Pericardiectomy is Associated with Improvement in Longitudinal Displacement of Left Ventricular Free Wall Due to Increased Counterclockwise Septal-to-Lateral Rotational Displacement

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Background: Pericardiectomy is an effective intervention for constrictive pericarditis. Speckle-tracking echocardiography can provide quantitative information not only about longitudinal strain (LS) but about longitudinal displacement (LD) and septal-to-lateral rotational displacement (SLRD). The aim of this study was to investigate whether pericardiectomy improves myocardial mechanics using speckle-tracking analysis.

Methods: Eighty-three patients with constrictive pericarditis who underwent echocardiography were retrospectively assessed (mean age, 58 ± 12 years; 72 men; 50 idiopathic, 20 postoperative, four viral, three radiation, and six others) and compared with 20 healthy volunteers. LD and SLRD were measured from the apical four-chamber view and global LS from three apical views.

Results: LD was less in the constrictive pericarditis group compared with control subjects ($P < .001$). Only lateral LS was significantly less than that of control subjects ($P < .001$), but septal LS was similar ($P = .48$). In pre- and post–pericardial surgery comparisons ($n = 27$), values of septal and lateral LD were almost identical (mean, 13.6 ± 4.7 vs 13.3 ± 5.4 mm; $P = .70$) before pericardiectomy, but septal LD decreased (mean, 9.3 ± 3.5 mm; $P < .001$) and lateral LD increased (mean, 16.8 ± 4.7 mm; $P = .0106$) after the surgery, even though the difference in LS between the septal and lateral walls decreased (from 5.6 ± 5.3% to 2.5 ± 4.2%, $P = .008$). Systolic whole-heart swinging motion significantly increased to a counterclockwise direction after surgery (mean SLRD, −0.8 ± 3.3° vs 2.1 ± 3.0°; $P = .001$). Although the change in SLRD after pericardiectomy was not different between patients with decreases and increases in New York Heart Association class, SLRD change was significantly greater in patients who received fewer diuretics after surgery (mean, 4.00 ± 0.91 vs 0.27 ± 1.47; $P = .027$).

Conclusions: After surgical removal of the pericardium, LD of the septal and lateral walls became significantly different, and counterclockwise SLRD increased, reflecting loss of pericardial support. (J Am Soc Echocardiogr 2015;28:1204-13.)

Keywords: Displacement, Strain, Longitudinal rotation, Constrictive pericarditis, Pericardiectomy

Constrictive pericarditis (CP) is a rare but potentially curable disease, characterized by impaired diastolic cardiac filling due to the encasement of the heart by a rigid pericardium. Surgery is the accepted standard treatment for patients with chronic CP who have persistent and prominent symptoms.[1] However, outcomes after pericardiectomy are variable for reasons that are not well understood.[2] Diastolic dysfunction and septal bounce often persist after surgery, and there are no parameters to evaluate whether the pericardial encasement was adequately released.

Recently evolved deformation imaging has enabled quantitative analyses.[3,4] Both tissue Doppler–derived and speckle-tracking-derived deformation analyses can provide not only strain (and strain rate) but displacement and rotation of the myocardium.[5-8] In addition to short-axis rotation, more recently, speckle-tracking echocardiography has had the capability to assess longitudinal septal-to-lateral rotational displacement (SLRD), which can quantify the rocking or swinging motion of the whole heart.[9-11] Although several studies have evaluated left ventricular (LV) mechanics of patients with CP quantitatively,[12] few have assessed the change before and after pericardiectomy,[13] and none has compared with outcomes after the operation.

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Abbreviations

CP = Constrictive pericarditis

GCS = Global circumferential strain

GLS = Global longitudinal strain

GRS = Global radial strain

LD = Longitudinal displacement

LS = Longitudinal strain

LV = Left ventricular

MRI = Magnetic resonance imaging

NYHA = New York Heart Association

SLRD = Septal-to-lateral rotational displacement

We hypothesized that SLRD would be decreased after pericardiectomy and that the reduction would be related to clinical outcomes evaluated as the changes in New York Heart Association (NYHA) class or diuretics dose. Thus, we sought to perform comprehensive analyses of the change in LV mechanics before and after pericardiectomy using deformation parameters, such as displacement, strain, strain rate, and SLRD, and to compare it with the change in NYHA class and decrease in diuretics after surgery.

