward elimination using the Wald method was conducted.

To analyze intra- and interobserver variability, 40 randomly chosen patients and control subjects were reanalyzed in a blinded fashion by