Special Articles

Live/Real Time Three-Dimensional Transesophageal Echocardiographic Evaluation of Mitral and Aortic Valve Prosthetic Paravalvular Regurgitation

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Abstract:

Thirteen patients already scheduled for surgery for repair of prosthetic paravalvular regurgitation underwent intraoperative real time two-dimensional transesophageal echocardiography (2D TEE) and live/real time three-dimensional transesophageal echocardiography (3D TEE). In all patients, 3D TEE was able to provide more information regarding the location and size of the paravalvular defect as compared to 2D TEE. 3D TEE resulted in a more accurate localization of the defect and an estimation of the size of the defect that correlated much more closely with surgical findings when compared with 2D TEE. Our preliminary results demonstrate the superiority of 3D TEE over 2D TEE in the evaluation of paravalvular prosthetic regurgitation. 3D TEE not only provides an accurate assessment of the exact site of the leakage, but also gives a more accurate estimate of its size. This information could be valuable to surgeons who may encounter difficulty when localizing and estimating the size of paraprosthetic leaks while the heart is devoid of blood during surgery.

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Introduction:

Significant prosthetic paravalvular regurgitation can result in symptoms of heart failure and hemolytic anemia and has an incidence of 1–5%. Of note, the majority (60%) of prosthetic leaks occur within the first year status post valve replacement.[1] Echocardiography remains the main modality for the diagnosis of prosthetic valve dysfunction. Two-dimensional transthoracic echocardiography is often supplemented by real time two-dimensional transesophageal echocardiography (2D TEE) when evaluating prosthetic valves because the close proximity of the esophageal probe to cardiac structures results in superior quality images.[2] However, the technique is still limited since the two-dimensional transesophageal plane represents only a thin slice through the heart and this view can miss significant findings. The recent introduction of live/real time three-dimensional transesophageal echocardiography (3D TEE) has generated considerable interest among both cardiologists and cardiac surgeons as it serves to address the limitations of 2D TEE.[3,4] In particular, 3D TEE has been shown to give high quality 3D images of prosthetic valves in both the mitral and aortic positions.[3]

The purpose of the present study was to compare 3D TEE with 2D TEE in the evaluation of prosthetic paravalvular regurgitation, a major complication that can occur after the implantation of a prosthetic valve.

Methods:

Patients Thirteen patients, who had already been scheduled for surgery and who had been previously

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diagnosed with prosthetic paravalvular regurgitation by clinical findings and other investigations, were studied. Eleven of the patients had mitral valve prostheses and two had aortic prostheses. Seven of the patients were males and six were females with ages ranging from 54 to 76 years (mean age of 64.77 years). All of them underwent intraoperative 2D TEE and 3D TEE.

Equipment and Method of Examination:
Intraoperative 2D TEE and 3D TEE images were obtained with a 5.5-MHz X7-2t transducer, respectively, and a commercially available ultrasound system (Phillips iE33, Andover, MA, USA) capable of 2D, 3D, B-mode, and color Doppler imaging. 2D TEE was performed in a standard manner.[2] In all patients, an attempt was made to find paravalvular regurgitation and assess its site and size using visualized cardiac landmarks. Paravalvular regurgitation was identified by noting color Doppler flow signals originating outside the confines of the prosthetic elements in systole for mitral regurgitation and in diastole for aortic regurgitation.[5] Increased motion ("rocking") of any portion of the prosthesis was also noted. 3D TEE was performed as described in a previous study.[3] Both B-mode and color Doppler 3D datasets focusing on the prosthetic valve were acquired. These datasets were cropped using multiple plane angulations. In particular, an attempt was made to obtain en face views of the prosthetic valve to facilitate the visualization of the prosthetic ring and sites of paravalvular regurgitation. Since echo dropouts can occur with the 3D B-mode, paravalvular regurgitation was diagnosed only using color Doppler. Color Doppler suppression was then used to outline the full extent of the paravalvular defect which was subsequently measured. Increased motion ("rocking") as well as an absence of sutures or a decrease in the number of sutures in any portion of the prosthetic ring was also noted. All 2D TEE and 3D TEE findings were correlated with surgical findings. Since the surgeon's view and the TEE images obtained are in different orientations, a surgical clock view was used to describe the location of the defect to facilitate correlations of 3D TEE findings with surgical findings. In this view of the mitral valve, the middle of the anterior annulus is toward the 12 o'clock position, the middle of the posterior annulus is toward the 6 o'clock position, and the left atrial appendage is at 9 o'clock. The aortic valve is oriented so that the left main coronary artery is located at 11 o'clock, the right coronary artery at 4 o'clock, and the interatrial septum at 7 o'clock.[6–8] For the aortic prosthesis, the interatrial septum was used as the most easily recognized landmark on 3D TEE. 3D TEE was also done in five patients after surgery following termination of cardiopulmonary bypass but prior to closure of the chest wall. Two of the authors, independently and without knowledge of the operative findings, reviewed the 2D TEE images and 3D TEE datasets and identified any areas of prosthetic paravalvular regurgitation. Intraobserver variability was also assessed by having a single observer review the findings 6 weeks later.

