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# The Usefulness of Transesophageal Two-Dimensional Color Doppler Echocardiography in Mitral Valve Surgery

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## Abstract

To assess the usefulness of transesophageal two-dimensional color Doppler echocardiography (TEE) in valvular surgery, 31 patients scheduled for mitral valve surgery were studied. In 14 patients, epicardial echocardiography was also compared with TEE. Intraoperative diagnosis was discrepant from preoperative one in 1 of 31 cases, and the planned procedure was altered by intraoperative TEE findings. By TEE mitral valve repair was found inadequate in 3 of 17 cases resulted in further operation (2; mitral valve replacement, 1; tircuspid annuloplasty and revision of mitral valve repair). TEE could detect mitral regurgitation (MR) more than epicardial approach significantly. Of 15 cases undergoing mitral valve replacement, transvalvular MR jets were observed in 4 of 8 patients with bioprosthetic valve and in all 7 patients with mechanical prosthetic valve. Thus TEE can provide continuous intraoperative assessment of valvular function, and is helpful for surgeons to make their decision for an appropriate surgical procedure.

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## Introduction

The introduction of transesophageal two-dimensional color Doppler echocardiography (TEE) has provided an instantaneous and continuous assessment of valvular integrity and cardiac function during surgery[1,2]. In patients undergoing valvular surgery, it is important to reconfirm the preoperative diagnosis before the contemplated surgery, and also to evaluate the results of the surgical procedure before the chest is closed. Especially in the valve repair surgery, intraoperative findings by TEE can help to modify the intended surgery and a further procedure can be performed. The purpose of this study is to assess the utility of this modality for evaluating the valvular function in patients undergoing mitral valve surgery.

## Materials and Methods

After approval of the institutional research

committee, informed consent was obtained from all patients. TEE was performed in 31 patients scheduled for mitral valve surgery including combined surgery, e. g., multiple valvular surgery or coronary artery bypass grafting (CABG). There were 11 men and 20 women with a mean age of 56 years (range 23 to 80). Seven patients were ranked as New York Heart Association class II, 19 as class III, and 5 as class IV. Their planned surgical procedures consisted of 18 mitral valve repairs (MV repair) and 13 mitral valve replacements (MVR). Scheduled and performed operations are listed in Table 1. After induction of anesthesia and tracheal intubation, an endoscopic phased array probe (3.75 MHz, Toshiba model ESB-37LR, Japan) was inserted orally into the esophagus, then attached to the color Doppler flow imaging system (Toshiba model SSH-65A, Japan). The transesophageal probe was positioned so as to obtain a longitudinal four- or two-chamber view to identify the mitral valve. The images were recorded on a video tape recorder (Panasonic AG-3000, Japan) with simultaneous recording of electrocardiogram. Color Doppler assessment of mitral regurgitation (MR) was semiquantitatively graded according to the maximum length of regurgitant jet, and classified as following: slight, the regurgitant jet was present just above the mitral valve; mild, it extended up to one-third length of left atrium; moderate, up to two-thirds; severe, over two-thirds[3]. In 14 patients, epicardial echocardiography was also performed during pre- and post-cardiopulmonary-bypass (CPB) periods using a conventional 3.75 MHz phased array probe (Toshiba model PSB-37A, Japan). The transducer was covered with a sterile plastic sleeve and was placed directly on the epicardial surface of the heart. An image similar to a parasternal long-axis view was obtained to visualize the mitral valve, and the results were compared with those in TEE. Statistical significance was determined using a chi-square analysis with $p<0.05$. Hemodynamic parameters, such as arterial blood pressure, pulmonary arterial and

**Table 1** Scheduled and Performed Operations

| | Scheduled Operations | Performed Operations |
|---|---|---|
| MV repair | 18 | 17 |
| MV repair | 10 | 10 |
| MV repair+CABG | 6 | 5*+ |
| MV repair+TAP+CABG | 1 | 1 |
| MV repair+AVR | 1 | 1+ |
| MVR | 13 | 15 |
| MVR | 6 | 6 |
| MVR+CABG | 3 | 4+ |
| MVR+TVR | 1 | 1 |
| MVR+AVR | 2 | 3+ |
| MVR+AVR+CABG | 1 | 1 |
| CABG | | 1* |
| Total | 31 | 33 |

Abbreviations: MV repair, mitral valve repair; CABG, coronary artery bypass grafting; TAP, tricuspid annuloplaty; AVR, aortic valve replacement; MVR, mitral valve replacement; TVR, tricuspid valve replacement.

