Severe mitral paravalvular leakage: echo-morphologic description of 47 patients from real-time three-dimensional transesophageal echocardiography perspective

İleri paravalvüler mitral yetersizliği: Gerçek zamanlı üç boyutlu transözofageal ekokardiyografi bakış açısından 47 hastanın ekomorfolojik incelenmesi

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Abstract

Objective: Paravalvular leaks (PVLs) commonly occur in mitral prostheses. Real-time 3-dimensional transesophageal echocardiography (RT-3D TEE) may provide invaluable information about complex 3D anatomy of mitral PVLs compared to two-dimensional (2D) TEE findings. We, herein, aimed to evaluate the detailed description of anatomical characteristics of severe mitral PVLs using RT-3D TEE.

Methods: Patients with diagnosis of severe mitral PVLs were simultaneously examined with 2D transthoracic echocardiography (TTE), 2D TEE, and RT-3D TEE. 3D characteristics of PVLs (localization, number, size, shape, etc.) were recorded and compared to 2D findings. Results were also compared with surgical findings.

Results: The study comprised 47 cases (3 bioprosthesis, 44 mechanical) with 61 severe mitral PVLs. The most common PVL localizations were anterolateral commissure, posteromedial commissures and posterolateral region. The mean PVL width measured by 2D TEE was 3.1±1.3 (range; 2-7) mm and the mean width of defect measured by 3D TEE was 3.1±1.1 (range; 2-7) mm (p=0.7). The mean length of defect measured by 3D TEE was 11.1±6.5 mm. The most common defect type was 'oval/round' shaped (n=29; 48%). There were also 19 'crescentic' (31%), 9 'slit like' (15%), and 2 tunnel-like shaped defects. In 22 patients, the site and dimension of the PVLs were all confirmed surgically.

Conclusion: RT-3D TEE permits detailed structural evaluation of the prosthesis and description of paravalvular leak morphology compared to 2D TEE. It may provide more accurate information to the clinician in decision making and may contribute to the success of the potential corrective procedures. *(Anadolu Kardiyol Derg 2013; 13: 633-40)*

Key words: Paravalvular mitral regurgitation, real-time three-dimensional transözofageal echocardiography

Özet

Amaç: Paravalvüler kaçaklar (PVK) genellikle mitral protez kapaklarda görülür. Gerçek zamanlı üç-boyutlu transözofageal ekokardiyografi (GZ-3B TÖE) iki boyutlu transözofageal ekokardiyografi (2B TÖE) ile kıyaslandığında mitral protez kapağın kompleks 3B anatomisi hakkında paha biçilmez bilgiler sunar. Bu çalışmada GZ-3B TÖE'yi kullanarak ileri mitral PVK'ların detaylı anatomik özelliklerini incelemeyi hedefledik.

Yöntemler: İleri PVK'sı olan hastalar eş zamanlı 2B transtorasik ekokardiyografi, 2B TÖE ve GZ-3B TÖE ile incelendi. PVK'ların 3B özellikleri (yerleşimi, boyutları, şekilleri, sayıları vs.) kaydedildi ve 2B görüntülerle kıyaslandı. Sonuçlar cerrahi bulgularla da kıyaslandı.

Bulgular: Çalışma 47 mitral protez kapak hastasını (3 biyoprotez, 44 mekanik) ve toplam 61 PVK'yı kapsıyordu. En sık PVK yerleşimi anterolateral komissür, posteromediyal komissür ve posterolateral bölge idi. 2B TÖE ve 3B ile ölçülen ortalama defekt eni sırasıyla 3,1±1,3 (aralık; 2-7) mm ve 3,1±1,1 (aralık; 2-7) mm idi (p=0,7). 3B TÖE ile ölçülen defekt uzunluğu ise 11,1±6,5 mm idi. En sık defekt türü 'oval/yuvarlak' (n=29; %48) idi. Ayrıca 19 hilal şekilli (%31), 9 kesik şekilli (%15) ve 2 tünel-tipi şekil saptandı. PVK yeri ve boyutları 22 hastada cerrahi ile doğrulandı.

