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

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Abstract

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.

Keywords

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 information⁸ 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 $\geq$ 40% and QRS duration $\leq$ 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 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 $(EDA-ESA) \times 100/EDA$.

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 $36.6\% \pm 12\%$ before CPB and $33.4\% \pm 12.4\%$ after CPB ($p = 0.213$). In the eight patients with adequate images for STE analysis, change in FAC correlated with change in RS (correlation coefficient = 0.73, $p = 0.041$) but not with RS synchrony (correlation coefficient = -0.56, $p = 0.15$, Fig 3).

Basal sections were analyzable with STE in 9% of patients, but sections did not encompass full epicardial borders in 52% and image quality was inadequate in 38%. Nine percent of patients had apical sections analyzable with STE. Image quality was inadequate in the remainder. There were no unanticipated adverse events associated with this study.

DISCUSSION

The results illustrated limited value of current techniques for intraoperative STE and minimal utility in selecting patients for temporary BiVP. In patients with systolic dysfunction and QRS prolongation, the authors found transgastric TEE views inadequate for STE analysis in most patients. Cardiac enlargement and poor image quality were the predominant deterrents. High-quality basal or apical images were more difficult to obtain, causing twist analysis to be more challenging. Among patients with adequate midpapillary images, there were no significant changes in RS or RS synchrony after CPB. Changes in FAC correlated significantly with changes in RS, consistent with previous findings and validation against sonomicrometry.^{18–20} Changes in FAC did not correlate significantly with RS synchrony, which may have been due to limited sample size or limitations of STE in detecting dyssynchrony in this setting.

STE with TTE cannot be assumed to apply to TEE images,²¹ and few studies have explored feasibility of STE using trans-gastric TEE in the perioperative setting. Kukucka et al reported feasibility of midesophageal TEE for STE in 10 patients with low EF undergoing elective coronary artery bypass grafting (CABG) surgery.²² Marcucci et al also studied patients undergoing elective CABG and found adequate transgastric TEE images in 56% of basal segments, 57% of midpapillary segments, and 49% of apical segments analyzable with STE, a significant decrease from 70% with TTE.²¹ Lower success rates in this study likely reflected differences in patient populations. The authors focused on patients with systolic dysfunction and electrical dyssynchrony who were at risk for cardiac dysfunction after CPB and, thus, enrolled patients undergoing valve repair in addition to CABG. The patient population was, therefore, different from previous studies that focused on patients

undergoing CABG alone. Two-thirds of this population had pressure or volume overload and chamber enlargement, which increased the difficulty in obtaining full epicardial borders.

The BIPACS trial found a statistically significant improvement in cardiac index with temporary BiVP in patients who underwent aortic valve repair or simultaneous aortic and mitral valve repair by 29% compared to the unpaced group.²³ The current study did not find consistent changes in strain, synchrony, or FAC after CPB in patients who underwent aortic or simultaneous aortic and mitral valve repair, further suggesting the limited value of STE in this setting.

There were limitations to this study. One limitation was the sample size. Although the power analysis showed that a sample size of 16 would detect changes in synchrony and torsion after CPB, the study was concluded at 21 patients based on the assumption that image quality would prove adequate for analysis in 80% of studies. Subsequent processing demonstrated that a much larger quality margin was necessary. The authors focused primarily on the feasibility of STE in the perioperative period in this patient population and with the low success rate encountered, the authors did not consider this analysis feasible. For this reason, intra- and interobserver variability were not measured, which was another limitation to this study.

The study was also limited by the heterogeneity of this patient population. The purpose of the BiPACS trial was to investigate the effects of temporary BiVP on all patients at risk for cardiac dysfunction after CPB, and the aim of this study to determine the utility of perioperative STE in this setting. Temporary BiVP and STE may be more effective for specific surgeries, which would be an aim for future studies. Another limitation of the study was the focus on the short-axis transgastric view. The authors did not assess the feasibility of using long-axis, midesophageal views and, thus, cannot attest to the feasibility of that technique in this setting. Additionally, the utility of other STE modalities such as 3D STE were not investigated. These would be aims for future studies.

