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Strain Imaging Using Speckle Tracking in the Cardiometabolic Syndrome (CMS): method and utility

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During the past twenty years, there has been a dramatic increase in obesity and the cardiometabolic syndrome (CMS). In the United States alone, there are an estimated 42 million persons affected by CMS.¹ In addition to complications from diabetes and hypertension, this population is at risk for the development of both ischemic and non-ischemic heart failure.² Although it is fairly well accepted that obesity and other aspects of CMS contribute to left ventricular (LV) remodeling and diastolic dysfunction, controversy does exist as to the effects of CMS on systolic function.² This is partly due to the fact that obesity is associated with an increase in plasma volume.² Thus, any load-dependent measures of systolic function, e.g., cardiac output, are necessarily affected by alterations in volume as well as contractility. Different methods for indexing LV systolic function measures in obese subjects may also affect systolic function results. For example, cardiac output may be increased in obesity but when indexed for body surface area, cardiac index may be low. Thus, newer, more load-independent noninvasive methods are necessary for better characterizing LV systolic function.

Tissue Doppler imaging (TDI), an echocardiographic method previously described in the *Images in CMS* section of the *Journal of the Cardiometabolic Syndrome*, is considered to be relatively load-independent.³ Although, TDI is relatively easy to perform and measure, it does have some limitations. TDI provides a longitudinal assessment of the function of an entire wall rather than of a segment, so localization of the segmental wall motion abnormalities using TDI is limited.⁴ Additionally, because it is a Doppler-derived parameter, it is necessarily angle-dependent, and so TDI-derived measures of function are angle-dependent.

A new echocardiographic technique called strain imaging, overcomes some of the limitations of TDI. Like TDI, strain imaging is thought to be relatively load-independent, but strain imaging has other advantages as well. Strain imaging allows for segmental wall motion quantification and (when quantified using speckle tracking) is not angle-dependent.

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In order to explain this technique it is first important to define “strain” as it pertains to LV systolic function. Strain means deformation and is calculated as the change in length divided by the original length.⁴ As such, strain is dimensionless and typically represented as a negative fractional or percentage change in dimension. Since LV contraction in systole causes LV deformation (strain), strain is a measure of contractility.⁴ (The rate at which the LV deforms may also be measured echocardiographically and is termed “strain rate,” but this imaging article will focus on strain). LV contraction is a three-dimensional process that involves radial and longitudinal cardiac muscle fibers. As longitudinal fibers shorten the ventricle, radial fibers squeeze in and twist in a clockwise direction at the base and counter-clockwise at the apex. The result is an efficient wringing motion comprising of radial, circumferential, and longitudinal contractility. Measuring regional strain is used for the detection and quantification of segmental wall motion abnormalities, and myocardial strain derangements have been correlated with ischemia.⁵ Regional strain was first quantified non-invasively in humans using magnetic resonance imaging. While this method is accurate, it is costly, not widely available, and has limited temporal resolution. Strain may also be quantified using echocardiography using a Doppler-derived method.⁶ However, this technique, while useful for quantification of segmental wall systolic function is angle-dependent.

Speckle Tracking

This is a new echocardiographic method for quantifying myocardial deformation, which measures two-dimensional myocardial muscle movement rather than Doppler-derived movement, and so, speckle tracking is angle-independent. Utilizing computerized software, the basic principle of speckle tracking is based on the reflected ultrasound, giving rise to an irregular or speckled pattern (Figure 1 A–C). This distribution of speckles is unique to a wall segment. As a segment of the LV moves from one frame to the next, the position of the individual speckles will shift slightly. The amount of speckle movement in systole reflects the LV tissue deformation or strain.⁷ Echocardiographic strain software tracks changes longitudinally and transversely, yielding two-dimensional strain values. This is an important feature as it not only allows off-axis imaging but also provides a more accurate evaluation of a process that is clearly not one-dimensional. Post-processing of speckle tracking-derived strain data is now often semi-automated, which likely contributes to its relatively fast analysis and high inter-observer reproducibility (85%).⁸

Case Study

In order to illustrate the utility of echocardiographic strain imaging using speckle tracking, we performed strain imaging on a 35-year old woman subject with CMS. The subject was also reevaluated using strain imaging after gastric bypass surgery (GBPS) and consequent improvement of her CMS. Table 1 shows this subject’s baseline and post-GBPS characteristics and lab values as they pertain to CMS. Before GBPS, the subject weighed 141kg and had a body mass index of 56.8 kg/m² and a waist circumference of 137 cm. Twelve months after GBPS-induced weight loss she weighed 93kg and had a body mass index of 38kg/m². Her ejection fraction was within normal limits pre- and post-surgery (69 and 66%, respectively).