Surgical Assessment:
The surgeon identified the paravalvular defect by close inspection and localized the defect using the surgical clock view or other landmarks.

Results:
In all of the patients, 3D TEE was able to provide more information regarding the location and size of the paravalvular defect as compared to 2D TEE (Table I, Figs. 1–6). In the first patient, 3D TEE showed a defect at the 12–2 o'clock position, with dimensions of 1.3 × 1.2 cm which correlated well with the surgeon's finding of a 1.5 × 1.0 cm defect at the anterior annulus. In all of the other patients, 3D TEE again provided very good localization of the defect based on the surgeon's clock view or other landmarks. In addition to correlating well with the surgical findings, 3D TEE also provided an estimate of the size of the defect. In one patient with a mitral prosthetic leak, fewer sutures were visualized in the region of annulus. Also, in two patients, both with mitral prosthesis, increased motion ("rocking") of the ring during the cardiac

Table-I

Real Time Two-Dimensional and Live/Real Time Three-Dimensional Transesophageal Echocardiography in the Evaluation of Mitral and Aortic Prosthetic Paravalvular Regurgitation

Case	Age/Sex. Type of Prosthesis.	2D TEE Findings Site and Width of the Paravalvular Defect	3D TEE Findings .Site and Size of the Paravalvular Defect	Operative Findings .Site and Size of the Paravalvular Defect	Surgery
1	55/M. St. Jude mitral 29 mm	Medial. 0.7 cm	1–3 o'clock. 1.3 × 1.2 cm. Area 1.12 cm^2	1.5 cm × 1.0 cm. Anterior annulus	MV Repair
2	61/M. Metallic mitral	Possible lateral. Cannot assess size	5 o'clock. 1.4 × 0.8 cm. Area 0.54 cm^2	Posterior annulus	Edward Tissue MVR. 33 mm
3	66/M. Tissuemitral	Medial. 0.25 cm	6 o'clock. 0.9 × 0.2 cm. Area 0.69 cm^2	Posteriolater alannulus 6–8 o'clock	St Jude MVR 27 mm
4	54/F. Metallicmitral	Medial. 0.4 cm	9–12 o'clock. 1.2 cm × 0.3 cm. Area 0.23 cm^2	Anterior annulus	St Jude MVR. 29 mm
5	76/M. Metalicmitral	Medial. 0.5 cm	3–5 o'clock. 2.02 cm × 0.39 cm. Area 1.36 cm^2	3–8 o'clock	Edward Tissue MVR 31 mm
6	72/F. Tissuemitral	Cannot assess site 0.6 cm	3–6 o'clock. 1.4 cm × 0.4 cm. Area 0.75 cm^2	Mitral annulus near LVOT	Edward tissue MVR. 31 mm
7	59/M. Metallicmitral	Lateral. 0.5 cm	9–10 o'clock. 2.3 cm × 0.6cm. Area 0.50 cm^2	8–10 o'clock	Edward tissue MVR. 31 mm
8	59/F. StarrEdwards mitral	Lateral 0.7 cm	5–8 o'clock. 1.8 cm x 0.6cm. Area 0.92 cm^2	Posterior annulus	St Jude MVR. 29 mm
9	72/F. Tissuemitral	Lateral 0.5 cm	10–11 o'clock. 1.6 cm × 0.7 cm. Area 0.63 cm^2	10 o'clock	MV repair
10	76/F. Tissuemitral	No defect found	8–9 o'clock. 1.7 cm × 0.6 cm. Area 0.80 cm^2	8 o'clock	Edward tissue .29 mm
11	76/F. Tissuemitral	Medial. 0.6 cm	3 o'clock. 1.1 cm × 0.5 cm. Area 0.58 cm^2	3 o'clock	Edward tissue MVR. 31 mm
12	55/M. Metallicaortic	No defect found	7 o'clock. Area 0.22 cm^2	5–8 o'clock	Edward AVR. 21mm
13	61/M. Tissueaortic	Both anterior and posterior. 0.3 and0.2 cm, respectively	1 o'clock. 1.5 cm × 0.4 cm. Area 0.60 cm^2	Anterior annulus	St Jude AVR. 23mm

