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Original Article

Internal Medicine Section

Evaluation of Subtle Left Ventricular Systolic Abnormalities in Adult Patients with Hypertrophic Cardiomyopathy

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ABSTRACT

Background: Hypertrophic cardiomyopathy (HCM), an autosomal dominant disorder due to mutation of genes encoding sarcomeric proteins, leads to left ventricular diastolic dysfunction. Recently, the research in this area suggests that systolic dysfunction exists in the patients with HCM even though traditional measures of systolic dysfunction are normal. So, we carried out this study to determine global systolic dysfunction in patients with HCM.

Materials and Methods: A total of 18 patients, diagnosed with HCM according to echocardiography parameters, that is thickness of interventricular septum/posterior wall thickness >1.3 or hypertrophy involving apex only with or without left ventricular outflow tract obstruction, were included in the study and were compared with normal age-matched controls. We measured torsion and strain imaging by 2-dimensional echocardiography as well as strain imaging by tissue Doppler echocardiography.

Result: The results of the study showed that there was considerable increased torsion in patients with HCM as compared to normal subjects (16.61±7.43 vs. 10.42±4.73, p=0.006). Tissue Doppler indices—systolic annular velocity (7.7±0.7 vs. 8.7±1.00, p=0.012) and lateral wall E/E' (12.52±5.27 vs. 6.66±1.67, p<0.001) were significantly different in patients with HCM and normal subjects. The average systolic strain and strain rate as well as diastolic strain rate were significantly different in both the groups when strain imaging was performed by tissue Doppler echocardiography. We also observed significantly reduced global longitudinal, circumferential and radial strain in patients with HCM when strain analysis was carried out with 2-dimensional speckle tracking echocardiography.

Conclusion: The global subtle systolic dysfunction, as measured by left ventricular torsion and strain imaging, is present in patients with HCM even though traditional measure of systolic dysfunction is normal.

Keywords: Global systolic dysfunction, Hypertrophic cardiomyopathy, Left-ventricular torsion, Strain imaging

INTRODUCTION

Hypertrophic cardiomyopathy (HCM) is an autosomal dominant disease which results due to mutation in genes encoding sarcomeric protein [1]. HCM is characterized as myocardial disarray, interstitial fibrosis and asymmetrical left ventricular hypertrophy (LVH) in the absence of hypertension or valve disease. As a result of these pathologies, diastolic dysfunction is observed in patients with HCM. In these patients, the diastolic dysfunction is associated with relaxation abnormalities in early stage which may proceed to more restrictive physiology with the progression of the disease.

Even though HCM is stated as disease predominantly associated with diastolic dysfunction along with preserved systolic function in early stage, recently the research in this area suggests that systolic dysfunction exists in patients with HCM [2-3]. The systolic dysfunction in HCM patients is related to maximal wall thickness and decreased exercise capacity [3]. However, traditional measures of systolic dysfunction, left ventricle ejection fraction (LVEF) and fractional shortening (FS), are normal.

Tissue Doppler indices and strain imaging are used to assess myocardial dysfunction in various cardiac diseases. Torsion is also recently proven an important parameter used to quantify systolic dysfunction as it is sensitive index to endocardial and epicardial contraction, concentric remodelling and fibrous structure of the heart [4]. So, we designed this study with the aim of quantifying subclinical systolic dysfunction in patients with HCM. The main objectives of this study are: (1) To assess myocardial dysfunction in patients with HCM using tissue Doppler indices, (2) To assess myocardial dysfunction by strain imaging using tissue Doppler imaging (TDI) and 2-D speckle tracking echocardiography (2-D STE), (3) To observe the difference in left ventricular torsion between normal healthy individuals and the patients with HCM using 2-D STE.

MATERIALS AND METHODS

Study Design

This was prospective case-control and single-centre study carried out at Kasturba Medical College and Hospital, Manipal, India between November 2012 and July 2013. The protocol of the study was approved by institutional ethics committee of the hospital before the commencement of the study. Informed consents were obtained from all the patients enrolled in the study.