Sonuç: GZ-3B TÖE, 2B TÖE'e nazaran protez kapağın yapısal özelliklerinin ve defekt morfolojisinin detaylı incelenmesine olanak tanır. Klinisyene klinik karar verme aşamasında daha doğru bilgiler sunabilir ve olası girişimsel işlemlerin başarısını arttırabilir.
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Anahtar kelimeler: Paravalvüler mitral yetersizliği, gerçek-zamanlı üç-boyutlu transözafajiyal ekokardiyografi

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Introduction

Recent advances in material and design have led to more hemodynamically efficient and durable artificial heart valves. However, the postoperative complications after prosthetic valve implantation is not uncommon and clinically significant paravalvular leakage (PVL) occurs in 2 to 5% of the patients (1, 2).

In most cases, postoperative leaks are mild and have no clinical consequences; otherwise, leak size, and morphology determine the subsequent clinical presentation and the severity of heart failure. Symptoms may be also due to hemolytic anemia as a result of hemolysis in the high shear stress regurgitant jet (3). Clinically significant PVLs more commonly occur in association with mitral prostheses (4), compared to PVLs located in other valves due to high velocity of the regurgitant jet which occurs because of the larger pressure gradient of the systolic phase (5).

Although two-dimensional transesophageal echocardiography (2D TEE) is significantly superior to 2D transthoracic echocardiography (2D TTE) in terms of accurate estimation of regurgitation, distinguishing between central/paravalvular leaks, and determination of the degree and causes of the regurgitation (6), it offers minimal assistance in delineation of PVL anatomy and adjacent cardiac structures (7). Real-time 3-dimensional transesophageal echocardiography (RT-3D TEE) has been introduced as an excellent tool which provides invaluable information about complex 3D anatomy and spatial orientation of mitral PVLs (8) compared to 2D TEE findings.

In this study, we aimed to evaluate the detailed description of the anatomical characteristics of severe mitral PVLs using RT-3D TEE.

Methods

Selection of the study population

This study comprised patients who underwent echocardiographic examination in Koşuyolu Kartal Heart Training and Research Hospital, Echocardiography Laboratory between December 2008 and 2011 May and had prompt diagnosis of severe mitral paravalvular regurgitation. Patients were simultaneously examined with 2D transthoracic echocardiography (TTE), 2D TEE, and RT-3D TEE in this single-center study. Written informed consent was obtained from the participants and the study was approved by the local Ethics Board.

Echocardiographic evaluation

Intravenous beta-blocker (metoprolol) was administered in patients with tachycardia in the absence of contraindications and heart rates of all patients were attempted to be maintained between 65-85 beats per minute. 2D and 3D images were initially evaluated by two experienced echocardiographers independently; they were transferred to the Philips Xcelera workstation and analyzed offline by the first reviewer in a subsequent session.

2D TTE

Transmitral gradients and effective orifice area were measured with 2D TTE according to the current guidelines (9). Doppler color flow mapping was used to assess the competence of the prosthetic valves. A high-velocity, eccentric turbulent jet with its origin beyond the edge of the sewing ring was considered PVL. A laminar, low-velocity regurgitant jet with its origin within the orifice of the sewing ring was considered transvalvular. The presence of a regurgitant flow was also checked using continuous-wave Doppler (5).

A TEE study was scheduled when there was an echocardiographic and/or clinical suspicion of paravalvular regurgitation.

2D TEE

Transesophageal echocardiogram was performed using a x7-2t transducer on an iE33 ultrasound machine (Philips Medical Systems, Andover, USA) capable of both multiplane 2D and real-time 3D imaging.

The severity of PVL was assessed semiquantitatively using visual estimation. Severe PVL of the mitral prosthetic valve was defined as maximum widths of the vena contracta of > 6 mm (10).

RT-3D TEE

2D and 3D TEE imaging were performed during the same procedure. Initially, gain settings were optimized using the narrow-angled acquisition mode, which allows real-time 3D imaging of a pyramidal volume of approximately 30° X 60°. The 3D zoom mode and full-volume wide-angle acquisition mode were subsequently used to image prosthetic valve and the paravalvular defect from atrial side. Images were assessed offline.