AVR = aortic valve replacement; F = female; LVOT = left ventricular outflow tract; M = male; MV = mitral valve; MVR = mitral valve replacement.

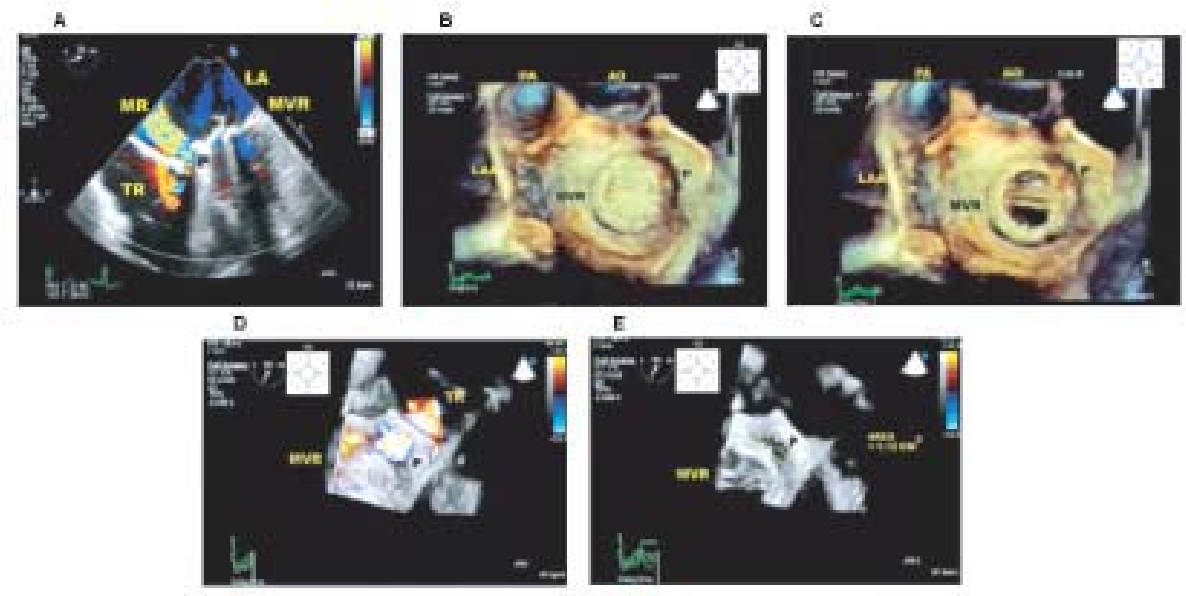

Fig.-1: *Paravalvular mitral prosthetic regurgitation (Case 1). A. Two-dimensional transesophageal echocardiogram shows medial paravalvular (P) mitral regurgitation (MR) in this patient with St Jude mitral valve replacement (MVR). B–E. Live/real time three-dimensional transesophageal echocardiogram. En face views. The paravalvular (P) defect is localized at the 1–3 o' clock position in both systole (B) and diastole (C). Color Doppler examination (D) confirms the site of the paravalvular (P) defect. The paravalvular (P) defect after color Doppler suppression is shown in E. The defect measured 1.12 cm2. AO = aorta; LA = left atrium; LAA = left atrial appendage; PA = pulmonary artery; TR = tricuspid regurgitation.*