Data Acquisition

Echocardiograms were performed with the subjects lying in a supine position using a GE Vivid 7 ultrasound machine equipped with an M4S multi-Hertz transducer (GE Medical Systems, Milwaukee, WI, USA). Images acquired for two-dimensional speckle tracking were taken from three standard echocardiographic views (apical 4-, apical 2-, apical 3-

chamber) of the LV. Frame rates were adjusted to 40–80 frames per second. Frequency, gain, image width and depth were adjusted to maximize spatial visualization of the myocardium. The subjects were asked to hold respiration during acquisition for further myocardial enhancement, and to minimize translational motion artifact.

Data Analysis

Images were analyzed with Q-analysis on the EchoPAC system (GE Medical Systems, Milwaukee, WI, USA) using commercially available software. The region of interest was defined as myocardium located between the endocardial and epicardial borders, from apex to base, excluding the papillary muscles. Once the software approved the borders, the automated software tracked the movement of the intra-myocardial speckles throughout the cardiac cycle and calculated segmental strain. If the myocardium was not properly tracked, the borders were redefined by the analyzer and reprocessed.

Evaluation of LV Strain

Three components of systole are measured using strain analysis and are used to determine the systolic ventricular function (See images 1 and 2).

1. Early systolic phase. This occurs immediately after the QRS complex and serves as the reference for strain values. In a normal left ventricle, strain begins at 0% and progressively becomes more negative throughout the cardiac cycle, indicating the myocardial speckles are moving towards each other. In diseased states such as ischemia and hypertrophic cardiomyopathy, however, a brief pre-stretch phase occurs immediately following the QRS resulting in a positive (P) deflection. If the myocardium is viable, this phase is followed by a negative deflection throughout the remainder of systole.
2. Systolic phase. Beginning with electrical systole, this phase encompasses the early systolic phase described above and lasts until aortic valve closure (AVC). A normal left ventricle will reach peak systolic longitudinal strain (S) values between −18 to −20%.⁹
3. Post-systolic phase. This phase begins after AVC, indicating the onset of early diastole. As the myocardium relaxes, speckles begin to move apart generating a positive deflection in the strain curve. However, if the myocardium continues to contract after AVC, as is observed in ischemia and hypertrophic cardiomyopathy, a negative post-systolic strain is generated and is generally recorded as the global peak strain (G). This is used to calculate the post-systolic index (PSI) by the formula $G-S/G$. Abnormal S values in conjunction with a PSI greater than 2% indicate a decrease in myocardial blood flow.¹⁰

In our subject with CMS there was no significant pre-systolic stretching appreciated in pre- or post-gastric bypass. S values were within normal limits in both studies but were slightly improved post-gastric bypass. There was slight post-systolic strain pre- and post- in the apical septal (green) and apical lateral (purple) segments, but given the normal S values, this did not suggest the presence of ischemia. (Figure 2 and Figure 3).

Summary

Strain imaging is a valuable technique for the quantification of LV systolic function. Echocardiographic strain imaging is a relatively load-independent, angle-independent (using speckle tracking), noninvasive, reproducible technique that may be used for the quantification of LV systolic function. Strain imaging can detect subtle abnormalities in LV systolic function, which may go undetected by more load-dependent and global measures.

Thus, strain imaging is well-suited for detecting and following LV systolic dysfunction, which may result from CMS, its components, or its complications (e.g., ischemia).⁸ Because strain imaging can detect and quantify segmental wall motion abnormalities, it may be added to standard stress echocardiographic imaging for the detection of myocardial ischemia, another common complication of CMS.