Characteristics of PVL

1. Localization

The study was performed analyzing the mitral annulus in a clock-wise format from an echocardiographer's view indicating the location of the leakage with the corresponding hour. Six o'clock was assigned as the mid-point of the anterior annulus and 12 as the mid-point of the posterior annulus, as viewed from the atrium. Hour 8 was assigned to the postero-medial commissure, hour 4 was assigned to the antero-lateral commissure (Fig. 1).

2. Size

The largest width and longest diameter of the paravalvular defect were measured on RT-3D TEE recordings using image grid method. Images were divided automatically into 2 or 5 millimeters based on the size of the images (Fig. 2). Area of the defect was measured in square millimeters.

PVL was defined as 'small' if the defect was lower than 10% of the circumference of annular ring, defined as 'moderate' if the defect was between 10-20% of the ring and defined as large if

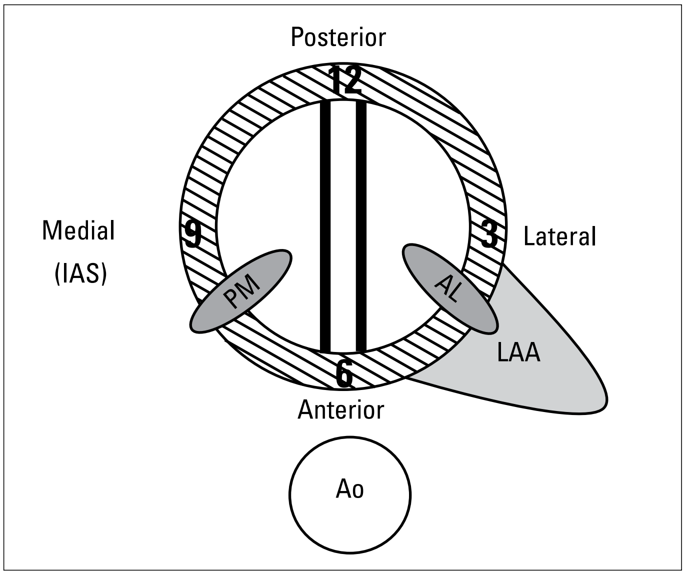

Figure 1. Schematic figure shows the mitral prosthesis and the relationship between cardiac structures from atrial side on clock-wise format
AL - anterolateral commissure, Ao - aorta, IAS - interatrial septum, LAA - left atrial appendage, PM - posteromedial commissure

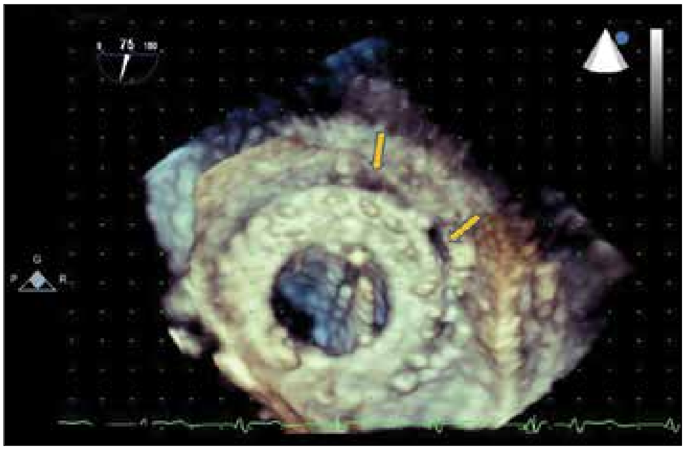

Figure 2. The grid method permitted measurement of the multifenestrated paravalvular defect size on RT-3D TEE. The distance between 2 dots corresponds to 5 mm
3D - three-dimensional, RT - real-time, TEE - transesophageal echocardiography

exceeded 20% of the ring. 'Dehiscence' was defined as the rocking of the valve ring when the large paravalvular defect exceeds 25% of the circumference of annular ring (Fig. 3).

3. Shape

The defects were defined as 'crescentic', 'slit-like', 'oval & round' and tunnel-like shapes.

Crescentic: The curved defect around the annular ring was defined as 'crescentic shaped'. In some circumstances, it was divided by tight sutures and was also defined as 'multi-fenestrated' crescentic-shaped PVL.