Patient Population

During the study period, 18 patients diagnosed with HCM and 18 age matched controls were included in the study. The patients were diagnosed with HCM if the echocardiographic examinations showed non-dilated, hypertrophic left ventricle (LV) without any known cause i.e. long-term hypertension or other cardiac/systemic disease and the ratio of thickness of interventricular septum (IVS) and posterior wall thickness (PW) was >1.3 with or without left ventricular outflow tract obstruction (LVOTO) or systolic anterior motion of mitral valve (SAM) or patients diagnosed with apical HCM. The patients having LVEF <50% or irregular rhythm were excluded from the study. The enrolled patients were compared with 18 healthy age-matched control subjects. Based on the echocardiographic examinations, we have classified HCM into 4 categories as follows:

- **Type 1:** hypertrophy involving IVS and anterior wall (AW) of LV.
- **Type 2:** hypertrophy involving IVS, AW and lateral wall (LW) of LV.

Variables	HCM (N=18)	Control (N=18)	p-value
Clinical Characteristics			
Age (years)	50.22±18.03	Matched	
Male:Female	14:4	15:3	
Echocardiographic Characteristics			
LV end-diastolic dimension (mm)	43.22±7.01	47.22±4.57	0.042
LV end-systolic dimension (mm)	26.00±5.19	29.39±3.52	0.028
Interventricularseptal thickness (mm)	18.22±4.87	8.94±1.06	<0.001
Posterior wall thickness (mm)	10.06±2.75	8.67±1.28	0.061
Relative wall thickness	0.67±0.15	0.38±0.05	<0.001
LV mass index	251.01±86.24	142.01±34.36	<0.001
LV ejection fraction (%)	70.89±5.81	67.22±3.69	0.030
Fractional shortening (%)	40.17±4.42	37.22±3.25	0.022
E/A	1.50±0.78	0.94±0.38	0.019
Deceleration time (ms)	141.56±28.29	193.17±25.34	<0.001

[Table/Fig-1]: Clinical & Echocardiographic characteristics of patients with HCM and control, *Unpaired t-test or Mann-Whitney test was used depending upon normality distribution of the data. p<0.05 was considered statistically significant*

Variables	HCM (N=18)	Control (N=18)	p-value
Lateral Wall E/E'	12.52±5.27	6.66±1.67	<0.001
Lateral Wall E'/A'	1.52±0.89	1.18±0.43	0.150
Interventricular Septal E'/A'	0.89±0.31	1.03±0.278	0.144
Systolic annular velocity (S), cm/s	7.7±0.7	8.7±1.00	0.012

[Table/Fig-2]: Tissue doppler indices, *Unpaired t-test or Mann-Whitney test was used depending upon normality distribution of the data. p<0.05 was considered statistically significant*

Variables	HCM (N=18)	Control (N=18)	p-value
2-D Speckle Tracking Echocardiography			
Global longitudinal strain	14.18±2.06	22.82±2.19	<0.001
Global circumferential strain	20.43± 3.69	27.33±4.90	<0.001
Global radial strain	24.14±8.04	32.85±7.54	0.003
Tissue Doppler Imaging			
Strain Imaging (Average of all segments)	18.88±2.23	23.37±1.37	<0.001
Systolic strain rate (Average of all segments)	0.95±0.17	1.35±0.13	<0.001
Diastolic strain rate (Average of all segments)	0.71±0.13	1.36±0.10	<0.001

[Table/Fig-3]: Strain imaging measurement by 2-D STE & TDI *Unpaired t-test or Mann-Whitney test was used depending upon normality distribution of the data. p<0.05 was considered statistically significant*

- **Type 3:** hypertrophy involving apex only.
- **Type 4:** Concentric HCM, involving all the segments of LV.

