Effects of antegrade versus integrated blood cardioplegia on left ventricular function evaluated by echocardiographic real-time 3-dimensional speckle tracking

Maneesha Bhaya, MD, DNB,[a] Selvin Sudhakar, MD,[a] Kamel Sadat, MD,[a] Rajesh Beniwal, MD,[b] Deepak Joshi, MD,[a] James F. George, PhD,[a] Navin C. Nanda, MD,[a] Gerald D. Buckberg, MD,[c] and Constantine L. Athanasuleas, MD[a]

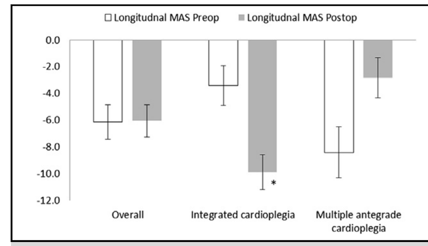
ABSTRACT

Objective: The objective of this study was to evaluate left ventricular free wall and interventricular septal function by 2-dimensional transthoracic echocardiography and live/real-time 3-dimensional transthoracic speckle tracking echocardiography before and after on-pump cardiac surgery and to assess the effect of mode of cardioplegia delivery.

Methods: A total of 22 patients were studied 1 day before and 4 to 5 days after surgery. Cold blood cardioplegia was delivered by intermittent antegrade infusion or by the integrated method. The latter includes a combination of intermittent antegrade and retrograde cardioplegia with a terminal warm amino acid–enriched reperfusion.

Results: The overall group displayed significant deterioration of septal function after surgery by 2-dimensional transthoracic echocardiography, as assessed by wall motion score index, yet subgroup analysis by 3-dimensional transthoracic speckle tracking echocardiography permitted distinction of outcomes achieved by antegrade or integrated delivery methods. Analysis after surgery showed that only the antegrade group displayed statistically significant deterioration in the strain parameters of some of the segments of the septum and free wall when strain was measured in the free wall and septum in the longitudinal, circumferential, and radial modes of deformation ($P < .05$). In contrast, only the integrated group displayed significant improvement in global radial, circumferential, and longitudinal strain ($P < .05$).

Conclusions: These findings by 3-dimensional transthoracic speckle tracking echocardiography indicate that integrated cardioplegia offers superior myocardial protection of the left ventricular free wall and septum compared with the antegrade mode of cardioplegia delivery. (J Thorac Cardiovasc Surg 2015;149:877-84)



Septum strain (lengthening) worsens after only antegrade but improves by integrated blood cardioplegia.

Central Message

Preserving function tests myocardial protection adequacy. The same blood cardioplegic solution was delivered either antegrade or in an integrated way. Three dimensional speckle-tracking echocardiogram showed functional deterioration after only antegrade delivery but improvement to normality after integrated delivery. Focus should be on strategies, not only on solutions.

Author Perspective

Cardioplegia discussions currently only involve what solution is used. Myocardial protection considerations must address delivery (insuring good distribution), perfusion pressure, and temperature, especially during reperfusion of unprotected areas. Similar patients received the same blood cardioplegia solution either by antegrade or integrated delivery. Three dimensional speckle tracking of pre- and postoperative strain showed deterioration after antegrade delivery, but improvement after integrated delivery. Septum longitudinal shortening was impaired after antegrade, but improved by integrated delivery. The commonplace septal damage was avoided by considerations that addressed the strategies of protection, rather than only focusing on solution composition.

See Editorial Commentary pages 884-5.

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Supplemental material is available online.

From the Department of Community Medicine,[a] University of Alabama, Birmingham, Ala; Department of Community Medicine,[b] SSR Medical College, Belle Rive, Mauritius; and Department of Cardiothoracic Surgery,[c] University of California Los Angeles Medical Center, Los Angeles, Calif.

M.B. and S.S. contributed equally to this work.

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Address for reprints: Gerald D. Buckberg, MD, Department of Cardiothoracic Surgery, UCLA Medical Center, Rm 62-258 CHS, Box 951741, Los Angeles, CA 90095-1741 (E-mail: gbuckberg@mednet.ucla.edu).

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Paradoxical motion developed after valve and coronary artery bypass procedures in approximately 50% of approximately 3300 patients with normal preoperative septal function undergoing cardiac surgery.[1] This study used 2-dimensional (2D) echocardiography.[2] Other reports document abnormal septal motion, with paradoxical bulging developing in some patients after M-mode echocardiography[3-5] and radionuclide ventriculography.[3,6-8]

The integrated method of myocardial protection using antegrade and retrograde amino acid substrate–enriched cardioplegia has been described.[9] Abnormal septal motion did not occur using integrated blood cardioplegia in 119 consecutive patients undergoing on-pump[10] procedures. These favorable results imply that septal dysfunction may reflect a reperfusion injury that is preventable.

Abbreviations and Acronyms

LV = left ventricle
RV = right ventricle
STE = speckle tracking echocardiography
3D = 3-dimensional
TTE = transthoracic echocardiography
2D = 2-dimensional

Transient ischemic changes may be responsible for septal dysfunction,[11] when analyzed by 2D speckle tracking after on-pump cardiac surgery.[12] So far, no study has assessed the septal function and lateral free wall of the left ventricle (LV) after cardiac surgery using 3-dimensional (3D) speckle tracking. During 2D echocardiographic thin-slice imaging, the chance of a specific speckle moving out of the examining plane during the cardiac cycle is high, and this could introduce false results. Conversely, 3D speckle tracking echocardiography (STE) images a large pyramidal data set and reduces the likelihood of error in evaluating septal and LV free wall strain and strain rate.

