# Impact of Global and Segmental Hypertrophy on Two-Dimensional Strain Derived from Three-Dimensional Echocardiography in Hypertrophic Cardiomyopathy: Comparison with Healthy Subjects

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*Background:* Patients with hypertrophic cardiomyopathy (HCM) present unusual myocardial mechanics. The aim of this study was to assess the impact of hypertrophy on global and regional two-dimensional (2D) strain derived from both tomographic images (2D/2D) and volumetric image acquisition (2D/three-dimensional [3D]) in patients with HCM compared with control subjects.

*Methods:* Comprehensive resting 2D and 3D echocardiography was performed in 40 patients with HCM and in 53 control subjects, with comparable distributions of age, gender, and left ventricular (LV) ejection fraction. LV global and segmental measurements of all 2D/2D and 2D/3D peak strain components (global and segmental longitudinal strain, global and segmental circumferential strain, global and segmental radial strain, and global and segmental area strain) and 3D indexed LV end-diastolic myocardial mass were obtained from all patients. LV wall thickness was assessed in short-axis views and classified in four quartiles (<10.5, 10.5–13.0, 13.0–16.5, and >16.5 mm).

*Results:* The reproducibility of 2D/3D strain was similar or greater and more consistent for all components compared with 2D/2D strain analysis. There was a significant correlation between 3D LV end-diastolic mass and all 2D/3D strain components ($P < .05$). Two-dimensional/3D global circumferential strain had the strongest association with 3D LV ejection fraction ($r = 0.50$, $P = .001$). For segmental deformation, patients with HCM had lower longitudinal deformation whatever the LV wall thickness, whereas circumferential function was increased in nonhypertrophied and poorly hypertrophied segments compared with control subjects.

*Conclusions:* Two-dimensional/3D strain is a reliable technique to assess myocardial deformation. Myocardial mass is related to 2D/3D strain components in patients with HCM. Circumferential deformation, compared with longitudinal deformation, seems to be the main component of the maintenance of systolic function in HCM. (J Am Soc Echocardiogr 2015;■:■-■.)

*Keywords:* Echocardiography, Hypertrophic cardiomyopathy, Myocardial thickness, Myocardial mass, 3D strain

With an approximate prevalence of 0.2%,[1] hypertrophic cardiomyopathy (HCM) is the most frequent genetic cardiomyopathy.[2] This pathology is characterized by a myocardial asymmetric or concentric hypertrophy associated with myocardial fiber disarray and fibrosis, leading to global and regional variability and heterogeneity of systolic and diastolic deformation.[3] As mentioned in a recent guideline document, "a better assessment of underlying pathophysiology and anatomy is crucial to improve the management of HCM patients."[4] Therefore, assessment of systolic deformation by either magnetic resonance imaging[5] or echocardiography[6,7] has been extensively studied (Figure 1A–1C). Impairment of the global and regional longitudinal deformation of the myocardium is well recognized in this population.[8,9] However, there are some discrepancies in the literature regarding other deformation parameters, such as circumferential strain.[9-14] Assessment of deformation in the three directions with two-dimensional (2D) speckle-tracking can be difficult because of out-of-plane motion, left ventricular (LV) foreshortening, changes in heart rate and loading conditions. Furthermore, acquisitions of the 6 required LV views can be time consuming.[15] Moreover, matching different segments between apical and short-axis views may be challenging. Two-dimensional strain calculated from three-dimensional (3D) echocardiographic acquisitions

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Control subjects were included in the STANISLAS COHORT, which is supported by grants from the French Ministry of Health (Programme Hospitalier de Recherche Clinique Inter-Régional 2008) and sponsored by CHU Nancy (Nancy, France).

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0894-7317/$36.00



http://dx.doi.org/10.1016/j.echo.2015.03.010

**Abbreviations**

**GCS** = Global circumferential strain

**GLS** = Global longitudinal strain

**HCM** = Hypertrophic cardiomyopathy

**LA** = Left atrial

**LV** = Left ventricular

**LVEF** = Left ventricular ejection fraction

**SLS** = Segmental longitudinal strain

**SRS** = Segmental radial strain

**3D** = Three-dimensional

**2D** = Two-dimensional

(2D/3D) has emerged as a potential solution, allowing measurement of all strain components in all LV segments from a single acquisition, thereby also addressing the difficulty of matching different segments (Figure 1D–1G). The potential interest of 3D echocardiography has been suggested in some recent studies in patients with HCM,[14,16,17] but further investigation is needed to confirm the feasibility and reliability of this approach.