Echocardiographic evaluation

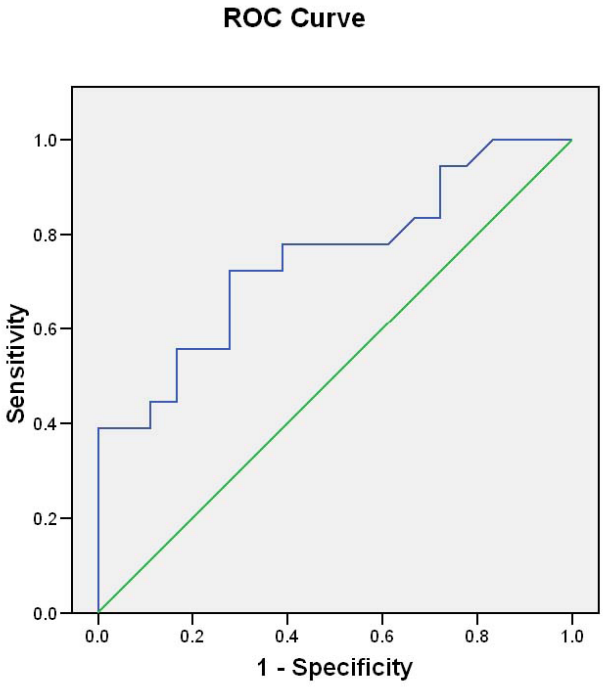
All 36 individuals enrolled in the study were scanned using Vivid 7 dimension ultrasound machine, GE Healthcare with 3.5 MHz transducer. Images were obtained in the apical four-chamber, long-axis view, left ventricular short axis view and two-chamber view. For all echocardiographic evaluation, we had defined proper short axis levels as follows: mitral valve was considered as the basal level and LV cavity (alone with no visible papillary muscle) was considered as the apical level. The LV short axis was made as circular as possible and the frame rate was kept 65.8 frames/s with optimum sector width and image depth with gray-scale 2D-mode. The color tissue velocity imaging (TVI) images were saved with a colour frame-rate of 100–140 frames/s (depending on the sector width), in the three standard apical views. Using high spatial resolution at a depth of 16 cm and pulse repetition frequencies between 500 and 1000

Variables	HCM (N=18)	Control (N=18)	p-value
Apical rotation	11.35±7.15	6.97±3.34	0.024
Basal rotation	-5.33±4.15	-3.83±2.40	0.040
Torsion	16.61±7.43	10.42±4.73	0.006

[Table/Fig-4]: LV rotational behavior in patients with HCM and control by2-D STE, *Unpaired t-test or Mann-Whitney test was used depending upon normality distribution of the data. p<0.05 was considered statistically significant*

Parameters	AUC	Confidence Interval	Cut-off point	Sensitivity	Specificity
Torsion	0.747	(0.586-0.908)	6.73	0.944	0.278
Strain Imaging	0.985	(0.951-1.018)	22.1	1.000	0.944
Systolic strain rate	0.986	(0.959-1.013)	1.21	1.000	0.833
Diastolic strain rate	1.000	(1.000-1.000)	1.09	1.000	1.000

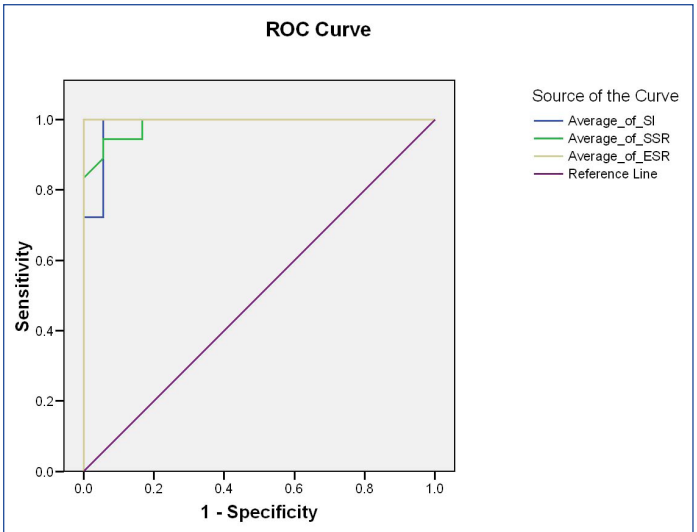
[Table/Fig-5]: ROC curve analysis



[Table/Fig-6]: ROC curve analysis for torsion

Hz with aliasing velocities between 16 and 32 cm/s, these colour TVI images were recorded with digital media. Three cardiac cycles were saved in digital format onto a magneto-optical disk for off-line analysis (EchoPac BTO 6.0.0, GE Medical Systems) of speckle tracking imaging by the observer.

We also measured strain and strain rate using both the techniques (TDI and 2-D STE) in 6 myocardial segments (anteroseptal, anterior, anterolateral, posterior, inferior, inferoseptal) at apical and basal level. TVI strain and strain rate were measured from the slope of the regression line of all the velocity estimates between two points in the middle of each myocardial segment (separated by a distance of 12 mm). If walls were poorly visualized, measurements were avoided. The region of interest was tracked manually in each frame in order to maintain a mid-myocardial position and avoid intra-cavity velocities. Global longitudinal, circumferential and radial strains were calculated by averaging the values of all segmental longitudinal, circumferential and radial strain values respectively. The endocardial borders were traced at the end-systolic frame of the 2D images from the three basal views. On the basis of this line, the software automatically tracked myocardial motion, creating basal regions of interest. The observer adjusted endocardial trace line by trial and error to achieve better tracking quality. Numerical and graphical displays of deformation parameters (reflecting the average value for tracking all



