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ECHOCARDIOGRAPHY OF THE MITRAL VALVE

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Abstract

The mitral valve is a complex anatomical and functional structure, composed of the mitral leaflets, mitral annulus, chordae tendineae, papillary muscles and adjacent myocardium. Normal function of all parts of the mitral valve apparatus is essential for normal function of the mitral valve. Different conditions and diseases can cause mitral valve dysfunction, namely mitral regurgitation and mitral stenosis. Echocardiography is a key diagnostic procedure to evaluate the mitral valve. Transthoracic echocardiography is a basic investigation in assessing the mitral valve. When detailed evaluation of the mitral valve is required, transesophageal echocardiography is indicated with the advantage of better resolution and additional views. Two-dimensional echocardiography is useful in the evaluation of mitral valve morphology, heart size and function. Three-dimensional echocardiography is especially useful before surgical procedures, since it gives a better view of the complex mitral valve structure in a “surgeon’s view”. To detect possible mitral valve dysfunction, colour-Doppler echocardiography is used. To properly evaluate the degree of mitral valve regurgitation and stenosis, pulse and continuous-wave Doppler echocardiography is mandatory. Mitral valve evaluation requires a thorough echocardiographic investigation with different echocardiographic modalities and with the use of novel echocardiographic methods, such as three-dimensional echocardiography.

Key words: echocardiography, mitral valve, mitral regurgitation, mitral stenosis

Anatomy of the mitral valve

Mitral valve is a complex anatomical and functional structure. Mitral apparatus consists of three parts: mitral annulus, mitral valve leaflets and subvalvular apparatus (chordae tendineae and papillary muscles). For its function left atrial and ventricular myocardium is also important. Normal function of all parts of the mitral valve apparatus is essential for the normal function of the mitral valve (1, 2).

Mitral annulus is a saddle shaped fibrous structure, which anteriorly borders to the aorta. Posterior annulus is close to circumflex coronary artery at the lateral side and to coronary sinus at the medial side. Mitral annulus is in a fibrous continuity with aortic and tricuspid valve (3).

Mitral leaflets consist of a larger and longer anterior (AMVL) and shorter posterior mitral valve leaflet (PMVL). Based on Carpentier's classification mitral leaflets are divided in eight segments. Anterior and posterior leaflet have three scallops each: medial (A3, P3), middle (A2, P2) and lateral (A1, P1). The middle scallop is the largest. The leaflets are connected by two commissures: anterolateral, adjacent to left atrial appendage, and posteromedial commissure (1-5).

Subvalvular apparatus consists of chordae tendineae and papillary muscles. Chordae are thin filaments that connect margins of the mitral leaflets to the papillary muscles. There are primary, secondary and tertiary mitral chordae which are attached to two papillary muscles: posteromedial and anterolateral papillary muscle. Chordae from the medial part of both leaflets attach to the posteromedial papillary muscle and from the lateral part to the anterolateral papillary muscle (1-3, 5).

Assessment of the mitral valve

Echocardiography plays a central role in the evaluation of the mitral valve. It enables the assessment of its morphology and function. The basic investigation is transthoracic echocardiography (TTE) which can routinely be used in everyday clinical practice. When detailed evaluation of the mitral valve is required, transesophageal echocardiography (TEE) is indicated with the advantage of better resolution and additional views.

Transthoracic echocardiography

For the assessment of the mitral valve different views can be used. The mitral valve is best seen in the parasternal long and short-axis views and in the apical views (3, 6).

In the *parasternal long-axis view* both mitral leaflets and their motion can be evaluated (Figure 1). The mitral leaflets are thin. Chordae are attached to the free edge and to the ventricular surface of the leaflets and extend to the papillary muscles. The mitral annulus with its minor axis is seen in this view. With M-mode echocardiography motion of the mitral leaflets can be evaluated and this view is useful in the detection of mitral valve prolapse (Figure 2) (3, 6, 7).

