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Original Article

Intraoperative Transesophageal and Postoperative Transthoracic Echocardiographic Evaluation of a Mechanical Heart Valve Prosthesis Implanted at Aortic Position

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Objective: The aims of this study were to evaluate the intraoperative transesophageal echocardiographic (iTEE) characteristics and Doppler flow profile of aortic Chitra heart valve prosthesis (CHVP) under stable hemodynamic and loading conditions, and to compare and correlate the iTEE data with the postoperative transthoracic echocardiography (TTE) data obtained at 48 hours (TTE_1) and 3 months (TTE_2) after the surgery.
Design: Prospective, observational study.
Setting: University-level tertiary referral hospital.
Participants: Forty patients between 18 years and 65 years of age undergoing elective aortic valve replacement (AVR) using CHVP during the period January 2015 to August 2016.
Interventions: After obtaining permission from institutional ethics committee, 40 patients undergoing elective AVR were studied prospectively. The iTEE examination was performed in the pre-cardiopulmonary bypass (CPB) and post-CPB period in all the study subjects. CHVP was subjected to iTEE two-dimensional (2D) echo, color Doppler, and spectral Doppler evaluation under stable hemodynamic and loading condition in the post-CPB period after the administration of protamine. The CHVP were re-evaluated using TTE in all the patients 48 hours after the surgery (TTE_1) and 3 months after the surgery (TTE_2). The iTEE and postoperative TTE Doppler values were compared and correlated.
Measurements and Main Results: The CHVP could be imaged adequately and interrogated with Doppler in all the patients. None of the patients had restriction of occluder mobility or unstable seating of the valve. The intraoperative flow dependent (peak velocity [PV] and mean pressure gradient [MPG]) and less flow dependent (Doppler velocity index, acceleration time, acceleration time/ejection time, effective orifice area [EOA] and indexed EOA) Doppler parameters of CHVP were measured as per the American Society of Echocardiography recommendations. The PV and MPG of CHVP measured by iTEE showed no statistical difference ($p > 0.05$) and were in limits of agreement when compared with TTE_1 and TTE_2 data.
Conclusion: The iTEE features of CHVP were found compliant with the criteria set by the ASE defining normal functioning of an aortic valve prosthesis. The iTEE Doppler parameters obtained under stable loading conditions strongly predicted the postoperative values of Doppler parameters on TTE examination. The iTEE Doppler values can be used as the reference values for the postoperative follow up studies.

Key Words: Chitra heart valve prosthesis; intraoperative transesophageal echocardiography; Doppler evaluation; postoperative transthoracic echocardiography

INTRAOPERATIVE TRANSESOPHAGEAL ECHOCARDIOGRAPHY (iTEE) has become a routine monitoring tool for prosthetic valve evaluation that has been reported to alter the course of surgery after termination of cardiopulmonary

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bypass (CPB) on many occasions.[1,2] Major intraoperative complications associated with prosthetic valves are valve regurgitation, occluder malfunction with or without stenosis, and patient-prosthesis mismatch (PPM).[3,4] These complications have been described in the postoperative studies based on transthoracic echocardiography (TTE), whereas, such studies associated with the iTEE are reported less frequently. Intraoperative Doppler features of prosthetic valves, especially those pertaining to the flow-dependent parameters such as peak velocity (PV) and mean pressure gradient (MPG) may be dissimilar to those measured in the postoperative follow-up period. This may be attributed to governance of the intraoperative cardiac output by variables like inotropes, hemodilution, changing preload, CPB-induced myocardial edema, and depressed myocardial contractility. To overcome the impacts of these confounding factors, guidelines published by the American Society of Echocardiography (ASE) advocate estimation of less flow-dependent parameters such as acceleration time (AT), ratio of AT with ejection time (ET), Doppler velocity index (DVI), effective orifice area (EOA), and indexed-EOA (EOAi).[5] Chitra heart valve prosthesis (CHVP) is a tilting-disc valve, which is stitched to the innate valve annulus through a sewing ring. It has low negative pressure gradients and absence of cavitation effects, thereby reducing blood thrombosis and damage.[6] It is widely used in the developing countries. Numerous follow-up studies have proven the long-term safety and efficacy of the CHVP.[7–10] However, there are scanty reports illustrating the echocardiographic and hemodynamic characteristics of the CHVP in the intraoperative period.[11] To the best of the authors' knowledge, there are no studies comparing intraoperative echocardiographic observations with that of 48 hours and 3 months after the surgery. Hence, the authors conducted this study to evaluate the iTEE characteristics and Doppler flow profile of aortic CHVP under stable hemodynamic and loading conditions. The authors hypothesized that the intraoperative pressure gradients obtained with TEE would correlate with the postoperative TTE data obtained both at 48 hours and 3 months after surgery.

