A New Speckle Tracking Algorithm can Accurately Analyze Left Ventricular Wall Motion - a Multicenter Study by the Israeli Echocardiography Research Group

Noah Liel- Cohen [1], Ronen Beeri [2], Yoram Agmon [3], Micha S Feinberg [4], Dan Gilon [2], Ilan Hay [4], Rafael Kuperstein [4], Marina Leitman [5], David Rosenmann [6], Alik Sagie [7], Sarah Shimoni [8], Yossi Tsadok [1], Mordehay Vaturi [7], Wolfgang Fehske [9], David S Blondheim [10]

[1] Cardiology , Biomedical Engineering, Soroka University Medical Center and Ben Gurion University, Beer Sheva, [2] Heart Institute, Hadassah University Hospital, Jerusalem, [3] Cardiology, Rambam Medical Center, Haifa, [4] Heart Institute, Sheba Medical Center, Tel Aviv, [5] Cardiology, Asaf Harofe Medical Center, Zerifin, [6] Cardiology, Shaare Zedek Medical Center, Jerusalem, [7] Cardiology, Rabin Medical Center, Petah Tikva, [8] Cardiology, Kaplan Medical Center, Rehovot, Israel, [9] Cardiology, St. Vinzenz-Hosp, Cologne, Germany, [10] Cardiology, Hillel-Yaffe Medical Center, Hadera, Israel

Introduction: Left ventricular wall (WM) motion assessment is crucial in echocardiogram interpretation, but despite technology improvements no automatic tool yet replaced visual reading. We hypothesized that 2D strain, a new speckle-tracking technique, can assess WM automatically with high concordance to visual assessment.

Methods: Echocardiograms (3 apical views, 18 segments) of 105 patients (ten duplicated), (28 healthy, 62 AMI, 15 dilated cardiomyopathy) were blindly read by 10 readers. Segments were scored: normal-dyskinetic (1-4). Segmental "gold-standard" for visual scoring (VSS) was computed using majority score assigned to each segment. 2DS was applied and segmental peak systolic strain (PSS) determined [Vivid 7, AFI(GE)]. PSS scores were divided: <-14% normal, -14 to -11% hypokinetic, - 11 to 2% akinetic, >2% dyskinetic.

Results: 1890 segments were analyzed, 66% categorized by VSS as normal and 30% as abnormal (13.5% hypokinetic, 12.1% akinetic and 1.7% dyskinetic), (4% unscorable). The sensitivity and specificity of PSS vs. VSS for identifying normal vs. abnormal segments was 88% and 85%. 85% of normal and 88% of akinetic segments were correctly identified by PSS. Kappa values for VSS inter and intra observer variability (4 categories): 0.50 and 0.57. When dichotomized into normal (score 1) and abnormal (2-4), inter and intra observer variabilities were 0.65 and 0.71. For PSS, Kappa values for inter and intra observer variability were 0.71 and 0.77, and when dichotomized, 0.79 and 0.83.

Conclusions: Automated PSS can accurately distinguish normally and abnormally contracting segments with good agreement to visual assessment by experienced echocardiographers, thus may assist WM analysis performed by less experienced readers.

Reduction in Mitral Regurgitation in Patients Undergoing Cardiac Resynchronization Treatment: Assessment of Predictors by Two Dimensional Radial Strain Echocardiography

Sorel Goland [1,2], Asim M Rafique [2], James Mirocha [2], Robert J Siegel [2], Tasneem Z Naqvi [2]

[1] Cardiology, Cardiology, Kaplan Medical Center, Rehovot, Israel, [2] Cardiac Non Invasive Lab, Cardiology, Cedars Sinai Medical Center, Los Angeles, USA

Background. Cardiac resynchronization treatment (CRT) is associated with reduction in mitral regurgitation (MR), however few studies have defined specific predictors of acute MR reduction. We hypothesized that left ventricular (LV) mechanical dyssynchrony in mid-LV segments corresponding to papillary muscles insertion sites can predict early MR reduction post CRT, due to improved synchrony in papillary muscle contraction. We utilized the novel approach of 2-D radial strain (2-DRS) to evaluate our hypothesis.