[Table/Fig-7]: ROC curve analysis for stain imaging, diastolic and systolic strain rate

of the acoustic markers in each segment) were then automatically generated for all six segments from basal view. Strain rate was obtained from the peak negative value of the TVI or 2D systolic curves (before aortic valve closure) in each segment. End-systolic strain was measured at end-systole on the TVI and 2D curves. The first zero-crossing of the velocity curve was used to denote end-systole for 2D strain. Off-line analysis of apical and basal rotation was then performed on digitally stored images. LV ejection fraction was calculated by modified Simpson's method. We calculated LV mass by using the equation of Devereux et al., We have calculated relative wall thickness and LV torsion by using software.

STATISTICAL ANALYSIS

The sample size was calculated using 80% power value (N= 202 $(Z1\text{-}\alpha/^2 \pm Z1\text{-}\beta)^2 / d^2$; $Z1\text{-}\alpha/^2 = 1.96$ with 5% level of significance; $Z1\text{-}\beta = 0.84$ with 80% power value; $\sigma^2 = 10.24$; d= 3). Continuous data were expressed as mean±standard deviation. Kolmogorov-Smirnov test was carried out to assess normality distribution of the data. If data were normally distributed, unpaired t-test was used otherwise Mann-Whitney test was used. p-value <0.05 was considered statistically significant. We also performed receiver operating characteristic (ROC) curve analysis. Statistical analysis was performed using Statistical Package for Social Sciences (SPSS; Chicago, IL, USA) program, version 15.

RESULTS

During the study period, 18 patients diagnosed with HCM were included in the study. Among these patients, concentric hypertrophy (Type-4) was observed only in one patient whereas Type 2 and Type 3 HCM were present in nine and four patients respectively. There were four patients identified in whom SAM, LVOTO and mitral regurgitation (MR) were noted during echocardiography. [Table/Fig-1] demonstrates clinical and echocardiographic characteristics of patients with HCM and controls. Statistically significant difference was observed in LV mass index (251.01±86.24 vs. 142.01±34.36, p<0.001) and relative wall thickness (0.67±0.15 vs. 0.38±0.05, p<0.001) between two groups.

Tissue Doppler Indices

[Table/Fig-2] represents tissue Doppler indices in both the groups. Systolic annular velocity which indicates systolic dysfunction was found significantly lower in HCM patients (7.7±0.7 vs. 8.7±1.00, p=0.012).

Strain Imaging

Strain imaging and systolic strain rate, the novel parameters of systolic dysfunction, are significantly lower in patients with HCM when measured by TDI as shown in [Table/Fig-3]. While measuring strain imaging by using 2-D STE, statistically significant difference was observed in global longitudinal, radial and circumferential strain imaging.

Left Ventricular Torsion

There was considerable increased in apical rotation (11.35±7.15 vs. 6.97±3.34, p=0.024) and decreased in basal rotation (-5.33±4.15 vs. -3.83±2.40, p=0.040) which thereby increased torsion in HCM patients as compared to healthy subjects (16.61±7.43 vs. 10.42±4.73, p=0.006) [Table/Fig-4].

The results of ROC curve analysis have been shown in [Table/Fig-5]. [Table/Fig-6 and 7] showed that among the parameters for systolic dysfunction, systolic strain rate (0.986) and strain imaging (0.985) have higher area under curve followed by torsion (0.747).

DISCUSSION

LVEF–a tool for the measurement of systolic function, is normal in patients with HCM. It is because LVEF is load dependent and the preserved LVEF may be due to decreased after load as a result of small LV cavity [5]. The result of our study clearly revealed significant higher LV mass index and relative wall thickness.

Tissue Doppler Indices

Diastolic dysfunction is observed in patients with HCM as a result of LVH. This impaired LV diastolic function leads to elevation of LV filling pressure [6]. LV filling pressure can be assessed by mitral inflow patterns, i.e., E/A ratio and deceleration time (DT). However, in patients with HCM in whom LVEF is > 50% (normal systolic function), the mitral variables (E/A ratio and DT) poorly correlate with hemodynamics [7-8]. This may be because of variation in the extent of delayed LV relaxation which may lead to variable transmitral pressure gradients and thereby variation in mitral E-wave velocity and mitral A-wave velocity for similar left atrial pressure [9]. So, in order to assess left ventricular diastolic dysfunction in patients with HCM, we have determined tissue Doppler parameters, i.e., early diastolic mitral annular velocity (E'), late diastolic mitral annular velocity (A') and systolic mitral annular velocity (S).