Methods

After obtaining approval from the Institutional Ethics Committee (IEC no: SCT/S/311/2014) and written informed consent from the patients, this prospective, observational study was conducted on 40 patients between 18 years and 65 years of age in a university-level tertiary referral hospital during the period January 2015 to August 2016. The patients were subjected to elective aortic valve replacement (AVR) using CHVP without concomitant repair or replacement of other valves. Patients were excluded from analysis if they had any of the following 9 criteria: 1) left ventricular ejection fraction (LVEF) $< 40\%$, 2) moderate-to severe or severe mitral regurgitation, 3) moderate-to-severe or severe mitral stenosis, 4) significant coronary artery disease with or without requirement for revascularization, 5) presence of intracardiac or extracardiac shunts, 6) redo AVR, 7) contraindication to TEE probe placement, 8) patient refusal to participate in the study, and 9) inability to image the prosthesis satisfactorily to interpret the results. Patients fulfilling the inclusion criteria were selected as the study subjects after obtaining informed consent.

In the operating room, an adult-size TEE probe was inserted after induction of anesthesia, and the heart was inspected using an ultrasound system (IE 33, Philips Ultrasound, Bothell, WA). The TEE examination in the pre-CPB period consisted of measurement of LVEF and left ventricular end diastolic volume index (LVEDVi). Other valves were examined to rule out the presence of more than mild stenosis or regurgitation.

After heparin administration, the CPB was established and the CHVP was implanted at aortic position in all patients. Inotropic infusions were commenced in all the patients before weaning from CPB, in accordance with the institutional protocols. Patients with good LV function received infusion of dobutamine at a dose of 5 μg/kg/min, whereas epinephrine 0.05 μg/kg/min was added when the LV systolic function was deranged. Dobutamine was avoided in the presence of severe LV hypertrophy and when the heart rate exceeded 100 beats/min. Those with reduced afterload, as detected by normal LV end-diastolic area, but low end-systolic area in the iTEE transgastric mid-papillary short-axis view and low diastolic BP with a wide pulse pressure were treated with infusion of norepinephrine, 0.05 μg/kg/min. The management of hemodynamic parameters in the post-CPB period was guided by the TEE examination of the left ventricle (LV) with assessment of the preload, contractility, and afterload. The preload was adjusted by maintenance of the CVP to 8 to12 mmHg in patients with good LV function and the LV end-diastolic volume index (LVEDVi) within 10% to 15% of its preoperative value. The mean arterial pressure was maintained within $\pm$ 20% of the preoperative values and the hematocrit between 30% and 35%. This stable preload condition was achieved in all the patients by infusion of fluids, blood, and titrating the inotropes.

Final TEE examination of CHVP was done after the administration of protamine by an echocardiographer when stable hemodynamic parameters were attained. Cardiac output was measured at the left ventricular outflow tract (LVOT) by tracing the spectral envelope of a pulse wave placed at LVOT and multiplying the LVOT velocity time integral with LVOT area and heart rate. The 2DE evaluation consisted of assessment of stability of valve seating, mobility of the disc, and adequacy of disc opening. The prosthesis was subjected to color Doppler imaging for detection of any paravalvular or intravalvular regurgitation. The prosthesis was interrogated using continuous wave Doppler in either transgastric long-axis view or deep transgastric 5-chamber view, wherein the ultrasound beam could be aligned parallel to the flow. The following parameters were evaluated as per the ASE recommendations[5]: PV, MPG, AT, AT/ET ratio, contour of the velocity jet, DVI, EOA by continuity equation, and EOAi.

The CHVP were re-evaluated using TTE in all patients 48 hours after the surgery (TTE_1) by an independent echocardiographer when inotropes were weaned off and stable

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