Monitoring the Variation in Myocardial Function With the Doppler-Derived Myocardial Performance Index During Aortic Cross-Clamping

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Objectives: **To investigate the effects of acute elevation in afterload on global (systolic and diastolic) myocardial function by performing serial intraoperative transesophageal echocardiograms during and after cross-clamp application on patients undergoing elective abdominal aortic aneurysm (AAA) surgery.**

Design: **A prospective observational study.**

Setting: **A tertiary care university hospital.**

Participants: **Patients undergoing elective AAA repair under general anesthesia (GA).**

Intervention: **The use of perioperative transesophageal echocardiography to calculate a tissue Doppler–derived myocardial performance index (MPI) during different stages of the surgery.**

Measurement and Results: **Twenty consecutive patients scheduled for suprarenal AAA repair under GA were included in the study. Perioperative transesophageal echocardiography was performed after the induction of GA. MPI was calculated with Doppler tissue imaging as the sum of isovolumetric contraction and relaxation times divided by the ejection time before cross-clamping of the aorta and then 2, 10, and 20 minutes after cross-clamp application. A final MPI was measured after unclamping of the aorta. As compared with baseline, cross-clamp application initially worsened MPI within 2 minutes and then MPI improved to baseline after 10 minutes of cross-clamp application. The MPI improved significantly after unclamping of the aorta.**

Conclusions: **The authors observed a temporal variation in global myocardial function after the application of a cross-clamp in the suprarenal position. There was transient deterioration of global myocardial function (the prolongation of MPI) 2 minutes after cross-clamp application, which improved within 10 minutes. Myocardial function returned to baseline after unclamping the aorta.**

KEY WORDS: abdominal aortic aneurysm, transesophageal echocardiography, myocardial performance index, Anrep effect

ABDOMINAL AORTIC CROSS-CLAMP (XCL) application is associated with variable alterations in preload and acute elevation in afterload.[1] These hemodynamic changes have been shown to be associated with a transient alteration in global myocardial systolic and diastolic function but do not have long-term sequelae.[2-5] Animal experiments also have shown a temporal variation in myocardial function after acute elevations of central aortic pressure, an immediate deterioration followed by a return to baseline, which is termed the "Anrep effect" after the physiologist who described it.[6,7] The return of myocardial function to baseline was erroneously termed as the "positive inotropic" effect of a sustained afterload increase. The exact cellular mechanism for this transient deterioration with gradual apparent "improvement" (ie, return to baseline in myocardial function) remains unknown. This phenomenon has been attributed to multiple factors including increased coronary perfusion pressure after increased aortic pressure, afterload-dependent stretch-related myocardial autoregulation, and calcium re-entry into the sarcoplasm.[8-12] Whether similar dynamic changes are observed in clinical situations associated with acute elevations of afterload has not been investigated.

XCL application during abdominal aortic aneurysm surgery is associated with a sudden elevation in afterload and changes in myocardial systolic and diastolic function.[2-5] Transesophageal echocardiography (TEE) has been used to monitor these changes in global myocardial function during abdominal aortic aneurysm (AAA) surgery.[2,4,5] Such echocardiographic observations are limited to "spot checks" of myocardial function at predetermined points (ie, pre-XCL and post-XCL) in time during periods of hemodynamic stability. It is quite possible that because of the presence of autoregulatory and adaptive feedback mechanisms, global myocardial function also could undergo a temporal variation after XCL application to optimize myocardial performance. The availability of sophisticated Doppler indices has now made it possible to appreciate subtle myocardial functional changes with a degree of precision. One such index, the Doppler-derived myocardial performance index (MPI) or the "Tei Index" has been validated as a monitor of global myocardial function (systolic and diastolic) and its correlation with left ventricular (LV) function has been confirmed with simultaneous echocardiographic and cardiac catheterization studies.[13-15] The utility of MPI as a simple and practical intraoperative monitor of global myocardial function using TEE also has been shown.[3] A prolongation of MPI from baseline implies a prolongation of isovolumetric contraction or isovolumetric relaxation time or shortening of the forward ejection time and therefore signifies the deterioration of global myocardial function (Fig 1). Excellent intra- and interobserver variability has been shown in multiple studies.[16,17] Therefore, the authors sought to characterize the changes in MPI over time with abdominal aortic XCL application and compared them with baseline (pre-XCL) and after unclamping of the aorta (post-XCL) values and hypothesized that it would show a temporal variation in global myocardial function after XCL application.

METHODS

After receiving institutional review board approval for this prospective observational study, 20 consecutive patients scheduled for elective suprarenal AAA repair under general anesthesia (GA) were included in the study. Written informed consent was obtained for all the partici-