Myocardial strain and strain rate imaging by the STE technique thereby provides considerable improvement over conventional 2D echocardiography in the estimation of LV and septal function because it objectively assesses radial, longitudinal, circumferential, and rotational deformation of each myocardial segment in 3 dimensions.[13,14] Normal septal function also is essential for right ventricular (RV) performance, because its spiral helical fibers cause the essential myocardial twisting function when pulmonary vascular resistance is increased. The septum constitutes 40% of the total ventricular weight[14,15] and has been termed "the lion of right ventricular function."[16] Moreover, it constitutes approximately half of LV weight, thereby accounting for a substantial component of LV function.[16,17]

The helical heart configuration of the ventricular architecture[18,19] shows that the right-sided helix or descending segment comprises the endocardium of the left side of the septum, and the left-handed helix or ascending segment constitutes the endocardium of the right side of the septum. Consequently, dysfunction of the inner shell formed by the descending segment would prolong its contraction and interfere with untwisting, because the natural temporal hiatus between the 2 helical arms is disrupted. Thus, diastolic dysfunction may develop.[20]

The purpose of the present study was to (1) compare the assessment of preoperative and postoperative septal and LV free wall function by 2D transthoracic echocardiography (TTE) and 3D STE in patients undergoing on-pump cardiac surgery and (2) evaluate the effect of the type of cardioplegia delivery on the postoperative function of the septum and lateral free wall of the LV.

MATERIAL AND METHODS

The institutional review board approved the study protocol. Each patient gave written informed consent. We prospectively acquired data on 22 patients (15 male and 7 female) aged 27 to 80 years (mean, 50.9 years) who underwent on-pump cardiac surgery and had 2D TTE and 3D STE 1 day before and 4 to 5 days after surgery at the University of Alabama Hospital. Patients were nonrandomized. Table 1 shows the procedures, route of cardioplegia delivery, baseline LV ejection fraction, and coronary angiogram. Two surgeons performed procedures included in the antegrade only group, and 1 surgeon performed procedures using the integrated method. Patients receiving integrated and antegrade cardioplegia had comparable baseline comorbidities. The cardioplegic solution is shown in Table 2, and only the integrated group received retrograde delivery and warm cardioplegic reperfusion. The pericardium was always left open.

The Artida system and a PST-25SX 1 MHz to 4 MHz phased-array matrix transducer, both manufactured by Toshiba Medical Systems Corporation (Otawara, Japan), were used for 2D and 3D image acquisition.

2D TTE was performed before and after surgery using standard parasternal long-axis, parasternal short-axis, apical 4-chamber, apical 2-chamber, and apical long-axis views.

The septum and LV free wall motion were scored independently by 2 blinded observers before and after surgery by American Society of Echocardiography recommendations: 1 = normal, 2 = hypokinetic, 3 = akinetic, 4 = dyskinetic/paradoxical, and 5 = aneurysmal.[21] The mean preoperative and postoperative wall motion scores were calculated for the basal, middle, and apical segments of the septum and LV free wall.[10]

For 3D examination before and after surgery, several data sets were acquired in full-volume mode using the 4 acoustic window view. Breath-holding during acquisition minimized any stitch artifacts. Optimal overall quality 3D data sets were saved for subsequent off-line analysis. Endocardial and epicardial boundary mapping was done by blood–tissue interface reference point placement at the LV apex and the base of the mitral valve leaflets. Region wall thickness was adjusted by manually modifying the automated tracing in areas of interest where endocardial and epicardial borders were not correctly identified by the computer. Then, automated analysis of the entire cardiac cycle was started to obtain various strain parameters.

Results were automatically displayed on the screen in the form of charts, time-to-variable value graphics, and color-coded LV schematics. A 16-segment model was used for analysis. Global radial, longitudinal, circumferential, area, and torsion strain and rate of rotation and un-rotation were analyzed for segments corresponding in the septum (basal anterior septum, basal inferior septum, mid-anterior septum, mid-inferior septum, and apical septum) and free LV lateral wall (basal anterolateral wall, basal inferolateral wall, mid-anterolateral wall, mid-inferolateral wall, apical lateral wall) as described previously[22] (Table E1).

Area strain defines the relative change in area in the combined longitudinal and circumferential strain.[23] "Twist" reflects the algebraic rotational difference between the cardiac base and the apex. For example, if the base rotates by $-10°$ and the apex rotates by $+30°$, the "twist" will be equal to 40°. Torsion strain is twist divided by the distance between base and base, expressed as degrees per centimeter.[24,25]

Rate of rotation and un-rotation measures rotational myocardial movement along an imaginary long-axis line from apex to base drawn through the middle of the LV cavity. Clockwise rotations are assigned negative value, and counterclockwise rotations are positive values. Normally, the cardiac base rotates clockwise and the apex rotates counterclockwise during systole.[24]

The maximum segmental strain (expressed as percent change from baseline) during systole was obtained from color-coded graphic display and compared preoperatively and postoperatively. The cardiac cycle was divided into 2 equal halves. The first half (starting from QRS interval onset) was considered as systole. This period includes early diastole and minimizes miscalculation of cardiac systole if mitral valve and aortic valve