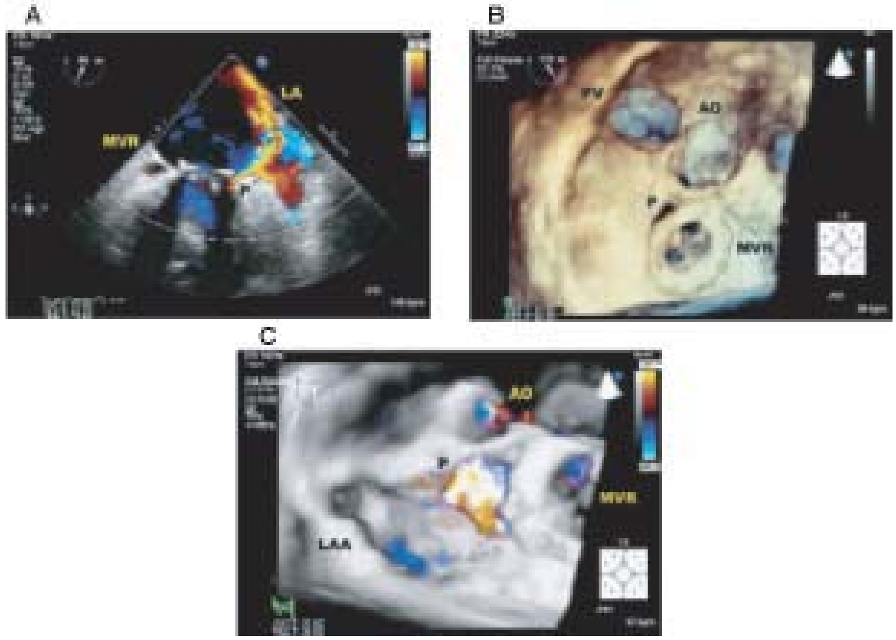

Fig.-2: *Paravalvular mitral prosthetic regurgitation (Case 9). A. Two-dimensional transesophageal echocardiogram shows lateral paravalvular (P) MR in this patient with porcine MVR. B, C. Live/real time three-dimensional transesophageal echocardiogram. En face views. The paravalvular (P) defect is localized at the 10–11 o' clock position (B). Color Doppler examination (C) confirms the site of the defect. PV = pulmonary valve. Other abbreviations as in the previous figure.*