The authors aimed to assess the feasibility of STE to analyze cardiac function in the perioperative period to predict response to temporary BiVP. The results demonstrated a low success rate using STE to assess strain, synchrony, rotation, and twist from short-axis transgastric images in this patient population.

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References

1. Wells G, Parkash R, Healey JS, et al. Cardiac resynchronization therapy: A meta-analysis of randomized controlled trials. *CMAJ*. 2011; 183:421–429. [PubMed: 21282316]
2. Epstein AE, DiMarco JP, Ellenbogen KA, et al. ACC/AHA/HRS 2008 guidelines for device-based therapy of cardiac rhythm abnormalities: A report of the american college of cardiology/american heart association task force on practice guidelines (Writing Committee to Revise the ACC/AHA/NASPE 2002 Guideline Update for Implantation of Cardiac Pacemakers and Antiarrhythmia

- Devices) developed in collaboration with the American Association for Thoracic Surgery and Society of Thoracic Surgeons. *J Am Coll Cardiol*. 2008; 51:e1–62. [PubMed: 18498951]
3. Straka F, Pirk J, Pindak M, et al. Biventricular pacing in the early postoperative period after cardiac surgery. *Physiol Res*. 2011; 60:877–885. [PubMed: 21995901]
 4. Dzembali O, Bakhtiyar F, Dogan S, et al. Perioperative biventricular pacing leads to improvement of hemodynamics in patients with reduced left-ventricular function—Interim results. *Pacing Clin Electrophysiol*. 2006; 29:1341–1345. [PubMed: 17201840]
 5. Garcia Bengochea JB, Fernandez AL, Sanchez Calvelo D, et al. Temporary epicardial left ventricular and biventricular pacing improves cardiac output after cardiopulmonary bypass. *J Cardiothorac Surg*. 2012; 7:113. [PubMed: 23088393]
 6. Chung ES, Leon AR, Tavazzi L, et al. Results of the Predictors of Response to CRT (PROSPECT) trial. *Circulation*. 2008; 117:2608–2616. [PubMed: 18458170]
 7. Risum N, Jons C, Olsen NT, et al. Simple regional strain pattern analysis to predict response to cardiac resynchronization therapy: Rationale, initial results, and advantages. *Am Heart J*. 2012; 163:697–704. [PubMed: 22520537]
 8. Perk G, Tunick PA, Kronzon I. Non-Doppler two-dimensional strain imaging by echocardiography—from technical considerations to clinical applications. *J Am Soc Echocardiogr*. 2007; 20:234–243. [PubMed: 17336748]
 9. Amundsen BH, Helle-Valle T, Edvardsen T, et al. Noninvasive myocardial strain measurement by speckle tracking echocardiography: Validation against sonomicrometry and tagged magnetic resonance imaging. *J Am Coll Cardiol*. 2006; 47:789–793. [PubMed: 16487846]
 10. Helle-Valle T, Crosby J, Edvardsen T, et al. New noninvasive method for assessment of left ventricular rotation: Speckle tracking echocardiography. *Circulation*. 2005; 112:3149–3156. [PubMed: 16286606]
 11. Tanaka H, Nesser HJ, Buck T, et al. Dyssynchrony by speckle-tracking echocardiography and response to cardiac resynchronization therapy: Results of the speckle tracking and resynchronization (star) study. *Eur Heart J*. 2010; 31:1690–1700. [PubMed: 20530502]
 12. Bertini M, Marsan NA, Delgado V, et al. Effects of cardiac resynchronization therapy on left ventricular twist. *J Am Coll Cardiol*. 2009; 54:1317–1325. [PubMed: 19778675]
 13. Russel IK, Gotte MJ, de Roest GJ, et al. Loss of opposite left ventricular basal and apical rotation predicts acute response to cardiac resynchronization therapy and is associated with long-term reversed remodeling. *J Card Fail*. 2009; 15:717–725. [PubMed: 19786261]
 14. Wang DY, Richmond ME, Quinn TA, et al. Optimized temporary biventricular pacing acutely improves intraoperative cardiac output after weaning from cardiopulmonary bypass: A substudy of a randomized clinical trial. *J Thorac Cardiovasc Surg*. 2011; 141:1002–1008. [PubMed: 20800242]
 15. Nguyen HV, Havalad V, Aponte-Patel L, et al. Temporary biventricular pacing decreases the vasoactive-inotropic score after cardiac surgery: A substudy of a randomized clinical trial. *J Thorac Cardiovasc Surg Epub*. Jul 27.2012
 16. Delgado V, Ypenburg C, van Bommel RJ, et al. Assessment of left ventricular dyssynchrony by speckle tracking strain imaging comparison between longitudinal, circumferential, and radial strain in cardiac resynchronization therapy. *J Am Coll Cardiol*. 2008; 51:1944–1952. [PubMed: 18482662]
 17. Sade LE, Demir O, Atar I, et al. Effect of mechanical dyssynchrony and cardiac resynchronization therapy on left ventricular rotational mechanics. *Am J Cardiol*. 2008; 101:1163–1169. [PubMed: 18394452]
 18. Leitman M, Lysyansky P, Sidenko S, et al. 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]
 19. Armstrong G, Pasquet A, Fukamachi K, et al. Use of peak systolic strain as an index of regional left ventricular function: Comparison with tissue doppler velocity during dobutamine stress and myocardial ischemia. *J Am Soc Echocardiogr*. 2000; 13:731–737. [PubMed: 10936816]
 20. Urheim S, Edvardsen T, Torp H, et al. Myocardial strain by doppler echocardiography. Validation of a new method to quantify regional myocardial function. *Circulation*. 2000; 102:1158–1164. [PubMed: 10973846]