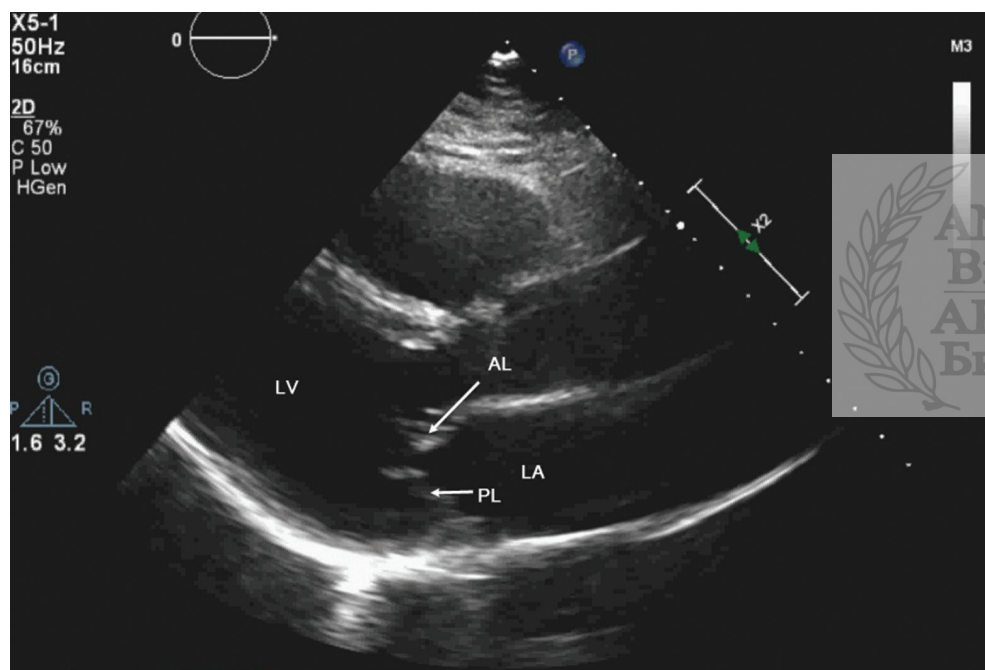


Figure 1. In the parasternal long axis view the anterior (AL) and posterior (PL) mitral valve leaflets are seen. LA – left atrium, LV – left ventricle.

Morphology of the mitral valve can be best evaluated in the *short-axis views*. At the mitral valve level both leaflets with the scallops and mitral commissures can be seen (Figure 3, 4). By planimetry, mitral valve area (MVA) can be measured in this view (Figure 5). Normal MVA is 4-6 cm². With angulation of the transducer more apically, the papillary or midventricular level is obtained where both papillary muscles can be visualized (3, 6, 7).