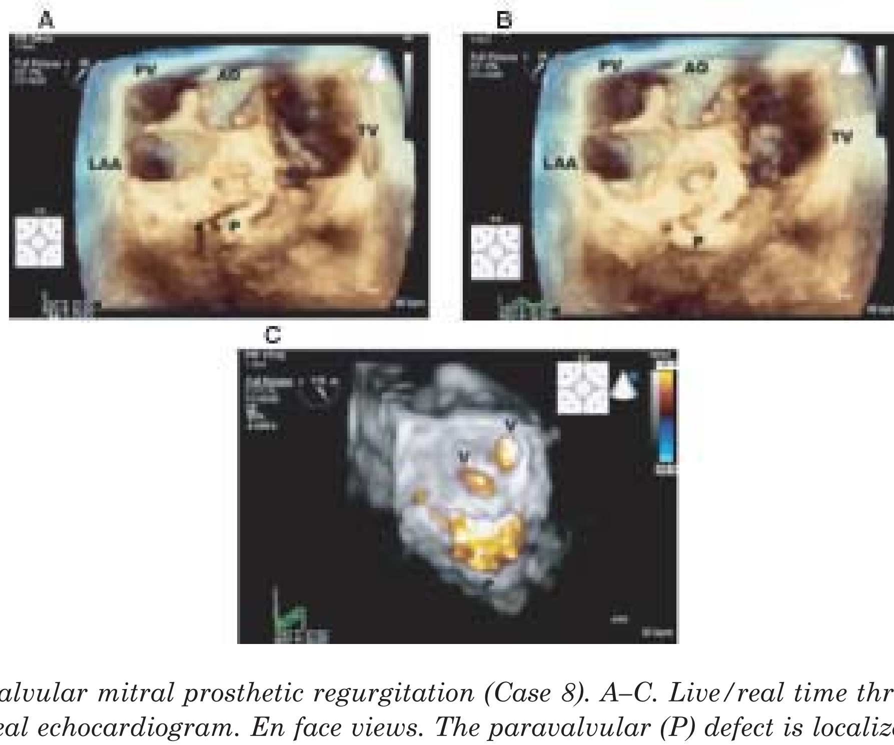

Fig.-3: *Paravalvular mitral prosthetic regurgitation (Case 8). A–C. Live/real time three-dimensional transesophageal echocardiogram. En face views. The paravalvular (P) defect is localized at the 5–8 o' clock position in both systole (A) and diastole (B) in this patient with Starr Edwards MVR. Color Doppler examination (C) confirms the site of paravalvular (P) defect. TV = tricuspid valve; V = valvular regurgitation. Other abbreviations as in previous figures.*

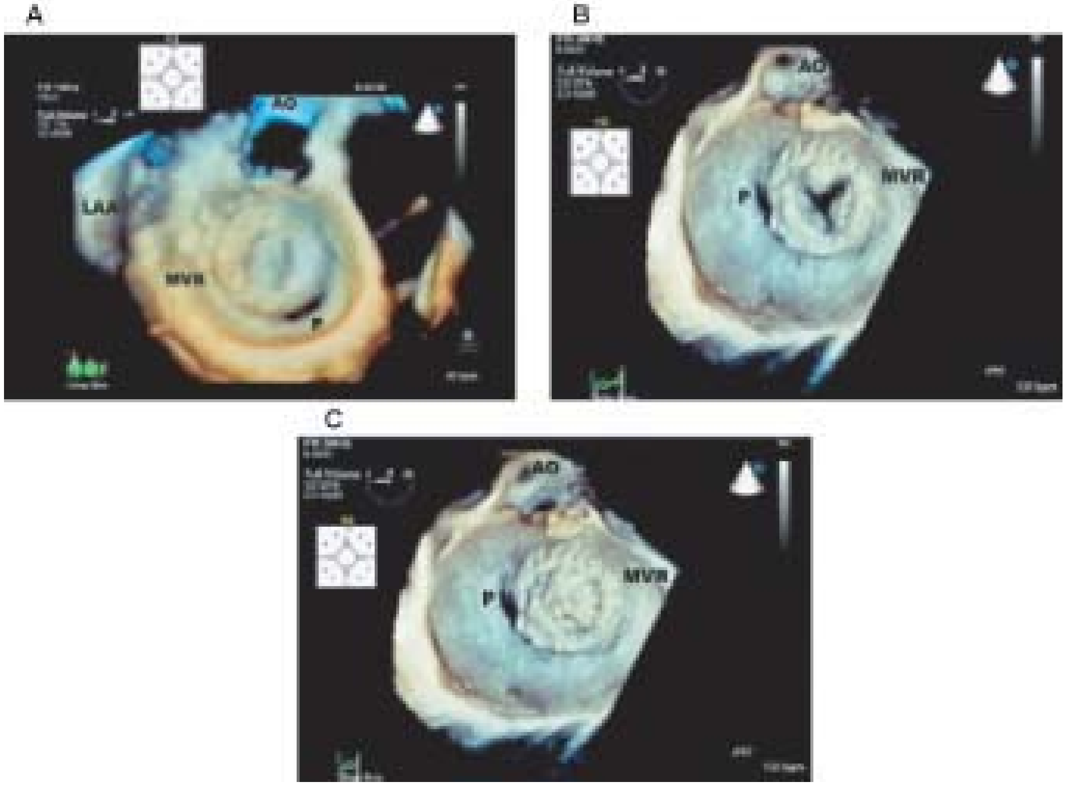

Fig.-4: *Paravalvular mitral prosthetic regurgitation. Live/real time three-dimensional transesophageal echocardiogram. En face views. A (Case 2). The paravalvular (P) defect is localized at the 5 o'clock position in this patient with a metallic prosthesis. B, C (Case 10). Another patient with a tissue prosthesis shows paravalvular (P) defect at the 8–9 o' clock position in both systole and diastole. Abbreviations as in previous figures.*