The primary aim of our study was to compare patients with HCM and control subjects regarding classical echocardiographic parameters and 2D- and 3D-derived deformation parameters and to determine the impact of global myocardial mass and regional thickness on all 2D/3D global and regional strain components. The secondary aim of our study was to investigate the feasibility and the reliability of 2D/3D strain analysis and to determine if deformation parameters may be related to systolic function and/or clinical events in patients with HCM.

## METHODS

The study group consisted of 40 patients with HCM diagnosed using previous validated criteria[1] (LV hypertrophy with LV wall thickness ≥ 15 mm for isolated cases and ≥13 mm for familial screening, with asymmetric distribution associated with a nondilated and hyperdynamic chamber in the absence of another cardiac or systemic disease [e.g., hypertension or aortic stenosis] associated with preserved LV ejection fraction [LVEF] [>50% assessed both by 2D and 3D methods[4]]), who were referred to our university center from January 2008 to January 2013. All patients underwent comprehensive 2D and 3D resting echocardiography as part as routine evaluation and therefore were prospectively included. The distribution of hypertrophy in patients with HCM was defined as described by Maron *et al.*[18]: focal, two or fewer hypertrophied segments; intermediate, three to seven hypertrophied segments; and diffuse, more than seven segments. A control group composed of 53 patients with normal clinical and echocardiographic findings and no family histories of HCM, who were included in a prospective survey approved by the institutional review board, underwent the same echocardiographic protocol. All patients with HCM gave their oral consent to use their data in this study.

### Echocardiographic Imaging and Analysis

Echocardiography was performed with commercially available standard ultrasound scanners (Vivid 7 and Vivid 9; GE Vingmed Ultrasound AS, Horten, Norway) with a 2.5-MHz transducer and a 3D probe (4V or 4D Volume Phased Array Probe).

Two-dimensional echocardiographic images of the left ventricle were obtained from the parasternal long-axis and short-axis views at the basal, median, and apical levels and from the three standard LV apical views (four, two, and three chambers). From the apical position, a full LV volume was acquired in a wide-angled acquisition "full-volume" mode. In this mode, a number of wedge-shaped subvolumes (four to six) are acquired over consecutive cardiac cycles during a single breath-hold and stitched together to create one pyramidal volume sample. All images were acquired at frame rates of ≥60 frames/sec for 2D imaging and 25 volumes/sec for 3D imaging.

### Two-Dimensional Echocardiographic Parameter Acquisition and Analysis

Classical 2D echocardiographic parameters were measured: interventricular septal and posterior wall thicknesses and end-diastolic and end-systolic LV diameters were measured from the parasternal long-axis view, and LVEF was calculated by using the biplane Simpson method from the apical four- and two-chamber views. Left atrial (LA) and right atrial areas were measured from the apical four-chamber view. Mitral inflow velocities of the E wave, the A wave, and the deceleration time of the E wave were assessed by Doppler imaging. Septal and lateral e′ velocities at the level of the mitral annulus were recorded with Doppler tissue imaging from the apical four-chamber view.

Maximal end-diastolic LV wall thickness was measured from the 2D short-axis view for each segment according to a 16-segment model.

All echocardiographic parameters were measured in accordance with the latest European guidelines.[19]

### Three-Dimensional Image Acquisition and Analysis

Three-dimensional echocardiographic images were recorded from the apical position in a wide-angled "full-volume" acquisition mode. Special care was taken to include the entire LV cavity within the pyramidal 3D volume and to adjust width to improve the temporal and spatial resolution.

The software (4D Auto LVQ; GE Healthcare, Little Chalfont, United Kingdom) automatically displays three apical and three short-axis views. Endocardial and epicardial surfaces are automatically detected with manual adjustments possible when necessary. The following 3D standard parameters are displayed: 3D LV end-diastolic and end-systolic volumes, LVEF, and LV end-diastolic mass.

The system then performs the wall deformation analysis and calculates 2D strain from 2D projections of the 3D images (slice thickness is determined automatically by the software, and the default value was used) and provides both the 2D/3D LV global peak value of each strain component (global longitudinal strain [GLS], global area strain, global radial strain, and global circumferential strain [GCS]) and segmental values (segmental longitudinal strain [SLS], segmental area strain, segmental radial strain [SRS], and segmental circumferential strain).

### Clinical End Points

Clinical follow-up was performed. Cardiovascular events were defined as hospitalization for heart failure, atrial fibrillation, and/or sustained ventricular arrhythmias.

### Statistical Analysis

Continuous variables are expressed as mean ± SD and categorical variables as numbers and percentages. One-way analysis of variance was performed to determine global *P* value for the comparison