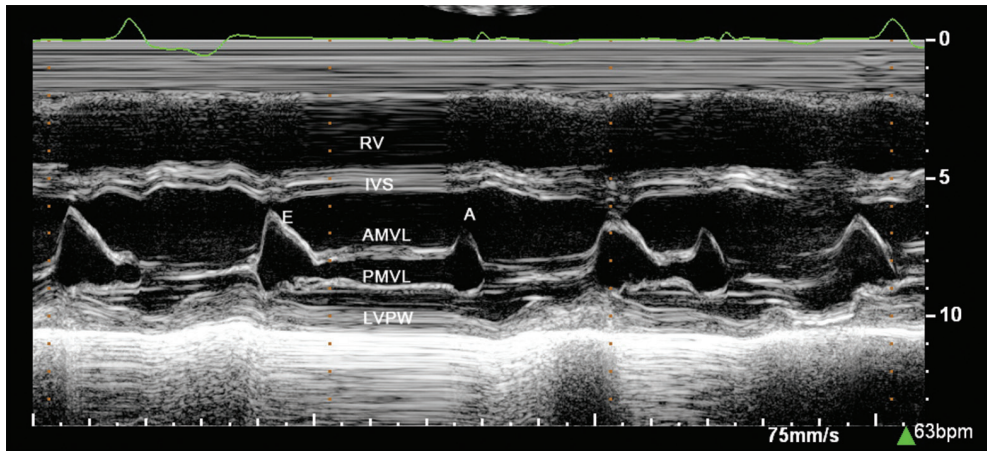


Figure 2. M-mode tracing of the mitral valve. In early diastole, the mitral leaflets open. The anterior leaflet (AMVL) moves towards the interventricular septum (IVS) and the posterior leaflet (PMVL) to the left ventricular posterior wall (LVPW). The maximum opening of the anterior leaflet in early diastole is termed the E point. In mid-diastole leaflets move closer to each other (diastasis) and in atrial systole open again, forming the A point of the anterior leaflet. The movement of the posterior leaflet is mirror-like. RV – right ventricle

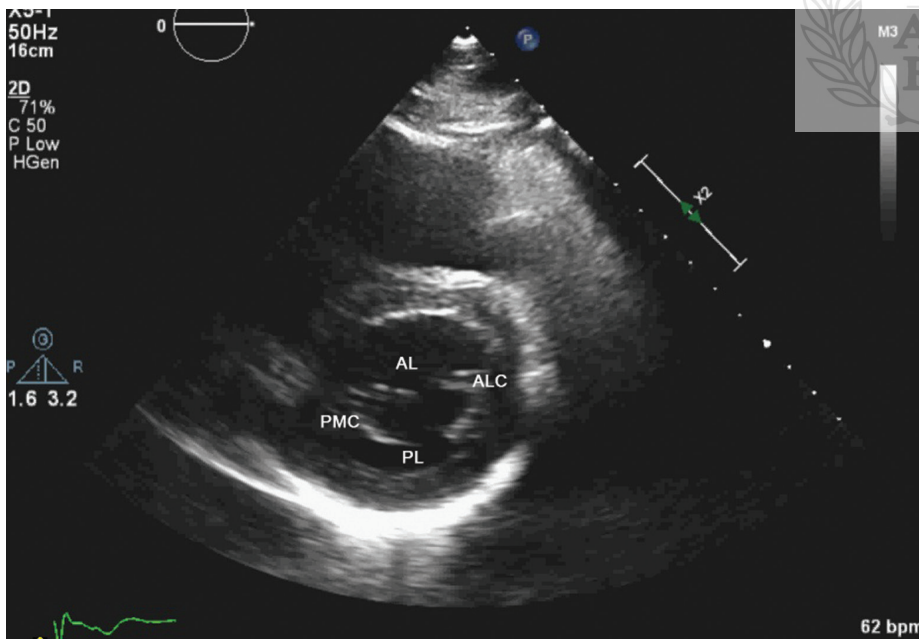


Figure 3. At the mitral valve short-axis level anterior (AL) and posterior (PL) mitral valve leaflets with anterolateral (ALC) and posteromedial (PMC) commissures are seen.