We measured E/E' ratio as it can be used to predict LV filling pressure throughout a wide range of systolic function. As per the recommendation of the guideline [9], we used lateral E' velocity as compared to septal E' velocity (in patients with HCM) to correlate with LV filling pressure and thereby diastolic dysfunction. In our study, the E/E' ratio was significantly higher in patients with HCM as compared to control group (12.52±5.27 vs. 6.66±1.67, p<0.001) which indicates significantly higher LV filling pressure as a consequence of diastolic dysfunction in HCM patients. The result of our study is comparable with the result of the study carried out by Saito et al., (HCM vs control, 16.2±6.0 vs 9.5±2.4, p<0.0001) [10].

Systolic annular velocity, a measure of systolic function, is significantly lower in patients with HCM (7.7±0.7 cm/s vs. 8.7±1.0 cm/s, p=0.012). The results of the study are comparable with that of the study carried out by Silva et al., which showed statistically significant lower systolic annular velocity in patients with HCM [11]. Abozguia et al., measured inferoseptal systolic annular velocity which was significantly lower in patients with HCM [12] Similar results were obtained in the study carried out by Nagueh et al., which demonstrated that lateral systolic annular velocity (6±0.8 vs. 15.6±2, p<0.01) and septal systolic annular velocity (5.7±1 vs. 14.5±1.4, p<0.01) were lower in patients with HCM [5] However, the study carried out by Maras et al., showed statistically insignificant difference in systolic annular velocity in patients with HCM and control at rest [13] but significantly decreased systolicannular velocity during stress condition in patients with HCM (7.9±2.1 vs. 11.3±1.7, p<0.001).

Cardim et al., had carried out the study in individuals who were genetically positive but phenotypically negative HCM and the results showed that even mutation carrier patients had significantly lower systolic annular velocity (8.0± 1.1 m/s vs. 12 ±1.0 m/s, p<0.001) [14]. However, the study carried out by Silva et al. showed statistically insignificant difference between mutation carrier and healthy subjects [11].

Strain Imaging

As a result of apical contraction, apical parts of the ventricle pull down the ventricular base. So, the wall motion velocity and displacement increase from base to apex and there is a possibility that the motion in the base is the result of apical contraction. Thereby ventricular wall motion is position dependent as even completely passive segments can show motion [15]. However, strain and strain rate overcome this limitation as they are position independent (if the velocity gradient is evenly distributed). There are several studies which demonstrated that early abnormalities in systolic function in patients with hypertrophied ventricles can be detected by strain analysis [16-18]. So, we used TDI and 2-D STE to measure strain and strain rate as a parameter of systolic function.

Our results showed statistically significant decrease in global systolic strain (measured by tissue Doppler imaging) in patients with HCM as compared to healthy subjects (18.88±2.23 vs. 23.37±1.37, p<0.001). Similarly, average systolic strain rate which represented global systolic dysfunction was also found to be decreased in patients with HCM (0.95±0.17 vs.1.35±0.13, p<0.001).

When strain analysis was carried out by 2-D STE, the global longitudinal strain (14.18±2.06 vs. 22.82±2.19, p<0.001), global circumferential strain (20.43± 3.69 vs. 27.33±4.90, p<0.001) and global radial strain (24.14±8.04 vs. 32.85±7.54, p=0.003) showed statistically significant difference. The results of our study are comparable with the results of the study carried out by Abozguia et al., [12]. They have also found significantly reduced longitudinal (–12.74±4.21 vs. –18.38±2.99, p<0.001), radial (17.52±7.86 vs. 29.63±13.26, p<0.001), and circumferential strain (–16.50±4.29 vs. –19.99±5.53, p<0.001) and strain rate in non-obstructive HCM patients compared with controls. However, Carasso et al., [19] had measured systolic myocardial function in 72 HCM patients using strain parameters (2-dimensional velocity vector imaging) and they found higher circumferential strain (–34±9 vs. –29±8, p<.05) and lower longitudinal strain (–16±4 vs. –21±4, p<.05) in patients with HCM as compared with control subjects. On the other hand, Paraskevaidis et al., [20] showed significant difference in longitudinal strain but insignificant difference in radial and circumferential strain.