* The operative plan was changed to CABG alone in #1 patient.

+ Initial MV repair was inadequate and consequently MVR was performed in #3 and #4 patients.

pulmonary capillary wedge pressures, and cardiac output were also measured.

## Results

### Confirmation of Preoperative Diagnosis

There was discrepancy between preoperative and intraoperative diagnoses in 1 of 31 cases (3.2%). The case (#1), scheduled to have CABG and MV repair for coronary artery disease (CAD) and MR, demonstrated no MR jet in pre-CPB period. Left ventricular (LV) antero-septal wall hypokinesis was detected by preoperative angiography but not by intraoperative TEE, suggesting preoperative MR was transient due to acute myocardial ischemia. The operative plan was changed to CABG alone (Table 2).

### Intraoperative Assessment of MV repair

Initial MV repair was inadequate and an additional procedure was necessary in 3 of 17 cases (17.6%) (Table 2). MV repair and aortic valve replacement were performed in the patient (#2) with mitral stenosis and regurgitation (MS/MR) and aortic steno-insufficiency. After CPB, MR (moderate) remained unchanged regardless of similar hemodynamic condition to pre-CPB, so

**Table 2** Patients Required the Alteration of Procedure

| Number of Patient | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Age | 68 | 72 | 72 | 32 |
| Sex | F | F | F | M |
| Preoperative Diagnosis | CAD, MR | MS/MR, AS/AR | CAD, MR | MS/MR |
| Scheduled Operation | CABG, MV repair | MAP, AVR | CABG, MAP | MV repair |
| Pre-CPB Findings | no MR | moderate MR<br>mild AR | moderate MR | moderate MR<br>no TR |
| Performed Operation | CABG | MAP, AVR | CABG, MAP | MV repair |
| Post-CPB Findings | no MR | moderate MR<br>no AR | moderate MR | no MR<br>severe TR |
| Further Operation | | MVR (Hancock) | MVR (Hancock) | TAP, revision of MV repair |
| Hemodynamic Data Pre-/Post-CPB | | | | |
| HR (beats·min$^{-1}$) | 45/85 | 92/75 | 74/81 | 102/81 |
| SAP (mmHg) | 102/120 | 114/106 | 101/60 | 84/112 |
| MAP (mmHg) | 74/68 | 70/62 | 58/40 | 62/88 |
| DAP (mmHg) | 58/39 | 48/43 | 39/30 | 51/74 |
| sPAP (mmHg) | 33/25 | 29/29 | 35/40 | 36/53 |
| mPAP (mmHg) | 22/16 | 16/22 | 21/26 | 28/36 |
| dPAP (mmHg) | 17/12 | 10/17 | 15/20 | 23/23 |
| CO ($l$·min$^{-1}$) | 1.8/2.6 | 3.9/6.1 | 4.9/3.4 | 3.0/5.0 |

Abbreviations: CAD, coronary artery disease; MR, mitral regurgitation; MS/MR, mitral stenosis and regurgitation; AS/AR, aortic stenosis and regurgitation; CABG, coronary artery bypass grafting; MAP, mitral annuloplasty; AVR, aortic valve replacement; MV repair, mitral valve repair; CPB, cardiopulmonary bypass; AR, aortic regurgitation; TR, tricuspid regurgitation; MVR, mitral valve replacement; TAP, tricuspid annuloplasty; HR, heart rate; SAP, systolic arterial pressure; MAP, mean arterial pressure; DAP, diastolic arterial pressure; sPAP, systolic pulmonary arterial pressure; mPAP, mean pulmonary arterial pressure; dPAP, diastolic pulmonary arterial pressure; CO, cardiac output.

that MVR was immediately performed (Fig. 1). The suture of mitral annuloplasty was found broken. The patient (#3), underwent CABG and MV repair for CAD associated with MR, had systemic hypotension (60/30 mmHg), high pulmonary arterial pressure (40/20 mmHg), and low cardiac index (2.1 $l \cdot min^{-1} \cdot m^{-2}$) at the time of weaning from CPB. TEE demonstrated unchanged LV wall motion but MR was not adequately corrected after MV repair. This finding made immediate decision for MVR. In the patient (#4) with MS/MR, severe tricuspid regurgitation was newly developed which was noted by TEE after MV repair. According to this finding, tricuspid annuloplasty and revision of MV repair were performed.