Slit-like: When the length of the defect was much larger than the width of the defect, it was called as *slit-like* shaped. They usually had cutting edges and could be multi-fenestrated.

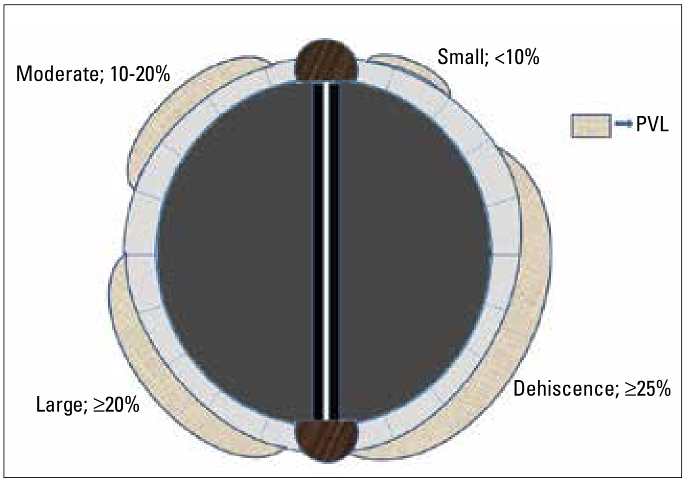

Figure 3. The PVLs were grouped based on their extension on circumferential annular ring, designed upon their size (small, moderate, and large)
PVL - paravalvular leak

Oval-round: The length of the defect was close to the width of the defect in *oval-round* defects.

Tunnel-like (small & slope tunnel shaped): Curved oblong shaped defect with a wide atrial orifice was called as 'slope-tunnel' shaped PVL.

4. Border regularity

PVLs were also classified due to contour of the defect.

I. Cutting-edged (regular)

II. Irregular

Number of PVLs

The number of PVLs (single & multiple) were recorded based on data required from 2D TEE, real-time 3D volume images and full volume 3D color Doppler findings (Video 1).

Extension of regurgitant jet

The paravalvular regurgitant jets were classified as either 'central' or 'eccentric' (laterally or medially) jets. Multiple jets with distinct extensions (eccentric and central jets in the same patient) were defined as 'mixed' jet.

Visual assessment of image quality analysis

The quality of 3D images were defined as either 'poor', 'fair' or 'good'.

The mean time of 3D TEE study

The time spent for 3D echocardiographic examination was recorded.

Surgical confirmation

Echocardiographic findings were compared with surgical findings in patients who underwent redo valve surgery due to clinically significant severe PVL.

Table 1. Characteristics of patients (n=47) with mitral PVLs at the time of admission

Variables	
Mean age, years	53±12
Gender, n (%) male/female	24 (51) / 23 (49)
Type of mitral prosthesis, n (%)	3(6) / 1(2%) / 43(93)
Bioprosthesis/monoleaflet/bileaflet	
Cardiac rhythm, n (%)	24 (51) / 23 (49)
Atrial fibrillation/Sinus rhythm	
Time since valve surgery, months	65±55 months (range, 1-200)
History of redo valve replacement, n (%)	11 (23)
Established diagnosis of infective endocarditis, n (%)	8 (17)
NYHA Class	2.2±0.8
Acute heart failure due to ventricular dysfunction, dehiscence etc., n (%)	3 (6.4)
Signs of hemolysis **, n (%)	34 (72)

Data are presented as mean and range enclosed in parentheses, and number (percentage)
**Both clinical (with or without need for transfusion) and laboratory findings (reduced hemoglobin, elevated LDH, bilirubinemia, etc.) were evaluated

The data were entered into a structured clinical database which included age, gender, type of prosthetic valve, cardiac rhythm, time elapsed since valve surgery, history of redo valve replacement surgery, infective endocarditis, ventricular functions and presence of hemolysis.

Statistical analysis

SPSS for Windows version 16.0 (SPSS, Inc., Chicago, Illinois, USA) was used for statistical analysis. The variables were investigated using analytical methods (Kolmogorov-Smirnov/Shapiro-Wilk's test) to determine whether or not they are normally distributed. Continuous variables are presented as medians and interquartile ranges or as mean±SD as appropriate. Categorical variables are presented as observed frequencies and percentages. The inter-rater agreement between the two echocardiographers and intra-rater agreement in determining PVL shapes (oval/ round, crescentic, slit-like) were investigated using the Kendall tau c test. Since the widths of the defects were not normally distributed; Mann-Whitney U test was conducted to compare 2D and 3D measurements. A p value of less than 0.05 was considered to show a statistically significant result.