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References

1. Sowers JR. The *Journal of the Cardiometabolic Syndrome*: Why it is needed. *J Cardiometab Syndr*. 2006; 1:5.
2. Ash-Bernal R, Peterson LR. The cardiometabolic syndrome and cardiovascular disease. *J Cardiometab Syndr*. 2006; 1:25–28.
3. Haider TA, Peterson LR. Evaluation of diastole in an obese young woman: mitral valve inflow Doppler vs. mitral annular tissue Doppler imaging. *J Cardiometab Syndr*. 2006; 1:74–75.
4. Smiseth OA, Ihlen H. Strain rate imaging: why do we need it? *J Am Coll Cardiol*. 2003; 42:1584–1585. [PubMed: 14607442]
5. Winter R, Jussila R, Nowak J, Brodin L. 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. [PubMed: 17555941]
6. Voigt JU, Arnold MF, Karlsson M, Hubbert L, Kukulski T, Hatle L, Sutherland GR. Assessment of regional longitudinal myocardial strain rate derived from Doppler myocardial imaging indexes in normal and infarcted myocardium. *J Am Soc Echocardiogr*. 2000; 13:731–737. [PubMed: 10936816]
7. Korinek J, Wang J, Sengupta PP, Miyazaki C, Kjaergaard J, McMahon E, Abraham TP, Belohlavek M. Two-dimensional strain--a Doppler-independent ultrasound method for quantitation of regional deformation: validation in vitro and in vivo. *J Am Soc Echocardiogr*. 2005; 18:1247–1253. [PubMed: 16376750]
8. Leitman M, Lysyansky P, Sidenko S, Shir V, Binenbaum M, Kaluski E, Karakover R, Vered Z. Two-dimensional strain - a novel software for real-time quantitative echocardiographic assessment of myocardial function. *J Am Soc Echocardiogr*. 2004; 17:1021–1029. [PubMed: 15452466]
9. Hurlbert HM, Aurigemma GP, Hill JC, Narayanan A, Gaasch WH, Vinch CS, Meyer TE, Tiche DA. Direct ultrasound measurement of longitudinal, circumferential, and radial strain using 2-dimensional strain imaging in normal adults. *Echocardiogr*. 2007; 7:723–731.
10. Kukulski T, Jamal F, Herbots L, D'hooge J, Bijmens B, Hatle L, DS I, Sutherland GR. Identification of acutely ischemic myocardium using ultrasonic strain measurements, a clinical study in patients undergoing coronary angioplasty. *J Am Coll Cardiol*. 2003; 41:810–819. [PubMed: 12628727]

Figure 1.

Figure 1A Speckle tracking. The echocardiographic software defines a region (called a “kernel”) in the myocardium and defines a unique speckle pattern within it (red dots). Within a defined search area (blue box), the new position of the kernel in the next frame (green dots) can be recognized by finding the same speckle pattern in a new position. The movement of the kernel (thick blue arrow) can then be measured. (Figures 1A–C and legends adapted from the website created by Asbjørn Støylen, MD http://folk.ntnu.no/stoylen/strainrate/#strain_rate).

Figure 1B Typical speckle pattern in the myocardium. The two enlarged areas (in the red boxes) highlight the unique speckle patterns of different regions of the myocardium. This unique ‘fingerprint’ can be identified in different locations at different times in the cardiac cycle, allowing for the measurement of strain.

Figure 1C A cartoon of the measurement of 2 dimensional strain by speckle tracking. Each red point represents a kernel for speckle tracking, and the blue arrows depict the motion of those kernels during cardiac contraction.

Figure 2.

Strain data from patient with CMS before GBPS.

A Upper left. demonstrates myocardial borders detected by software in an apical four chamber view and divided into six equal segments: basal, mid-, and apical septum; apical, mid-, and basal lateral (yellow to red).

B Lower left. Anatomical M-mode along a stationary line in an “unfolded” left ventricle. Colored squares correspond to the six LV segments seen in image A providing a map of strain throughout the cardiac cycle shown by the ECG below.

C Top right. Quantitative strain curve beginning near 0% at the onset of the QRS and uniformly becoming more negative throughout systole until reaching peak systolic strain (S), at or near, aortic valve closure (AVC).

D Bottom right. Peak values for global strain (G), systolic strain (S) and positive strain (P). If peak global strain occurs during systole or at AVC, S and G are equal. If peak global strain occurs *after* systole, S and G are *not* equal and S is generally quantified at AVC.

Figure 3.

Strain data from patient in image 1 after GBPS.

A The upper left demonstrates the four chamber view, lower left

B The upper right is the unfolded view,

C The lower right is the strain curve,

D The peak values for global (G) systolic (S), and positive strain (P), as described in Figure 1. Note: The strain y-axis scale is slightly different from Figure 2 because it is automatically adjusted for best-fit by the software.

Table 1

	Pre Gastric Bypass	Post Gastric Bypass
Triglycerides, mg/dL	130	138
HDL Cholesterol, mg/dL	38	42
Systolic blood pressure, mmHg	138	123
Diastolic blood pressure, mmHg	73	66
Plasma glucose, mM	5.11	4.83