MR repair decreased the severity of MR to less than mild in 15 of 17 cases (Fig. 2). In 2 MS/MR patients, MR was worsened by MV repair, but both were less than mild. Two patients (#2 and 3) remained to have moderate MR and MVR was performed.

### Intraoperative Assessment of Prosthetic Valve

Mechanical prosthetic valve (Medtronic Hall Valve) was used in 7 cases and bioprosthetic valve (Hancock Porcine Valve) in 8 patients

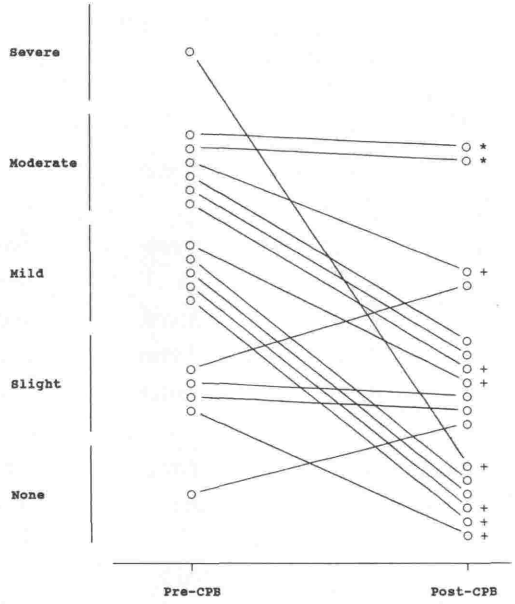


**Fig. 2** Results of mitral valve repair in the severity of mitral regurgitation(MR). The severity of MR was decreased to less than mild in 15 of 17 patients. * The patients (#2 and 3) showed inadequate correction of MR, so that mitral valve replacement was performed. + Patients associated with coronary artery disease.
Abbreviation: CPB, cardiopulmonary bypass.

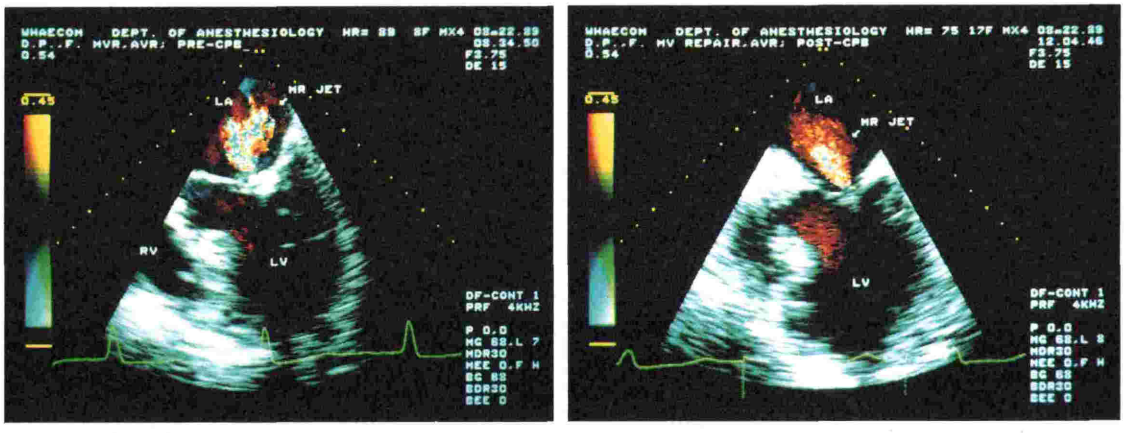


**Fig. 1** Left: Moderate MR jet was demonstrated in pre-CPB. Right: After mitral valve repair, MR was not adequately corrected, so that decision for mitral valve replacement was made immediately.
Abbreviations: MR, mitral regurgitation; LA, left atrium; LV, left ventricle; RV, right ventricle; CPB, cardiopulmonary bypass.

underwent MVR. There was no evidence of prosthetic valve malfunction including paravalvular leakage. All patients replaced with Medtronic valve demonstrated transvalvular MR jets. Transvalvular MR jets were observed in 4 of 8 patients with Hancock valve (50%), but was smaller than those observed in Medtronic valve (Fig. 3). Transvalvular MR jets were less turbulent, smaller, and of short duration compared with pathological MR jets.