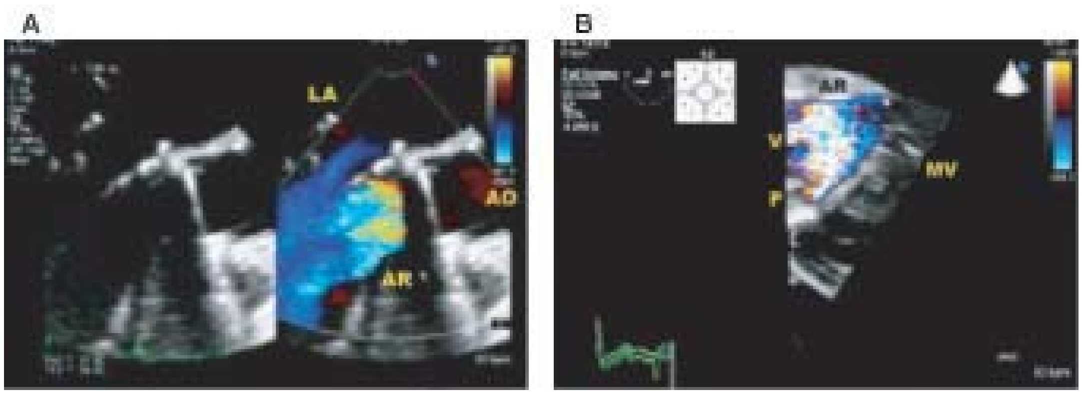

Figure 5. *Paravalvular aortic prosthetic regurgitation (Case 12). A. Two-dimensional transesophageal echocardiogram. In this patient with a metallic prosthesis, color Doppler signals fill the whole extent of proximal left ventricular outflow tract in diastole consistent with severe aortic regurgitation (AR). It is difficult to assess the site of AR but it appears primarily valvular, not paravalvular. B. Live/real time three-dimensional transesophageal echocardiogram. Paravalvular (P) regurgitation is located at the 7 o' clock position. Two jets of valvular (V) regurgitation are also visualized within the confines of the prosthesis. MV = mitral valve. Other abbreviations as in previous figures.*