Left ventricular torsion in patients with HCM

In healthy human heart, the apex of the ventricle rotates counterclockwise and the base rotates clockwise during systole [21]. The twisting movement of the heart (torsion) due to this opposite rotation is necessary to propel the blood forward and at appropriate rate for organ perfusion [22]. So, LV torsion is important for determining LV systolic dysfunction.

The results of our study demonstrated that torsion in patients with HCM was found to increase as compared to normal subjects (16.61±7.43 vs. 10.42±4.73). Similar results were found in the studies carried out by Young et al., (19.9±2.4 vs. 14.6±2.7) and Saito et al., (16.1±7.4 vs. 11.5±4.5) [10,23]. According to the study carried out by Prinz et al., to evaluate the change in torsion in pediatric patients diagnosed with HCM, statistically significant increase in torsion was observed in children with HCM (2.8±1.6) as compared to healthy children (1.9±1.0) [24].

The mechanism for this increased torsion has been explained by various studies. In healthy heart, counter clockwise rotation of the subepicardial fibers dominates clockwise rotation of the subendocardial fibers (due to larger radius). An increased torsion in patients with HCM is the result of increased lever arm (to subepicardial fibers) due to concentric hypertrophy [4,25]. However, elevated torsion is also observed in individual who is HCM mutation carrier even though the wall thickness of LV is normal. Russel et al., observed similar findings i.e. increased torsion in HCM mutation carrier as compared to normal participants of the study (10.1±2.5 vs. 7.7±1.2, p=0.001) [26].

CONCLUSION

The global systolic dysfunction, as measured by LV torsion and strain imaging, is present in patients with HCM even though the patients are having normal LVEF.

REFERENCES

[1] Arad M, Penas-Lado M, Monserrat L, Maron BJ, Sherrid M, Ho CY, et al. Gene mutations in apical HCM. *Circulation.* 2005;112(18):2805-11. Epub 2005/11/04.

[2] Efthimiadis GK, Meditskou S, Giannakoulas G, Parcharidou D, Styliadis I, Mochlas S, et al. Normal systolic function in HCM: reality or myth? *Eur Heart J.* 2008;29(7):948; Epub 2008/03/04.

[3] Ganame J, Mertens L, Eidem BW, Claus P, D'Hooge J, Havemann LM, et al. Regional myocardial deformation in children with HCM: morphological and clinical correlations. *Eur Heart J.* 2007;28(23):2886-94. Epub 2007/11/01.

[4] Young AA, Cowan BR. Evaluation of left ventricular torsion by cardiovascular magnetic resonance. *Journal of Cardiovascular Magnetic Resonance.* 2012;14(1):1-10.

[5] Nagueh SF, Bachinski LL, Meyer D, Hill R, Zoghbi WA, Tam JW, et al. Tissue Doppler imaging consistently detects myocardial abnormalities in patients with HCM and provides a novel means for an early diagnosis before and independently of hypertrophy. *Circulation.* 2001;104(2):128-30. Epub 2001/07/12.

[6] Mottram PM, Marwick TH. Assessment of diastolic function: what the general cardiologist needs to know. *Heart (British Cardiac Society).* 2005;91(5):681-95. Epub 2005/04/16.

[7] Nishimura RA, Appleton CP, Redfield MM, Ilstrup DM, Holmes DR, Jr., Tajik AJ. Noninvasive doppler echocardiographic evaluation of left ventricular filling pressures in patients with cardiomyopathies: a simultaneous Doppler echocardiographic and cardiac catheterization study. *Journal of the American College of Cardiology.* 1996;28(5):1226-33. Epub 1996/11/01.

[8] Nagueh SF, Lakkis NM, Middleton KJ, Spencer WH, 3rd, Zoghbi WA, Quinones MA. Doppler estimation of left ventricular filling pressures in patients with HCM. *Circulation.* 1999;99(2):254-61. Epub 1999/01/20.

[9] Nagueh SF, Appleton CP, Gillebert TC, Marino PN, Oh JK, Smiseth OA, et al. Recommendations for the evaluation of left ventricular diastolic function by echocardiography. *European Journal of Echocardiography.* 2009;10(2):165-93.