### Comparison of Epicardial Echocardiography and TEE

Epicardial echocardiography was performed in 14 patients (10 in MV repair and 4 in MVR). In 10 cases of MV repair, the ability of evaluating MR was compared between epicardial approach and TEE. Epicardial echocardiography revealed MR jet after repair only in 1 case (10%). On the other hand, residual or newly developed MR was detected in 6 of 10 patients by TEE (60%). TEE could detect MR more than epicardial approach significantly ($p < 0.05$).

## Discussion

Transesophageal echocardiography with color flow mapping has recently been developed and available clinically. Because this modality can provide real-time information on morphology and blood flow characteristics[1,2], it allows immediate decision making for surgical procedure and anesthetic management before patients' condition becomes critical.

There may be a gap of several days from the time of preoperative examination by angiography and/or echocardiography to the day of surgery, so that it is possible the condition of patients have been changed. Preoperative diagnoses should be checked just before surgical procedures in patients undergoing valvular surgery. In our study, 1 patient was diagnosed to have MR in the preoperative period, however, MR was not evident in pre-CPB period, so that the patient did not require mitral valve surgery. The preoperative MR appeared to have been caused by acute myocardial ischemia.

MV repair is preferable to replacement in certain cases especially in young patients, because of its advantages, e. g., a lower risk of late complications than that of prosthetic valve replacement. In the repair cases, it is indispensable to ensure appropriate reconstruction[4]. In our

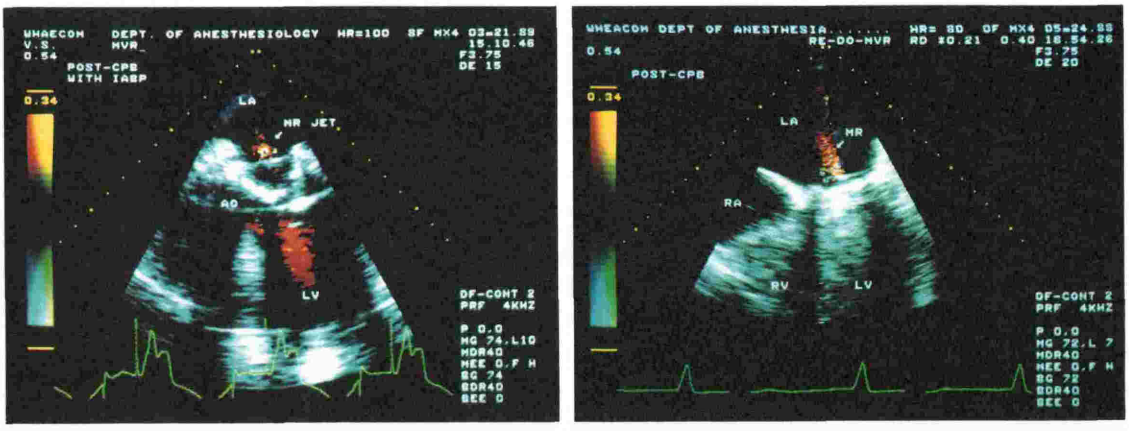


**Fig. 3** Left: Transvalvular MR jet in Hancock bioprosthetic valve. Right: Medtronic mechanical prosthetic valve shows transvalvular leakage and LV cannot be viewed due to ultrasound interference by metal leaflets.

Abbreviations: MR, mitral regurgitation; LA, left atrium; LV, left ventricle; RA, right atrium; RV, right ventricle; AO, aorta; CPB, cardiopulmonary bypass.

series of 17 repair cases, 3 patients have proceeded to further surgical intervention according to intraoperative TEE findings, 2 to the replacement and 1 to the revision of plasty. Otherwise these 3 patients might have required early reoperation.

Paravalvular leakage is one of the important complications of prosthetic valve, causing postoperative hemolysis. When evaluating pathological regurgitation, the existence of physiological regurgitation (even in 38-45% of normal healthy subjects[5])should be taken into consideration. Small MR jets demonstrated in Hancock valve resembled those observed in intact native valve. Every type of mechanical prosthetic valve requires a certain amount of back flow to close, which in turn causes the relatively big regurgitant jets[6]. These physiological leakages of mechanical valves can be distinguished from pathological regurgitation by the site, shape, extent, duration, and the intensity of turbulence, however, sometimes it is very difficult to analyze by these criteria.