Results

Echocardiographic examination revealed severe paravalvular regurgitation in 47 patients with mitral prosthesis. Characteristics of patients were shown in Table 1. Eleven patients (23%) had been operated at Cardiovascular Surgery Clinics of this center and the rest had been operated at other centers.

Forty-four patients (94%) had mechanical mitral prosthesis and 3 patients had bioprosthesis. The most common valve type was St. Jude bileaflet valve (23 patients; 49%). Nine patients had additional prosthesis (aortic: 8, tricuspid: 1).

Nine patients (19%) had history of redo valve surgery twice, whereas 2 patients (4%) had underwent redo valve surgery three times.

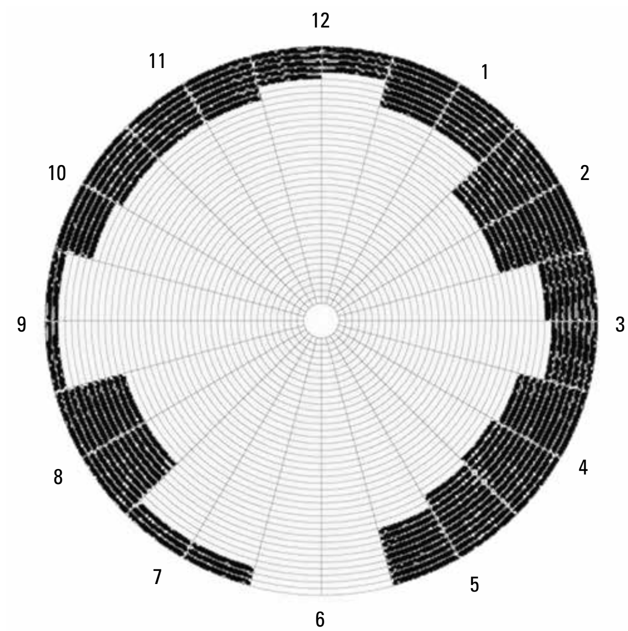

Figure 4. Dark colored columns indicate the localization of severe paravalvular leaks (n = 61) on clock-wise format

Echocardiographic characteristics of PVLs

The study comprised 47 cases with severe mitral regurgitation. Initial TTE study was able to demonstrate severe paravalvular regurgitation in 10 cases (21%); PVLs in the rest of the group were visualized with the utility of subsequent 2D and RT 3D TEE. Of 47 cases, 61 severe regurgitant jets were finally detected by 2D and 3D TEE; the latter showed the valvular anatomic appearance as seen from the atrial perspective.

Localizations of severe PVLs are demonstrated in Figure 4. The most common localizations included anterolateral commissure (4 o'clock), posteromedial commissures (8 o'clock) and posterolateral region (2 o'clock). Anterior (6-7 o'clock) and medial (9 o'clock) localizations were less commonly observed.

The width of the PVL defects could not be visualized and measured in 7 patients (15%) by initial 2D TEE. The mean PVL width measured by 2D TEE in the remaining patients was 3.1±1.3 (range; 2-7) mm and the mean width of the defect measured by 3D TEE in the same group was 3.1±1.1 (range; 2-7) mm (p=0.7). The mean length of defect measured by 3D TEE was 11.1±6.5 mm whereas 2D TEE was not able to show the mean PVL effective orifice length. The mean area of severe PVLs was 34±24 mm^2 exhibiting a wide range (8-100 mm^2). There were 22 (36%) small, 24 (39 %) moderate and 15 (25%) large severe PVLs. Of 15 large PVLs, three PVLs in 3 patients exceeded 25% of the circumference of annular ring; these dehisced prosthesis had 'rocking' motions.