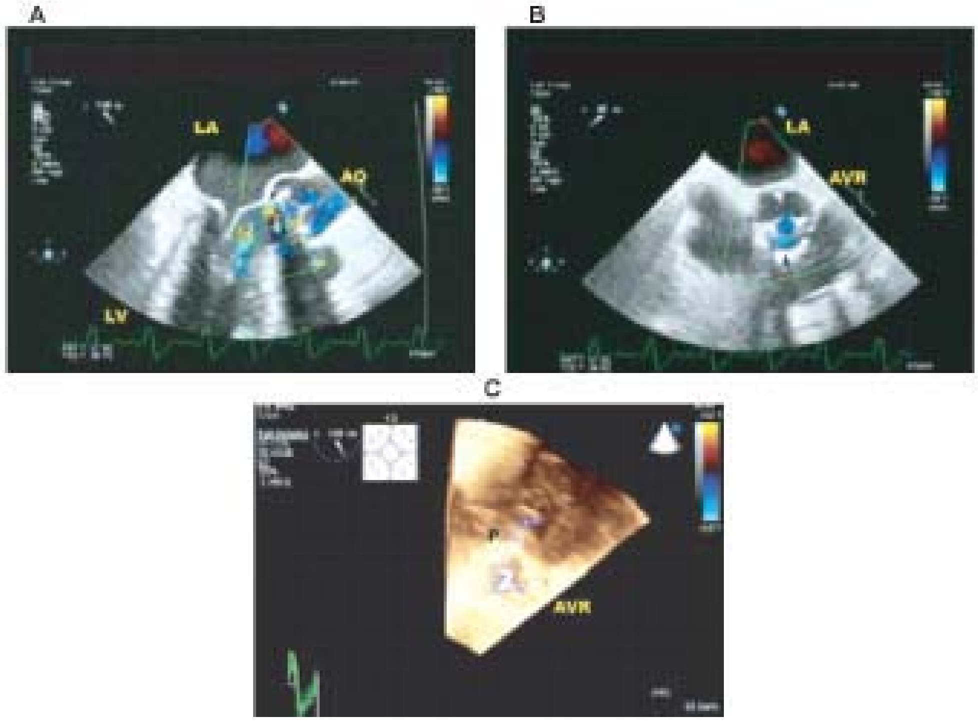

Fig.-6: *Paravalvular aortic prosthetic regurgitation (Case 13). A, B. Two-dimensional transesophageal echocardiogram. Both posterior (A) and anterior (B) paravalvular (P) regurgitation jets (arrow head) are seen in five-chamber and short-axis views, respectively, in this patient with a tissue aortic valve replacement (AVR). C. Live/real time threedimensional transesophageal echocardiogram. A large paravalvular (P) defect is seen anteriorly at the 1 o' clock position. LV = left ventricle. Other abbreviations as in previous figures.*

cycle was clearly noted. On the other hand, with 2D TEE, accurate localization of the site of the paravalvular defect was noted in only 5 of 13 patients. In one of these patients, 2D TEE localized an additional defect in the posterior annulus which was not observed at surgery. In five other patients, the defects were incorrectly localized. More specifically, in one of these patients, the paravalvular defect could not be localized and in two of them no obvious paravalvular regurgitation was detected. The size of the paravalvular defect was also markedly underestimated by 2D TEE as compared to 3D TEE and the "rocking" motion of the prosthesis was not observed by 2D TEE in any patient. Thus, 2D TEE was of limited value in the assessment of paraprosthetic regurgitation. 3D TEE more accurately localized prosthetic paravalvular regurgitation and defect size that correlated much better with surgical findings when compared with 2D TEE. 3D TEE performed in all five patients after they were taken off cardiopulmonary bypass showed no evidence of significant residual regurgitation or paravalvular defect.

Inter- and intraobserver reproducibility was excellent for both 2D TEE, ($r = 0.99$, Kappa value $= 0.60$; $r = 0.99$, Kappa value $= 0.58$; respectively) and 3D TEE ($r = 0.99$, Kappa value $= 0.83$; $r = 0.99$, Kappa value $= 0.81$; respectively).

Discussion:

Our preliminary results demonstrate the superiority of 3D TEE over 2D TEE in the evaluation of paravalvular prosthetic regurgitation. 3D TEE provides a more accurate assessment of the exact site and size of the leakage. This information may be valuable to the surgeon who may have difficulty localizing and estimating the size of the paraprosthetic defect when the heart is devoid of blood during cardiopulmonary bypass. The technique can also be used to evaluate the efficacy of defect repair after the patient has been weaned off cardiopulmonary bypass and before the chest wall is closed. This facilitates reentry if needed and saves the patient from undergoing another operation. Thus, this modality has the potential to be used by surgeons intraoperatively to help them make more confident decisions based on the more complete and precise views obtained by 3D TEE. 3D TEE may also be useful in the percutaneous closure of prosthetic paravalvular defects as demonstrated in a recently published case report.[9]

There are some limitations of 3D TEE that should be mentioned. Of note, examination needs to be focused on the prosthetic valve which has to be brought into the center of the sector scan for optimal results. Artifacts may also occur from probe motion or arrhythmias but these are generally well recognized and, at least in the patients we studied, did not pose any interpretation problems or inaccuracy. Frame rates are also slower when using color Doppler and can potentially lower temporal resolution.

Conclusion:

In the 13 patients who were studied, live/real time 3D TEE provided images that resulted in better correlation with surgical findings of both the site and size of the paravalvular defect as compared to live 2DTEE. Further studies using a much larger number of patients are needed to assess the exact role of 3D TEE in the assessment of prosthetic paravalvular regurgitation.

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