Feasibility of Speckle-Tracking Echocardiography for Assessment of Left Ventricular Dysfunction After Cardiopulmonary Bypass

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Objectives: Effects of temporary biventricular pacing after cardiopulmonary bypass are unpredictable, and the utility of speckle-tracking echocardiography in this setting is unclear. Accordingly, speckle-tracking analysis of transgastric echocardiograms taken during cardiac surgery was assessed as a potential tool to measure strain, synchrony, and twist as indices to predict response.

Design: Prospective observational study, in part, with a randomized controlled study of temporary permanent biventricular pacing after cardiopulmonary bypass.

Setting: Single-center study at university-affiliated tertiary care hospital.

Participants: Twenty-one cardiac surgery candidates with ejection fraction ≤40% and QRS duration ≥100 ms or who were undergoing double-valve surgery.

Interventions: Transgastric views of the basal, midpapillary, and apical levels of the left ventricle were acquired before and after bypass.

Measurements and Main Results: Midpapillary sections were analyzable in 38% of patients. The remainder had epicardial borders extending beyond the field of view (24%) or inadequate image quality (38%). Only 9% of basal or apical sections were analyzable. Midpapillary radial strain and synchrony changed insignificantly after bypass. Variation in fractional area change correlated with changes in radial strain ($p = 0.041$) but not with synchrony.

Conclusions: Intraoperative transgastric echocardiography is inadequate for speckle-tracking analysis with current techniques. Intraoperative predictors of temporary biventricular pacing response are lacking.

KEY WORDS:* *speckle-tracking echocardiography, transgastric echocardiography, perioperative biventricular pacing, strain, synchrony, twist, rotation

CARDIAC RESYNCHRONIZATION THERAPY (CRT), or permanent biventricular pacing (BiVP), improves morbidity and mortality for patients with low ejection fraction (EF) and prolonged QRS duration.[1,2] Temporary BiVP similarly improves postoperative cardiac function in patients with equivalent criteria undergoing cardiac surgery on cardiopulmonary bypass (CPB).[3,4]

With current inclusion criteria, BiVP response after CPB is still unpredictable,[5] similar to CRT, with nonresponse rates as high as 40%.[4] The multicenter PROSPECT trial revealed the limitations of M-mode, pulsed-wave Doppler, and tissue Doppler imaging for predicting response to CRT.[6] Several single-center studies, however, have found speckle-tracking echocardiography (STE) to be a useful predictor of response to CRT.[7]

STE is a relatively recent technique that analyzes myocardial motion by tracking the speckles in each ultrasonic image frame-by-frame. STE provides quantitative spatial and temporal information[8] including strain, synchrony, and rotation and has been validated against tagged magnetic resonance imaging, the noninvasive gold standard for measurement of systolic deformation.[9,10] Radial strain (RS) and RS synchrony measured by STE have been useful in predicting response to CRT.[11] Reversal of STE-measured torsion impairment during CRT also has predicted long-term LV reverse remodeling.[12,13]

STE in the perioperative period similarly might predict response to temporary BiVP after CPB, but the utility of STE in this setting has not been well established. Therefore, the authors examined the feasibility of STE to measure strain, intraventricular synchrony, and twist before and after CPB in patients at increased risk for postoperative LV dysfunction.

METHODS

Selection criteria established in the Biventricular Pacing After Cardiac Surgery trial (BiPACS)[14,15] as predictors of postoperative LV dysfunction that would benefit from temporary BiVP were used in a protocol approved by the Internal Review Board of Columbia University Medical Center. These included preoperative LV EF ≤40% and QRS duration ≥100 ms or double-valve replacement independent of preoperative function. Twenty-one patients were enrolled from June 2011 to March 2012; baseline characteristics are listed in Table 1. Seven patients had severe preoperative aortic and/or mitral insufficiency and six had severe aortic stenosis. Exclusion criteria included atrial fibrillation, external pacing, and any contraindication to transesophageal echocardiography (TEE).

All patients received routine monitoring with an arterial and pulmonary artery catheter. The anesthetic technique was general endotracheal anesthesia. After induction with midazolam/fentanyl, either propofol or etomidate (at the discretion of the anesthesiologist), and paralysis with vecuronium or rocuronium, anesthesia was maintained with isoflurane at a minimal alveolar concentration of 0.4-0.6. Fentanyl and midazolam were used as adjunct agents to attenuate autonomic responses. Suction via orogastric tube was used at the judgment of the anesthesiologist. Inotropes, vasopressors, or vasodilators were used at the discretion of the anesthesiologist based on real

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time TEE and hemodynamic monitoring. In general, norepinephrine infusion was used as a first-line postoperative vasoconstrictor/inotrope, with vasopressin infusion added if additional vasoconstriction was necessary. The primary inotropic agent was milrinone.

TEE was performed with an X7_2T transducer on an iE33 Philips Ultrasound system (Phillips Ultrasound, Inc., Bothell WA). Transgastric short-axis views of the basal, midpapillary, and apical levels of the LV were acquired by a skilled anesthesiologist immediately before and after CPB. Fluid and vasoactive drug administration were held constant during image acquisition. Penetration, resolution, and gain were optimized for each patient, and a frame rate between 50-70 frames per second was maintained. Imaging frequency ranged between 2 and 7 megahertz. The basal level was defined as the tips of mitral valve leaflets and the apical level was defined as the level proximal to complete end-systolic lumen obliteration. Midpapillary end-diastolic area (EDA) and end-systolic area (ESA) were measured with planimetry before and after CPB. Fractional area change (FAC) was calculated as (EDA–ESA) × 100/EDA.