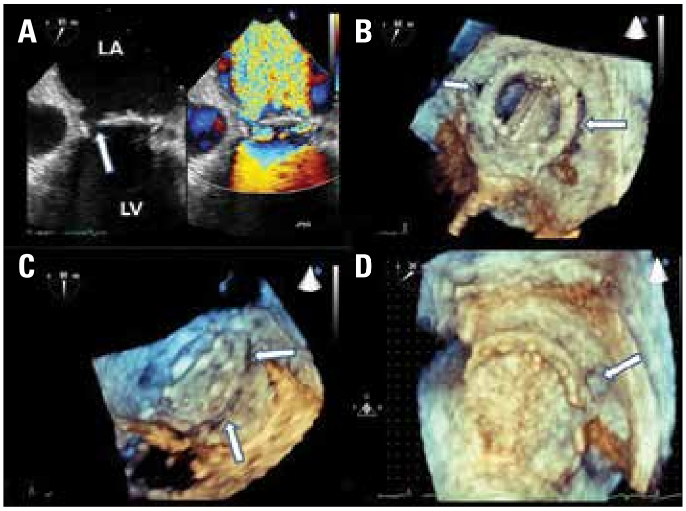

Figure 5. (A) 2D TEE revealed the PVL defect (arrow) and the severe mitral regurgitation. (B) 3D TEE revealed two PVLs; one round-oval shaped (small arrow) and one crescentic-shaped defect (large arrow). (C) 3D TEE revealed multifenestrated slit-like shaped PVL defect (arrow). (D) 3D TEE revealed small tunnel shaped PVL defect with atrial orifice (arrow)

3D - three-dimensional, LA - left atrium, LV - left ventricle, PVL - paravalvular leak, TEE - transesophageal echocardiography

RT-3D TEE clearly depicted the morphological characteristics of most of the PVLs (Fig. 5A-D and Fig. 6A-D). The most common defect type was 'oval / round' (n=29; 48%). Also, there were 19 'crescentic' (31%), 9 'slit like' (15%), and 2 tunnel-like (3%, one small-tunnel and one slope-tunnel) shaped defects. Two posteriorly-localized defects (3%) were not clearly visualized by RT-3D TEE and, therefore they were noted as 'indefinite' shaped.

Eight crescentic-shaped and 3 slit-like shaped PVLs were 'multi-fenestrated'. Besides, 74% of the crescentic shaped leaks had irregular borders (n=14). The oval / round, tunnel-like and slit-like defects had regular borders.

Among 61 severe PVLs, 31 'eccentric' (51%) regurgitant jets and 30 'central' (49%) regurgitant jets were demonstrated. Eleven (23%) patients had both eccentric and central regurgitant jets ('mixed'). In 5 cases (11%), RT-3D TEE was successful in distinguishing separate regurgitant jets which appeared as a single broad jet on initial 2D TEE.

Thirty-four patients had good (72%), nine patients (19%) had fair and four patients (9%) had poor visual quality on 3D TEE studies. The presence of giant left atrium (>6 cm) and posterior localization of paravalvular defect were the major causes for poor echocardiographic windows.

A mean of 10±3 additional minutes were spent for RT-3D TEE examination by the first echocardiographer.

Surgical confirmation

Surgical intervention was scheduled in twenty-two patients who suffered clinical deterioration in which the site and dimension of the dehiscence were all confirmed at the time of the surgery in each patient (100%).

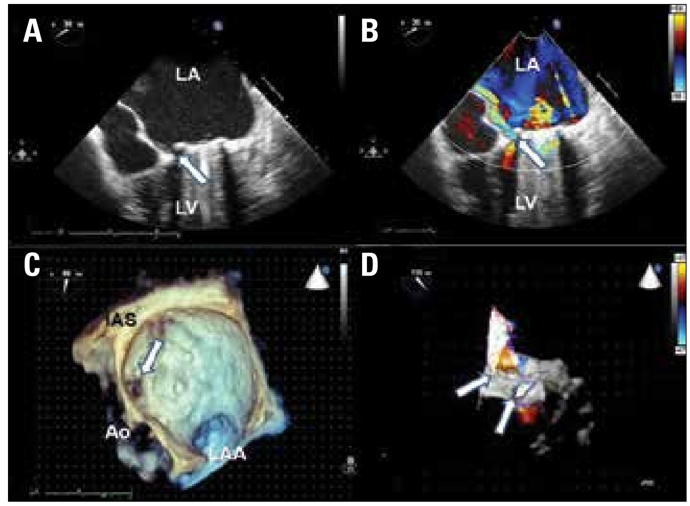

Figure 6. (A) 2D TEE revealed the PVL defect (arrow). (B) 2D TEE delineated the severe eccentric regurgitant jet (arrow). (C) 3D TEE revealed oval shaped PVL defect (arrow). (D) RT-3D TEE full-volume color Doppler examination permitted detection of two regurgitant jets (one large and one small; see arrows)