[10] Saito M, Okayama H, Yoshii T, Hiasa G, Sumimoto T, Inaba S, et al. The differences in left ventricular torsional behavior between patients with HCM and hypertensive heart disease. *International journal of cardiology*. 2011;150(3):301-06.

[11] Silva D, Madeira H, Almeida A, Brito D. Tissue Doppler imaging and plasma N-terminal probrain natriuretic peptide for the identification of HCM mutation carriers. *The American journal of cardiology.* 2013;112(7):996-1004. Epub 2013/07/09.

[12] Abozguia K, Nallur-Shivu G, Phan TT, Ahmed I, Kalra R, Weaver RA, et al. Left ventricular strain and untwist in HCM: relation to exercise capacity. *American heart journal.* 2010;159(5):825-32. Epub 2010/05/04.

[13] Maras D, Chung R, Duncan A, Li W, Thorp C, Morner S, et al. Patterns of cardiac dysfunction coinciding with exertional breathlessness in HCM. *International journal of cardiology.* 2013;170(2):233-38. Epub 2013/11/12.

[14] Cardim N, Perrot A, Ferreira T, Pereira A, Osterziel KJ, Reis RP, et al. Usefulness of Doppler myocardial imaging for identification of mutation carriers of familial HCM. *The American journal of cardiology.* 2002;90(2):128-32. Epub 2002/07/11.

[15] Dandel M, Lehmkuhl H, Knosalla C, Suramelashvili N, Hetzer R. Strain and strain rate imaging by echocardiography---basic concepts and clinical applicability. *Current cardiology reviews.* 2009;5(2):133-48. Epub 2010/05/04.

[16] Serri K, Reant P, Lafitte M, Berhouet M, Le Bouffos V, Roudaut R, et al. Global and regional myocardial function quantification by two-dimensional strain: application in HCM. *Journal of the American College of Cardiology.* 2006;47(6):1175-81. Epub 2006/03/21.

[17] Afonso LC, Bernal J, Bax JJ, Abraham TP. Echocardiography in HCM: the role of conventional and emerging technologies. *JACC Cardiovascular imaging*. 2008;1(6):787-800. Epub 2009/04/10.

[18] Leitman M, Lysyansky P, Sidenko S, Shir V, Peleg E, Binenbaum M, et al. Two-dimensional strain-a novel software for real-time quantitative echocardiographic assessment of myocardial function. Journal of the American Society of Echocardiography : *official publication of the American Society of Echocardiography.* 2004;17(10):1021-29. Epub 2004/09/29.

[19] Carasso S, Yang H, Woo A, Vannan MA, Jamorski M, Wigle ED, et al. Systolic myocardial mechanics in HCM: novel concepts and implications for clinical status. Journal of the American Society of Echocardiography : *official publication of the American Society of Echocardiography.* 2008;21(6):675-83. Epub 2008/01/12.

[20] Paraskevaidis IA, Farmakis D, Papadopoulos C, Ikonomidis I, Parissis J, Rigopoulos A, et al. Two-dimensional strain analysis in patients with HCM and normal systolic function: a 12-month follow-up study. *American heart journal.* 2009;158(3):444-50. Epub 2009/08/25.

[21] Shaw SM, Fox DJ, Williams SG. The development of left ventricular torsion and its clinical relevance. *International journal of cardiology.* 2008;130(3):319-25.
[22] Maréchaux S. Speckle-tracking strain echocardiography: Any place in routine daily practice in 2014? *Archives of Cardiovascular Diseases.* 2013;106(12):629-34.
[23] Young AA, Kramer CM, Ferrari VA, Axel L, Reichek N. Three-dimensional left ventricular deformation in HCM. *Circulation.* 1994;90(2):854-67. Epub 1994/08/01.
[24] Prinz C, Faber L, Horstkotte D, Körperich H, Moysich A, Haas N, et al. Evaluation of left ventricular torsion in children with hypertrophic cardiomyopathy. *Cardiol Young*. 2014;24(2):245-52
[25] Ingels N, Hansen DE, Daughters G, Stinson EB, Alderman EL, Miller DC. Relation between longitudinal, circumferential, and oblique shortening and torsional deformation in the left ventricle of the transplanted human heart. *Circulation research*. 1989;64(5):915-27.
[26] Rüssel I, Brouwer W, Germans T, Knaapen P, Marcus J, van der Velden J, et al. Increased left ventricular torsion in HCM mutation carriers with normal wall thickness. *Journal of Cardiovascular Magnetic Resonance.* 2011;13(1):3.

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