Methods. We evaluated 32 pts undergoing CRT (mean age 64±17 years, 54% male) with MR grade ≥3 determined by MR jet area/left atrial area ratio (JA/LAA) (grade 1, MRJA/LAA <20% to grade 4, MRJA/LAA >40%). Radial mechanical activation sequence maps were constructed using 2-DRS from mid-LV circumferential sites. Responders were defined as patients with post-CRT (1.9±1.0 months) reduction in MR to MRJA/LAA < 25%.

Results. The percent reduction in LV end-systolic volume was significantly higher in responders (p=0.03), as was improvement in LVEF (p=0.007). Post CRT, 67% of responders had mild or no MR and 33% had mild to moderate MR, while 70% of non-responders had grade 3 or 4 MR (p=0.0001). Significant delay of time-to-peak 2-DRS in the mid posterior and inferior segments prior to CRT was found in responders compared with non-responders (580±58 vs. 486±94, p=0.002 and 596±79 vs. 478±127 ms, p=0.005, respectively). Responders also had higher peak positive systolic 2-DRS in the posterior and inferior segments compared to non- responders (22±13 vs. 12±7%, p=0.01 and 17±9 vs. 9±7%, p=0.02, respectively). Logistic regression analysis showed that the difference in pre-CRT infero-anterior time-to-peak radial strain of >110 ms and MRJA/LAA <40% as well as 2-DRS >18% in the posterior wall were significant predictors of post-CRT improvement in MR.

Conclusion. 2-D radial strain can quantify LV dyssynchrony and predict post- CRT improvement in MR. Presence of a significant time-to-peak delay on 2-DRS between inferior and anterior LV segments, preserved strain of posterior wall and MRJA/LAA <40% were found to be associated with significant MR reduction in patients post CRT.

Is Left Ventricular Diastolic Dysfunction Associated with Elevated Pulmonary Artery Pressure in Patients with Preserved Left Ventricular Ejection Fraction?

Diab Mutlak, Doron Aronson, Jonathan Lessick, Shimon Reisner, Salim Dabbah, Yoram Agmon

Cardiology, Non-invasive Cardiology, Rambam Health Care Campus, Technion - Israel Insitute of Technology, Haifa, Israel

Background and Objectives: The role of isolated left ventricular (LV) diastolic dysfunction (DDFx) as a cause of pulmonary hypertension is unclear. The objectives of our study were: 1) to determine the distribution of pulmonary artery systolic pressure (PAP) in patients with advanced LV DDFx and preserved LV ejection fraction (LVEF); 2) to examine whether the severity of LV DDFx is related to PAP.

Methods: The computerized database of the echocardiography laboratory at our institution was used to identify consecutive patients with preserved LVEF (≥50%), advanced LV DDFx (pseudonormal or restrictive LV filling patterns), and no significant left-sided valve disease, in whom PAP was estimated. Advanced LV DDFx was defined as mitral inflow E/A ratio ≥1.0 *and* echocardiographic evidence of elevated LV filling pressures (at least one of the following: pulmonary venous systolic/diastolic flow ratio [PV S/D] <1, mitral inflow E/mitral annular e' ratio ≥15 [septal aspect of annulus], or E/e' ratio ≥10 [lateral annulus]).

Results: During the study period (44 months) – 407 patients fulfilled the inclusion criteria (age: 70±10 yrs; 43% male). PAP was <35 mmHg in 57 (14%) patients, 35-49 mmHg in 201 (49%) patients, 50-69 mmHg in 133 (33%) patients, and ≥70 mmHg in 16 (4%) patients. The PAP in patients with variable degrees of LV diastolic filling abnormalities is presented in the Table.