Sections were analyzed offline with STE software (QLAB 7.0, Philips). Only images of high quality encompassing full myocardial borders were used. The region of interest was drawn carefully by manual point-and-click method along the endocardial border and adjusted to fit epicardial borders. The region of interest was inspected over each beat and was adjusted if any segment did not track properly during the cardiac cycle. Results were averaged over three consecutive beats.

STE software automatically divided the LV into six equal segments (Fig 1A). Strain was defined as the peak deformation during the cardiac cycle as a percentage of the initial length at end-diastole. RS was calculated as the average peak strain in all 6 segments. RS synchrony was defined as the standard deviation of time to peak RS in all 6 segments at the midpapillary level. A greater value indicated more dyssynchrony.

The sample size was determined based on a power analysis of torsion and radial synchrony. Specifically, the authors assumed that the mean change in radial synchrony between responders and nonresponders was 51ms (SD = 71 ms)[16] and the change in torsion was 4.2 degrees (SD = 3.4) based on previously reported literature.[17] With a two-sided type-I error rate of 5%, 16 patients would achieve at least 80% power.

EDA, ESA, FAC, RS, and RS synchrony were compared before and after CPB using a paired *t*-test. The correlation between changes in FAC and changes in RS and RS synchrony was assessed using linear regression models.

RESULTS

Of the 21 patients studied, 38% had midpapillary sections analyzable with STE. In 24%, sections did not include the entire epicardial border, and in 38%, image quality was inadequate. Figure 1B illustrates a representative example of epicardial borders outside the imaging sector where strain and synchrony could not be measured reliably. EDA and ESA data before and after CPB are presented in Table 2. In 8 patients with midpapillary images adequate for STE analysis, RS averaged 15.8 ± 9.1 (SD) before CPB and 16.9 ± 10.1 after CPB ($p = 0.764$). RS synchrony averaged 0.063 ± 0.050 before CPB and 0.060 ± 0.047 after CPB ($p = 0.771$). Figure 2A and 2B show paired plots of RS and RS synchrony, respectively, for each patient before and after CPB. Patients who underwent aortic valve repair or simultaneous aortic and mitral valve repair surgery are designated by grey circles.

Figure 2C illustrates paired plots before and after CPB of FAC in 17 patients with adequate images. FAC averaged 36.6% ± 12% before CPB and 33.4% ± 12.4% after CPB

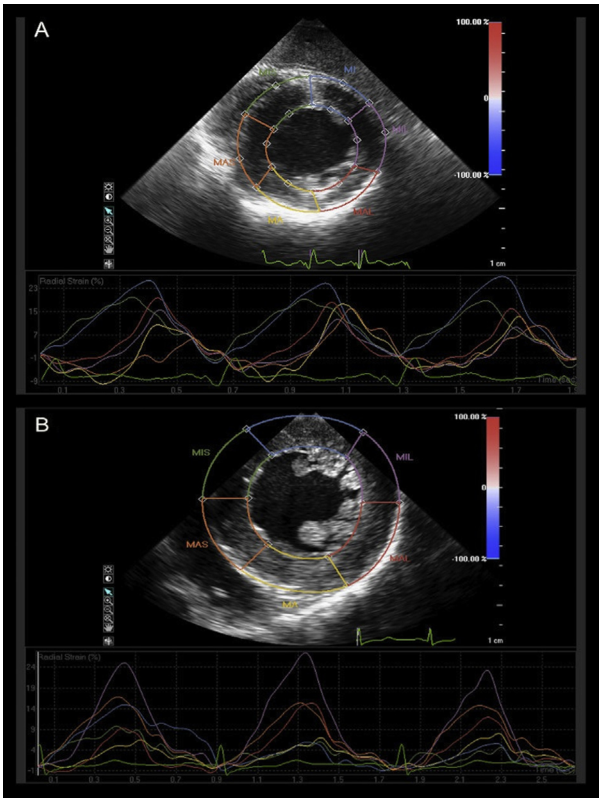

Fig 1. Midpapillary images for speckle-tracking echocardiography analysis. (A) Representative short-axis transgastric echocardiogram. Full epicardial borders are visible. Six separate radial strain waveforms corresponding to each section of the ventricle also are shown. All sections are tracked adequately, allowing calculation of global radial strain and synchrony. (B) Representative image with left ventricular dimensions extending beyond the echo window. Global radial strain and synchrony cannot be tracked accurately.

Table 1. Preoperative Characteristics

	Surgery				
Characteristics	CABG	CABG + Valve	Single Valve	Double Valve	Total Average
Ejection Fraction	28 (11)	32 (6)	31 (7)	43 (13)	33 (11)
QRS Duration	126 (28)	130 (0)	113 (17)	103 (22)	115 (23)
Age	63 (16)	56 (6)	60 (14)	61 (28)	61 (17)
Gender (M/F)	4/3	3/0	6/0	2/3	15/6
BSA	2.04 (0.21)	1.87 (0.23)	1.75 (0.17)	2.24 (0.29)	1.94 (0.27)

Average baseline preoperative characteristics are listed with standard deviation in parenthesis.

Abbreviations: BSA, body surface area; CABG, coronary artery bypass grafting; F, female; M, male.