21. Marcucci CE, Samad Z, Rivera J, et al. A comparative evaluation of transesophageal and transthoracic echocardiography for measurement of left ventricular systolic strain using speckle tracking. *J Cardiothorac Vasc Anesth*. 2012; 26:17–25. [PubMed: 21835637]
22. Kukucka M, Nasser B, Tscherkaschin A, et al. The feasibility of speckle tracking for intraoperative assessment of regional myocardial function by transesophageal echocardiography. *J Cardiothorac Vasc Anesth*. 2009; 23:462–467. [PubMed: 19217798]
23. Spotnitz HM, Cabreriza SE, Wang DY, et al. Clinical endpoints of the biventricular pacing after cardiac surgery trial. *Ann Thorac Surg*. in press.

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.

Fig 2.

Strain, synchrony, and fractional area change before and after cardiopulmonary bypass. For each patient, radial strain (A), radial strain synchrony (B), and fractional area change (C) are shown before and after cardiopulmonary bypass. Means are designated by open circles. Strain, synchrony, and fractional area change did not significantly change after bypass. Patients who had aortic valve or simultaneous aortic valve and mitral valve surgery are designated by grey circles.

Fig 3.

Correlation between fractional area change, strain and synchrony. Change in fractional area change correlates significantly with changes in radial strain (A) but not with changes in radial strain synchrony (B).

Table 1

Preoperative Characteristics

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

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

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

Table 2

Average Hemodynamics, and Strain, Synchrony Values Before and After Bypass

	Pre-CPB	Post-CPB	p Value
HR (beats/min)	68.0 (14.0)	80.0 (10.0)	0.001
EDA (cm ²)	27.8 (7.2)	24.7 (5.8)	0.006
ESA (cm ²)	18.3 (6.9)	16.8 (5.8)	0.115
FAC (%)	36.6 (12)	33.4 (12.4)	0.213
RS (%)	15.8 (9.1)	16.9 (10.1)	0.764
RS Synchrony (STD)	0.063 (0.050)	0.060 (0.047)	0.771

HR, EDA, ESA, FAC, RS, and RS synchrony pre- and post-cardiopulmonary bypass are listed above. Standard deviations are listed in parenthesis. HR significantly increased and EDA significantly decreased after bypass. ESA, FAC, RS, and RS synchrony did not significantly change after bypass.

Abbreviations: CPB, cardiopulmonary bypass; HR, heart rate; EDA, end-diastolic area; ESA, end-systolic area; FAC, fractional area change; RS, radial strain.