3D - three-dimensional, Ao - aorta, IAS - interatrial septum, LA - left atrium, LAA - left atrial appendage, LV - left ventricle, PVL - paravalvular leak, RT - real-time, TEE - transesophageal echocardiography

Intra- and interobserver agreement

The intra-rater agreement in determining PVL shapes was almost perfect (Kendall tau-c=0.80, p<0.001). The inter-rater agreement in determining PVL shapes was substantial (Kendall tau-c=0.61, p<0.001).

Discussion

This single-center study showed that RT-3D TEE has incremental value in describing detailed visualization of the PVL morphology and dimensions. According to this relatively large-scaled study, severe PVLs were mainly located at anterolateral and posteromedial commissures, and posterolateral region. Furthermore, the most common observed defect types were 'oval/round' and crescentic defects. The severity and the exact site of the mitral regurgitation (paravalvular versus transvalvular) could be assessed in all patients.

Characteristics of PVL

Paravalvular defects may be clinically inconsequential or may aggravate hemolysis or cause heart failure through regurgitation. Early paravalvular leaks may be the result of either suture knot failure, inadequate suture placement, or separation of sutures from a pathologic annulus in endocarditis with ring abscess, myxomatous valvular degeneration, or calcified valvular annulus as in calcific aortic stenosis or mitral annular calcification. Late small paravalvular leaks usually are caused by anomalous tissue retraction from the sewing ring between sutures during healing and tend to be small and difficult to locate by surgical or pathological examination (11).

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PVL are twice as likely to occur with mitral than with aortic prosthesis (3). Localization of PVLs were studied in several studies using echocardiographic examination and surgical inspection (1, 8, 12). Kronzon et al. (8) studied 18 patients with prosthetic mitral valve dehiscence and the PVLs were most commonly observed at posterior segments. Based on the findings from another study authored by De Cicco et al. (1) which included 135 patients undergoing redo valve surgery, mitral PVLs occurred more frequently at antero-lateral and postero-medial segments of mitral valve annulus. In our study consisting 47 patients with 61 PVLs, the defects were located in several localizations including posteromedial and anterolateral commissures, and posterolateral regions with closer percentages. One striking finding was that there were few PVLs in anterior (between 05.30 to 07.30 hours) and medial localizations (09 o'clock). This heterogeneity about the PVL in our study could be attributed to altered dynamics of mitral valve annulus and related artificial valve ring which was previously described by Komoda et al. (13).

Although the location and extent of the leaks vary individually, most reported leaks are either oval- or crescent shaped with irregular borders (14). In our study, oval-round and crescentic shaped PVLs contributed to 82% of all PVLs. There were significant differences between the sizes of the PVL defects (8-100 mm^2) although all of them were associated with severe regurgitation. A relatively large PVL commonly causes severe regurgitation whereas a small PVL may exhibit a wide range of regurgitation, from mild to severe degree. For instance, a small PVL may contribute to clinically significant severe paravalvular regurgitation necessitating corrective procedures.

