Utility of Transesophageal Echocardiography in Valvular Heart Surgery

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Transesophageal echocardiography (TEE) could provide a real-time insight for the structures and function of heart and large vessels during valvular surgeries. For its minimally invasive nature and uninterrupted surgical procedure, the application of TEE has been increased since it was used in the operating room about 20 years ago (1). At present, it is not cardiologists but the anesthesiologists who primarily perform the intraoperative TEE examination for valvular surgical patients, because they understand the valvular disease and the surgical procedure well. In addition, the anesthesiologists also have interest and time to take this job.

Before cardiopulmonary bypass (CPB), a comprehensive TEE examination could provide higher quality images of the heart and large vessels than transthoracic echocardiography (TTE). TEE is superior to TTE in displaying some structures located in the far field in TTE, such as left atrium and aortic valve. Therefore, a comprehensive TEE examination can help to confirm the preoperative diagnosis by TTE (2). For example, the aortic valve and the left ventricular outflow tract can be viewed clearly at mid-esophageal short axis view and long axis view, and the diagnosis of aortic valve disease including the severity of aortic valve stenosis or regurgitation will be more reliable than that by TTE. In order to confirm the surgical indication for aortic valve disease further, the degree of aortic valve regurgitation can be carefully evaluated by increasing the blood pressure in some anesthetized patients. Preoperative TEE examination may change the surgical procedure if new findings were detected timely before the heart is opened, such as finding new valvular lesions that require treatment, or detecting left atrial appendage thrombus before radiofrequency ablation of left pulmonary veins (3). Thus, TEE will decrease the surgical risk related to some missed diagnosis (4).

TEE examination for valvular disease often uses 2-dimensional (2-D) mode, pulsed wave Doppler and color flow Doppler to examine the structures and function of the diseased valves. 2-D mode is primarily used to display the valve leaflets, the subvalvular apparatus, and to measure the annulus diameter or orifice area. At mid-esophageal window, the mitral valvular structure, elasticity and the opening and closure movement can be viewed by rotating multiplane angle forward from 0 to 180 degrees, and the corresponding chordae tendineae and papillary muscles are easily examined simultaneously. The pulsed wave Doppler sampled from valvular orifice can be used to diagnose the valvular stenosis, and to calculate the orifice area for evaluating the severity of the stenosis. Similarly, the Doppler measurement of regurgitant jet can be used to evaluate the regurgitant volume. The dynamical conditions of blood flow through valves or vessels can be coded and showed by color flow Doppler. Generally, the color blood flow toward the transducer at the top is in red, flow away in blue, and progressively faster velocities of the flow are displayed in brighter shades of red or blue. For valve repair surgery, the key point of preoperative TEE examination is to assess the severity of valve regurgitation, the location of regurgitant jet, and the leaflet lesions. The reasons responsible for valvular insufficiency also should be found as possible, such as valve prolapse, annular dilation or rupture of chordae tendineae (5). For example, one patient with moderate mitral valve regurgitation diagnosed by TTE was scheduled for mitral valve repair. After anesthesia induction, TEE examination can confirm the definite location of the regurgitant...
jet, and identify the main reason for valve regurgitation. The comprehensive assessment by TEE will provide valuable suggestions on design for valve repair (6). Whereas, the focus of preoperative TEE examination for aortic valve replacement is to measure the diameter of aortic annulus precisely so as to choose a proper sized prosthetic valve (7). If the measured aortic valve annulus is too small to allow a prosthetic valve implantation, cardiovascular anesthesiologists should tell the surgeon to make preparations for aortic valve annulus or even ascending aortic enlargement.