	Terciles of Diastolic Parameters			
Diastolic parameters	**I**	**II**	**III**	***P* for trend**
Mitral inflow E/A ratio				
Tertiles (ranges)	<1.4	1.4-1.7	>1.7	
PAP	43 ± 11	46 ± 11	48 ± 13	<0.0001
E wave deceleration time (DT)				
Tertiles (ranges)	<170	170-200	>200	
PAP	50 ± 14	46 ± 11	43 ± 9	<0.0001
PV S/D ratio				
Tertiles (ranges)	<0.6	0.6-0.8	>0.8	
PAP	51 ± 14	46 ± 13	44 ± 10	<0.0001
Left atrial (LA) diameter				
Tertiles (ranges)	<4.3	4.3-4.7	>4.7	
PAP	42 ± 11	45 ± 11	48 ± 14	0.01

Greater abnormalities of LV filling (increasing values of E/A ratio and LA diameter and decreasing values of DT and PV S/D ratio) were associated with higher PAP. Female gender was associated with higher PAP (*P*=0.002) and there was an interaction between gender, the severity of DDFx, and its association with PAP. For example - PAP in the 3rd tertile of E/A ratio was higher in women (50±13 mmHg) than in men (45±13 mmHg).

Conclusions: PAP is significantly elevated in a large proportion of patients with advanced LV DDFx and preserved LVEF. More severe abnormalities of LV filling (reflecting more severe LV DDFx) are associated with higher PAP, suggesting a cause-and-effect relationship. Gender appears to modify this relationship, suggesting that women are more prone to developing pulmonary hypertension under these circumstances.

Differential Effects of Afterload on Left Ventricular Long-Axis and Short-Axis Function: Insights from a Clinical Model of Patients with Aortic Valve Stenosis Undergoing Aortic Valve Replacement

Shemy Carasso [1,3], Oved Cohen [2,3], Gil Bolotin [2,3], Shimon A Reisner [1,3], Yoram Agmon [1,3]

[1] Cardiology Department, Non Invasive Cardiology, [2] Cardithoracic Surgery, Rambam Health Care Campus, [3] Faculty of Medicine, Technion, Israel Institute of Technology, Haifa, Israel

Background and Objective: The differential effects of left ventricular (LV) afterload on longitudinal versus circumferential ventricular mechanics is largely unknown. The objective of our study was to examine the changes in LV deformation early after aortic valve replacement (AVR) in patients with aortic valve stenosis (AS), using 2-D myocardial strain imaging.

Methods: Paired echocardiographic studies before and early [7±3 days] after AVR, were analyzed in 29 patients (age: 72±9 yrs, 45% men) with severe AS. All patients had normal LV ejection fraction (LVEF) and no segmental wall motion abnormalities. Long-axis (longitudinal) myocardial function was assessed from 3 apical views (average of 18 segments from 4-chamber, 2-chamber, and long-axis views). Short-axis (circumferential) function was assessed from mid-LV and apical short-axis views (separate averages of 6 segments in each view). Myocardial deformation (strain), strain rate (SR), and LV twist (counterclockwise systolic rotation of apex relative to mid-LV) were measured using the 2-D Velocity Vector Imaging software (VVI, Siemens, Mountainview, CA).

Results: AVR resulted in a significant drop in transaortic pressure gradients (peak and mean gradients dropped from 93±13 to 35±1 and from 55±12 to 18±6 mmHg, respectively, p<0.001 for both), whereas LV size and LVEF did not change early post-AVR. The changes in myocardial longitudinal and circumferential function are listed in the Table.

	Pre-AVR	**Post-AVR**	**p**
Peak systolic strain (%)			
Longitudinal	-12.1±2.9	-15.3±3.4	<0.001
Circumferential			
Mid-LV	-27.6±6.2	-24.1±3.9	<0.001
Apex	-31.3±8.4	-31.6±6.3	NS
Early diastolic SR (%/sec)			
Longitudinal	0.49±0.16	0.65±0.22	<0.001
Circumferential			
Mid-LV	1.31±0.58	1.06±0.27	<0.001
Apex	1.44±0.54	1.53±0.46	NS
LV twist (°)	3.1±2.6	5.3±2.7	<0.001

Following AVR: 1) longitudinal systolic strain increased, whereas mid-LV circumferential strain decreased; 2) longitudinal early diastolic SR increased, whereas mid-LV circumferential strain decreased; 3) LV twist increased.

Conclusions: In this clinical model of significant afterload reduction (patients with severe AS undergoing AVR), afterload reduction resulted in differential effects on LV long-axis versus short-axis function (systolic and diastolic) without a change in overall LV performance (LVEF). These findings provide new insights into the mechanical adaptation of the LV to chronic afterload elevation and its response to acute unloading.