Pitfalls in 2D examination and contribution of RT-3D TEE

PVL severity, size, shape and morphology are important factors in determining subsequent clinical presentation and the severity of heart failure. 2D TEE permits the determination of the severity of the regurgitation on the base of standard criteria. However, it offers minimal assistance in delineating PVL anatomy and adjacent cardiac structures. Although 2D TEE is theoretically superior to TTE in distinguishing between central/paravalvular leaks, misdiagnosis may sometimes occur with 2D TEE study; RT 3D TEE may be necessary to determine the exact origin of the jet. Multiple jets may also appear as a single broad jet on 2D TEE. One pitfall of 2D imaging is that it cannot distinguish between a crescentric shaped defect and one that is circular (7). RT-3D TEE is uniquely capable of demonstrating the irregular shape of the defects and is better able to identify multiple defects and provide accurate sizing (15). In our study, the width of the defect wasn't statistically different between 2D and 3D TEE measurements. However, 2D TEE was not able to show the mean PVL effective orifice length because of the limited plane orientation which could be precisely measured by subsequent RT 3D TEE. So, RT-3D TEE is superior over 2D TEE in assessment of mitral prosthetic valve dehiscence (16). It provides additional information about the complex 3D anatomy, spatial orientation and size of the dehiscence, helps in planning the corrective procedure (8) and in facilitating procedural success (17, 18).

Transcatheter intervention has recently been used as an alternative approach to surgical repair. RT-3D TEE plays an invaluable role in guiding percutaneous closure of PVLs; in preprocedure sizing of the perivalvular defect, assessment of the suitability of the defect for closure (19), selection of an appropriate device, guidance of device deployment intraprocedure, and the confirmation of defect closure postprocedure. However, the existing devices are off-label which directly contributes to procedural failure. Because of the morphologic variability of PVLs, PVL device design may ultimately be based on data obtained from advanced imaging modalities such as 3D echocardiography and rapid prototyping to design true patient-specific or modifiable closure devices (20).

The surgical closure of paravalvular leaks is usually advised in severely symptomatic patients and in those requiring blood transfusions for persistent hemolysis. Operative mortality is 6% to 14% (21, 22). Besides, PVL can occur approximately in up to 10% of cases of prosthetic valve reoperation (23, 24). In most reoperation cases, exposure of the mitral valve is difficult due to severe adhesions. Therefore, the intraoperative localization of the paravalvular leakage site may be difficult due to the poor exposure, especially, the periprosthetic defect, which is frequently small in cases with hemolysis without heart failure (25). In this setting 'en face' view of mitral prosthesis by RT-3D TEE directly contributes to the success surgical repair of PVLs (26). In this study, with the utility of RT-3D TEE we were able to demonstrate the exact location of all the PVLs in 22 patients which were also surgically confirmed. This shows that RT-3D TEE should be performed preoperatively to confirm the location and the severity of PVLs.

Challenges in the RT-3D TEE and study limitations

Some disadvantages of RT3D TEE must be considered as well. The 3D pyramidal data set is subject to the same artifacts as 2D imaging. It has reduced temporal resolution and requires added training (14). Unobstructed visualization is not always possible; therefore, cropping features may be needed to remove obstructive anatomy to an *en face* view, a time-consuming process. A major diagnostic concern is tissue dropout secondary to an undergained image. Dropout may give the impression of a false anatomic defect, leading to speculation of nonexistent pathology, a hole where a hole should not be (14), so confirmation with color mapping should be performed. Some of the limitations can be overcome when the learning curve is completed and technological developments occur.

This study included only the mitral valves. Similar to native aortic and tricuspid valves, prosthetic valve leaflets in these locations are not as clearly visualized, because of the longer distance between these anteriorly localized structures and the transducer and the oblique angle of incidence of the ultrasound beam (27). Another limitation is that short and long-term clinical outcomes of the patients were not assessed as the aim of the study was to evaluate the echomorphological characteristics of severe PVLs.

Conclusion

RT-3D TEE permits detailed structural evaluation of the prosthesis and paravalvular leak morphology compared to 2D TEE. It may provide more accurate information to the clinician in decision making and may contribute to the success of the potential corrective procedures.

Conflict of interest: None declared.

Peer-review: Externally peer-reviewed.

Authorship contributions: Concept - M.Ö., O.M.G.; Design - M.A.A.; Supervision - T.G., M.Ö.; Material - A.Ç.A.; Data collection&/or Processing - Z.B., B.Ç.; Analysis &/or interpretation - S.K., M.Y.; Literature search - M.K.; Writing - O.M.G., M.Ö., G.K.; Critical review - N.E.D.

Video 1. RT-3D TEE full-volume color Doppler examination permitted detection of two regurgitant jets

3D - three-dimensional, RT - real-time, TEE - transesophageal echocardiography

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