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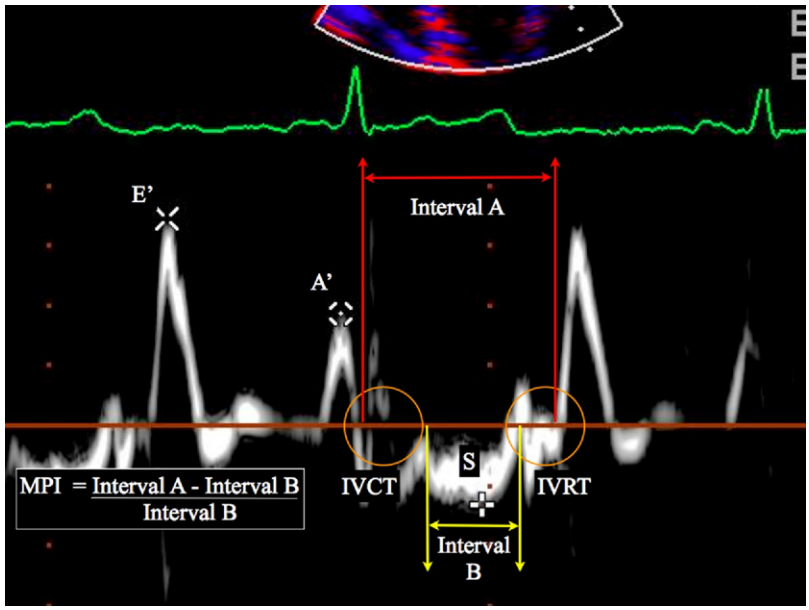

Fig 1. A spectral Doppler display of Doppler tissue waves derived from the lateral mitral annulus and the time intervals required for calculation of the MPI. E′, rapid relaxation wave; A′, atrial contraction wave; S, systolic wave; IVCT, isovolumetric contraction time; IVRT, isovolumetric relaxation time. (Color version of figure is available online.)

pants. Exclusion criteria included emergency surgery, patient refusal, rhythm other than sinus, aortic surgery requiring cardiopulmonary bypass, a history of dysphagia, esophageal or gastric surgery and esophageal stricture, and severe aortic or mitral valvular disorders.[18,19] In addition to the standard American Society of Anesthesiologists monitors, all patients had radial arterial catheters, central venous access, and a pulmonary artery catheter. The anesthetic management was not standardized but, with minor variations, included a regimen consisting of intravenous induction with etomidate and fentanyl, vecuronium for muscle relaxation, and a mixture of 50% oxygen and air and isoflurane (minimum alveolar concentration, 0.75-1%) for the maintenance of GA. Perioperative heart rate was maintained at or below 80 beats/min with β-adrenergic blocking drug administration (metoprolol and/or esmolol).

The TEE probe was inserted in the esophagus after the induction of GA and endotracheal intubation. The TEE examination was performed by a study investigator qualified by the Special Competence in Perioperative Transesophageal Echocardiography Examination of the National Board of Echocardiography. A comprehensive 2-dimensional intraoperative TEE examination was conducted according to the established guidelines.[20,21] An assessment of MPI was obtained using Doppler tissue imaging. From a midesophageal 4-chamber view a pulse-wave Doppler sample volume was placed on the lateral mitral annulus, and a spectral Doppler pattern was obtained by activating the Doppler tissue imaging presets (Fig 1).[2] "Interval A" was recorded from the end of the A' wave to the onset of the next E' wave. "Interval B" was measured as the duration of the S wave on the spectral Doppler display, the "ejection time" (Fig 1). All measures were made during periods of apnea on 3 successive beats, and the final value was calculated as the average of the 3 obtained values.[22-24] The MPI was calculated as (interval A − interval B)/interval B. A baseline MPI measurement was made after the induction of GA and before skin incision. Subsequent MPI measures were made 2, 10, and 20 minutes after XCL application. A final MPI value was measured after unclamping of the aorta and achievement of hemodynamic stability. An abnormal MPI was predetermined as ≥0.36.[2] In addition to MPI, an assessment of systolic function was made by estimating the ejection fraction by visual quantitative assessment from a combination of the transgastric short-axis view and midesophageal windows, and any specific wall motion abnormalities of the left and right ventricles were noted according to the guidelines.[21] The TEE probe was kept in situ for the duration of the procedure and was removed after the conclusion of the procedure before extubation or transfer to the recovery unit. All the studies were performed on the Philips Medical Systems IE-33 ultrasound system with an Omni-III TEE probe (Andover, MA). Digital data were reviewed on a General Electric Systems (Fairfield, CT) Echo-PACS web-viewing system. All studies were reviewed offline for accuracy and completeness by two echocardiographers (FM/RM).

All data are reported as median (range), mean ± standard deviation, or the incidence of group as appropriate. Analysis of variance repeated-measures analysis was performed to compare the measures of MPI throughout the XLC period. Post hoc analysis was performed using Tukey correction. Significance was determined at the $p \leq 0.05$ level.

RESULTS

Of 26 patients who consented to participate in the study, 20 completed the study (Table 1). The reasons for exclusion included severe aortic stenosis (3 patients), severe mitral regurgitation (1 patient) found on intraoperative TEE, and 2 patients because of insufficient data collection during the course of surgery (severe hemodynamic instability precluded data collection). Patient demographics and surgical characteristics are reported in Table 1.

The mean baseline MPI was 0.29 ± 0.13 before the application of XCL. Six subjects (30%) had an abnormal MPI (≥0.36). There was a significant temporal relationship between XCL application and removal and MPI (Fig 2). After application of the XCL, MPI was prolonged significantly at 2 minutes ($p \leq 0.05$), with 55% of subjects having MPI ≥0.36 at that time. Furthermore, there was a significant increase in the LV