Strain Imaging Improves the Accuracy of Dipyridamole Stress Echocardiography in Detecting Coronary Artery Disease

Sarah Shimoni [1], Shai Livschitz [2], Gabriel Loutati [1], Rosa Levi [2], Orly Edri [1], Abrahahm Caspi [1]

[1] Cardiology, Echocardiography, [2] Cardiology, Nuclear Cardiology, Kaplan Medical Center, Rehovot, Israel

Stress echocardiography is a cost-effective tool for noninvasive diagnosis of coronary artery disease. Several physical and pharmacological stresses have been used in combination with echocardiographic imaging including exercise, dobutamine and dipyridamole. The use of dipyridamole stress echocardiography (DE) for the diagnosis of mild to moderate coronary artery disease is controversial since dipyridamole stress is believed to mainly produce flow heterogenisity rather than ischemia. Myocardial strain imaging provides quantitative segmental analysis of myocardial function. It has been shown recently that segmental analysis of systolic strain rate has prognostic information that is independent and incremental to standard wall motion score index in dobutamine echocardiography. We sought to determine whether segmental quantification of DE using strain imaging improves the accuracy of standard DE in detecting coronary artery disease as defined by stress perfusion scintigraphy. We performed DE and Th-201 gated SPECT simultaneously in 73 patients with suspected or known coronary artery disease. DE images were analyzed using customized software to measure peak systolic longitudinal strain. Fifty-one patients had abnormal perfusion by SPECT. Standard DE reviled wall motion abnormalities in 24 patients while 57 patients had abnormal longitudinal systolic strain. The overall concordance between SPECT and wall motion assessment was 57% (k=0.30). The concordance between SPECT and DE using strain imaging was 80% (k=0.52). Analysis of agreement between SPECT and DE using strain imaging by coronary territory (n=218) revealed concordance of 82% at the LAD territory, 84% at the RCA territory and 68% at the circumflex territory. We conclude that myocardial strain imaging improves the accuracy of standard DE in detecting coronary artery disease. DE with strain imaging allows routine use of vasodilators in stress echocardiography.

Ultrasound Echocardiographic Assessment of Transmural Inhomogeneity of the Left Ventricular Contraction during the Heart Cycle

Noa Bachner [1], Dan Adam [1], Marina Leitman [2], Zvi Vered [2]

[1] Biomedical Engineering, Technion, Israel Institute of Technology, Haifa, [2] Cardiology, Institute, Assaf Harofeh Medical Center, Zerifin, Israel

Objectives: The normal adult left ventricle (LV) is characterized by regional nonuniformity. A spiral structure of the fibers around the LV generates rotation of the LV during contraction and relaxation. The inhomogenity of the human heart was investigated better with magnetic resonance tagging. We evaluated rotation and circumferential strain over the LV in normal subjects using novel echocardiography based signal processing method.

Methods: Circumferential strain and the myocardial rotation were calculated at 3 levels (apical, papillary muscle and mitral valve) from short-axis ultrasound echo cines in 11 normal subjects, utilizing speckle tracking imaging (UFI, GE Healthcare Inc., and Technion, Israel) and a novel signal processing method. This new method enabled high temporal and spatial resolution measurements of the myocardial velocities, so that the circumferential strain and the myocardial rotation were evaluated during a full heart cycle for 3 myocardial layers.

Results: A significant transmural difference was found in the myocardial rotation and circumferential strain. The rotation is larger in the endocardium and decreases towards the epicardium, while the apex and base rotate in counter directions (apex level: endocardium 7.7±3.4 [deg], midwall 5.0±2.3 [deg], epicardium 3.6±2.0 [deg], Papillary muscle level: endocardium 1.4±2.4 [deg], midwall 1.8±2.1 [deg], epicardium 2.3±1.3 [deg], mitral valve level: endocardium -4.4±2.0 [deg], midwall -1.9±2.4 [deg], epicardium -0.5±2.1 [deg]). Similarly, the circumferential strain is larger at the endocardium than at the epicardium. Furthermore, the circumferential strain is larger at the apex level than at the base level.

Conclusion: Transmural inhomogeneities of the left ventricular rotation and of the circumferential strain can be evaluated by echocardiography based method, and may serve as a simple, affordable and commonly available diagnostic modality.