After aortic cross-clamping is removed and the heart starts to beat, TEE examination then can be performed to evaluate the prosthetic valve. But the precise assessments should be accomplished after weaning from CPB, because the cardiac function will affect the prosthetic valve movement significantly. The precise assessments of the prosthetic valve include both of the stability and movement of valve leaflets, and the trans-prosthetic gradient also needs to be noticed in normal range (8) (Figure 1). Paravalvular leak (PVL) is a relatively rare complication after the prosthetic valve implantation with an incidence ranges from 2% to 10% (9). PVL can be detected soon after the heart starts to beat, and surgeons always concern about it carefully. If an obvious PVL is found by TEE, the position of prosthetic ring needs to be reinforced according to TEE findings under second aortic cross-clamping (10). After the heart starts to beat again, the disappeared PVL suggests that the prosthetic ring has been sutured steady. It is washing jet that needs to be identified from PVL (11). Washing jet was always regarded as a suspected leakage after mechanical valve replacement. It is produced by the blood flow through a narrow gap between the mechanical valve and prosthetic ring at systolic period. Usually, washing jet is a short-term flow and begins from the inside of the prosthetic ring towards to the center of the valve orifice (Figure 2). Immediate TEE assessment for the repaired valves should be performed after weaning from CPB and before protamine administration. The function of repaired valves including the opening and closure movement should be examined under normal heart function. Additionally, it was necessary to notice whether new lesions happen after surgery. For example, we should pay attention to the systolic anterior motion (SAM) of the mitral valve after mitral valve repair (12). If the valve repairment was unsuccessful, timely TEE evaluation could help to find the failure causes and give some suggestions for second valve repair or replacement. It was reported that with a routine intraoperative TEE, the incidence for pre-bypass surgical changes was 7.6% to 11%, and for the second pump runs was 4% to 5.7%, suggesting that TEE decreased the frequency of reoperations and postoperative interventions (13, 14).

Otherwise, TEE examination can help anesthesiologists to make decisions on hemodynamic monitoring and circulatory management during surgery (15). The strategy of anesthesia induction and hemodynamic management is different according to different type of valve lesions.
For instance, in order to ensure the cardiac output, to maintain a heart rate of 70-90 beats/minute is required for severe mitral valve stenosis patients, and slower is better than faster. Whereas, maintaining a heart rate of 80-100 beats/minute is considered for severe mitral valve regurgitation patients, and faster is better than slower. Besides heart rate, the optimal preload and afterload are also different in various valve lesions. Though continuous invasive blood pressure and central venous pressure could reflect the patient’s hemodynamics, they are often delayed and inaccurate. Moreover the effective volume assessed by central venous pressure is usually unreliable in patients with valve lesions. TEE can evaluate the heart function from different angles. The left ventricular trans-gastric mid short axis view is the most popular cross-section to assess the myocardial contractility and preload, and ejection fraction (EF) and fractional area change (FAC) also can be calculated in this cross-section. By measuring the Doppler flow patterns or the changes of vascular diameter of both hepatic vein and superior vena cave, TEE can tell the anesthesiologists whether the effective blood volume is enough or not (16). The effects of volume therapy also can be assessed immediately by the changes of Doppler flow pattern or vascular diameter after volume expansion. Diastolic heart failure is a common complication in patients with severe valve lesions. TEE is a useful tool in detection of diastolic dysfunction. The Doppler trans-mitral flow pattern, pulmonary venous flow pattern, mitral annular velocity and left ventricular wall thickness acquired by TEE can be used to evaluate the left ventricular diastolic function (17). If there is severe diastolic dysfunction or right ventricular failure before operation, TEE assessment can provide important suggestions to make strategy for following anesthesia and hemodynamic management. For valvular surgery, TEE is especially essential in the weaning from CPB period. If it is difficult to wean from CPB, immediately TEE assessment will assist surgeons and anesthesiologists to identify the reason for the surgical procedure or cardiac dysfunction. Thereby, TEE helps surgeons and anesthesiologists to make an effective treatment and decreases the adverse effects of an extended CPB. Furthermore, the cost-benefit analyses have revealed that intraoperative TEE application in valvular surgery is cost-effective with a saving of $230 per patient (14).

In summary, a comprehensive examination for the valvular lesions before CPB, a timely assessment of the repaired or replaced valves after surgery, and an effective monitoring of cardiac function provided by TEE can improve the outcome in patients undergoing cardiac surgery. Intraoperative TEE is becoming more popular with cardiovascular surgeons and is more widely used in operating room. On the other hand, cardiovascular anesthesiologists then play an essential role in complementary diagnosis of heart disease and help surgeons to make surgical decision by performing the TEE examination in operating room. It is a new field beyond the traditional working areas for cardiovascular anesthesiologists. A strong working relationship be-
Between cardiovascular surgeons and anesthesiologists will be built, and anesthesiologists can share the success of heart valve surgery with surgeons. Additionally, by taking the job of intraoperative TEE examination, anesthesiologists will understand more in pathophysiology of valvular lesions and the changes of hemodynamics induced by surgery. Therefore, their ability of anesthesia management for cardiovascular surgical patients will also be improved. However, there also exists limitation for TEE application, such as it is an expensive tool requiring exhaustive and time-consuming training for operators. In general, widely use of TEE in operating room is both clinically beneficial and cost effective for doctors and their patients.