Epicardial approach has also been used for assessment of valvular function[4]. In comparison with this approach, TEE has some advantages: 1) scanning can be continuously performed during the course of anesthesia and surgery without interruption of operation; 2) the stability of transducer position can be maintained; and 3) there is no risk for contamination of the sterile field as epicardial approach. In addition TEE is particularly suitable for assessment of mitral valve function, beause the probe is positioned right behind the left side of heart and the ultrasound beam direction is parallel to the transmitral flow. Thus excellent color flow mapping can be obtained, even in the presence of high echo-signals from prosthetic valve which may cause masking of left ventricle. The advantage of the epicardial approach is that it can provide multiple imaging planes, allowing assessment of the heart from different angles. Especially epicardial echocardiography is superior characterizing prosthetic valve stenosis.

The quantitative assessment of MR has not been established by echocardiography. The length[3,7], width, and area[7,8] of the regurgitant jet have been used for grading the severity of MR. However, these criteria may be correlated nonlinearly with flow volume and affected by numerous other factors[9,10]. Helmcke et al.[8] have demonstrated improved correlation between angiographic evaluation of MR and the ratio of jet area to left atrial area from multiple planes. This index seems to be inappropriate for chronic MR patients with dilated left atrial cavity[11]; moreover, it may not be suitable for TEE, because the whole left atrium cannot be viewed completely by transesophageal scanning. In vitro studies, Bolger[9] and Vandenberg et al.[10] have attempted to find an ideal index of quantitation such as jet energy or jet area corrected for stroke volume. In our study, hemodynamic variables were maintained stable during anesthesia, however, there is a remote possibility that hemodynamic difference in heart rate, cardiac output, and systolic blood pressure between pre- and post-CPB could have influenced intracardiac blood flow pattern and modified the results in some cases.

In conclusion, TEE enabled us to evaluate the valvular function promptly during the course of anesthesia and surgery in the majority of cases we studied. However, when the quantitative evaluation of mitral valve function is questionable, hemodynamic variables should also be taken into consideration for decision making. We believe the clinical usefulness of this technology can be further enhanced by the future availability of quantitative assessment.

## References

1) Kyo, S., Takamoto, S., Matsumura, M., et al.: Immediate and early postoperative evaluation of results of cardiac surgery by transesophageal two-dimensional Doppler echocardiography. Circulation **76(suppl V)**:V113-V121, 1987.

2) Orihashi, K., Matsuura, Y., Ishihara, H., et al.: Some advantages of transesophageal echocardiography during mitral valve replacement. Hiroshima J. Med. Sci. **37**:127-131, 1988.
3) Czer, L. S. C., Maurer, G., Bolger, A. F., et al.: Intraoperative evaluation of mitral regurgitation by Doppler color flow mapping. Circulation **76(suppl III)**:III108-III116, 1987.
4) Maurer, G., Czer, L. S. C., Chaux, A., et al.: Intraoperative Doppler color flow mapping for assessment of valve repair for mitral regurgitation. Am. J. Cardiol.**60**:333-337, 1987.
5) Yoshida, K., Yoshikawa, J., Shakudo, M., et al.: Color Doppler evaluation of valvular regurgitation in normal subjects. Circulation **78**:840-847, 1988.
6) Van den Brink, R. B. A., Visser, C. A., Basart, D. C. G., et al.: Comparison of transthoracic and transesophageal color Doppler flow imaging in patients with mechanical prostheses in the mitral valve position. Am. J. Cardiol. **63**:1471-1474, 1989.
7) Miyatake, K., Izumi, S., Okamoto, M., et al: Semiquantitative grading of severity of mitral regurgitation by real-time two-dimensional Doppler flow imaging technique. J. Am. Coll. Cardiol. **7**:82-88, 1986.
8) Helmcke, F., Nanda, N. C., Hsiung, M. C., et al.: Color Doppler assessment of mitral regurgitation with orthogonal planes. Circulation **75**:175-183, 1987.
9) Bolger, A. F., Eigler, N. L., Pfaff, J. M., et al.: Computer analysis of Doppler color flow mapping images for quantitative assessment of in vitro fluid jets. J. Am. Coll. Cardiol. **12**:450-457, 1988.
10) Vandenberg, B. F., Dellsperger, K. C., Chandran, K. B., et al.: Detection, localization, and quantitation of bioprosthetic mitral valve regurgitation: An in vitro two-dimensional color-Doppler flow-mapping study. Circulation**78**:529-538, 1988
11) Shah, P. M.: Quantitative assessment of mitral regurgitation. J. Am. Coll. Cardiol. **13**:591-593, 1989.