METHODS

Study Population

This retrospective cohort study was approved by the Cleveland Clinic Institutional Review Board. We used our CP database to identify patients with CP who underwent echocardiography performed between January 2007 and December 2010 using Vivid 7 or E9 (GE Medical Systems, Milwaukee, WI) ultrasound machines at our institution. Out of 98 patients identified, one was excluded because of significant valvular disease (severe aortic stenosis), four were excluded because of significant coronary artery disease, and one was excluded because of prior pericardiectomy. Out of the remaining 92 patients, nine were excluded because of poor image quality. Among the 83 patients remaining, the diagnosis of CP was established by a combination of imaging and invasive techniques, including echocardiography in 83 patients, tomographic imaging (computed tomography or magnetic resonance imaging [MRI]) in 77 of 83 patients, and dedicated invasive hemodynamic study that included simultaneous measurements of right ventricular and LV pressures in 69 of 83 patients (Appendix).

Out of the 83 patients, 50 were surgically treated, while 33 patients were treated medically (Supplemental Figure 1). In all surgically treated patients, pericardiectomy was performed through a sternotomy or left thoracotomy incision. The standard pericardial resection at our institution is an on-pump comprehensive pericardiectomy with removal of the diaphragmatic component, anterior pericardium from phrenic nerve to phrenic nerve, and posterior pericardium to the left phrenic nerve. Radical pericardiectomy was performed in most patients, but when it was not achievable, as much pericardium was resected as possible.[14,15] The visceral pericardium was also removed as required. Twenty-seven out of 50 surgically treated patients underwent postsurgical studies with a GE machine, and this was used for comparison before and after surgery. The median period between the presurgical echocardiographic examination and surgery was 8 days (interquartile range, 5–37 days), and the median period from surgery to follow-up echocardiography was 29 days (interquartile range, 7–54 days). Out of 33 medically treated patients, 16 were considered to have mild constriction, 11 had ongoing inflammation by MRI, and six were deemed poor surgical candidates because of concomitant systemic disease or cancer.

We randomly selected 20 control subjects >55 years of age from our database of 117 healthy volunteers free of any known cardiovascular disease, with normal results on physical examination and normal electrocardiographic results and not taking any cardioactive medications (except aspirin). The Institutional Review Board of Cleveland Clinic approved the database search. All of these control subjects gave written informed consent for participation in respective prospective studies.

Standard Echocardiography

Echocardiography was performed using standard commercial echocardiographic systems. Sector size and depth were adjusted to achieve optimal visualization of all LV myocardium at the highest possible frame rate. Acquisition was obtained at end-expiration. Multiple consecutive cardiac cycles of the standard views were acquired and stored digitally in a Digital Imaging and Communications in Medicine–based echocardiographic viewer (syngo Dynamics; Siemens Healthcare, Malvern, PA) for subsequent analysis. Ejection fraction was calculated using the biplane method of disks.[16] Tissue Doppler–derived indices were measured using the apical four-chamber view. Peak systolic (s′) and early diastolic (e′) mitral annular velocities were calculated by averaging septal and lateral mitral annular velocities. All pulsed-wave and tissue Doppler measurements were averaged over three cardiac cycles.

Measurement of Deformation Parameters

Images were saved in digital format and analyzed offline using commercially available software (EchoPAC PC version 11.0.0; GE Medical Systems) by a single operator who was blinded to clinical information.[4,17] The apical four-chamber view was used to obtain longitudinal displacement (LD) during one cardiac cycle at 56 ± 17 frames/sec. Special care was taken to avoid the pericardium when the width for the region of interest was determined. For LD, the basal segments were used for the analysis. After decortication, LD became different between the septum and lateral wall, so we compared the change in contraction of each segment using strain. Peak longitudinal strain (LS) was measured in the three apical views. The apical, middle, and basal segments were averaged separately in the septal and lateral walls for LS. Global LS (GLS) was calculated averaging the 18 segmental strain values from three apical views. Global circumferential strain (GCS) and global radial strain (GRS) were calculated by averaging the six segments from short-axis images at the level of the mid papillary muscle level.

SLRD was analyzed in the apical four-chamber view as previously described.[9] In brief, the region of interest was applied over the LV myocardium in an apical four-chamber view. The software automatically tracked down the rotational rate of myocardial motion with reference to the center of gravity of the region of interest. In accordance with engineering notation, a negative sign indicated clockwise rotation, and a positive sign signified counterclockwise rotation. The adequacy of tracking was verified manually, and the region of interest was readjusted to achieve optimal tracking. Figure 1 shows an example of LD, LS, and SLRD of a patient with CP.

Outcomes

Our prespecified outcomes were change in dose and/or number of diuretics used, and NYHA class. Specifically, a reduction in diuretics was defined as (1) a reduction in the dose of a diuretics (eg, furosemide 40 to 20 mg), (2) discontinuation of a diuretic (eg, furosemide 20 mg plus spironolactone 25 mg to furosemide 20 mg only), or both. Median reduction of furosemide was 40 mg (range, 20–160 mg), and reduction of spironolactone was 25 or 50 mg.

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