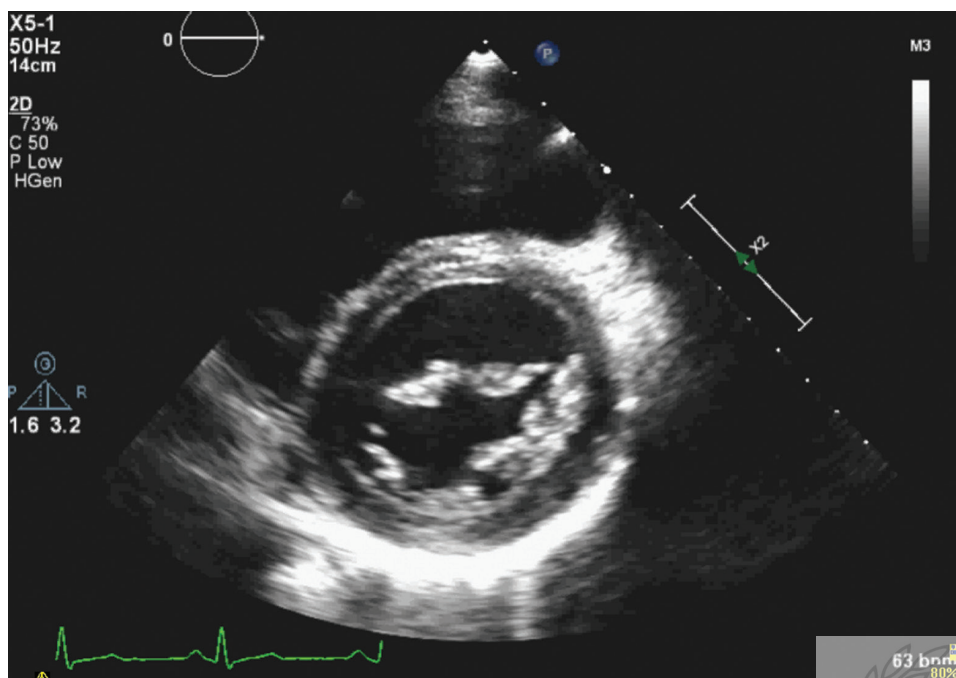


Figure 4. At the mitral valve short-axis level myxomatous changes of the mitral valve leaflets are seen. The leaflets are thickened and redundant.

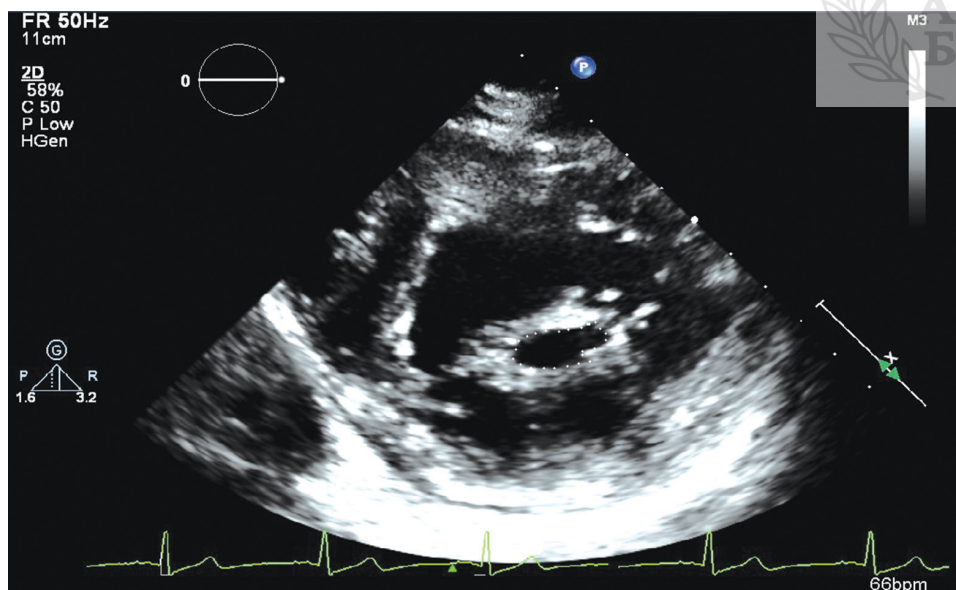


Figure 5. By planimetry mitral valve area (MVA) can be measured in the parasternal short-axis view. The figure shows severe rheumatic mitral valve stenosis with MVA of 0.9 cm².

In the *apical four-chamber view* the anterior leaflet is located closer to the interventricular septum, while the posterior leaflet is adjacent to the lateral wall of the left ventricle. Chordae from both leaflets extend and attach to the anterolateral papillary muscles. The major axis of the mitral annulus can be measured in this view. The mitral annulus normally lies less apically than the tricuspid valve annulus (Figure 6). To evaluate mitral valve function, colour-flow Doppler is used. In this view, mitral inflow by pulsed-wave Doppler and MVA by pressure half-time can also be assessed (Figure 7). The *apical two-chamber* and long-axis view are used for additional views of the mitral valve, to evaluate mitral valve scallops and with the use of colour-flow Doppler to assess the degree of mitral regurgitation (3, 6, 7).

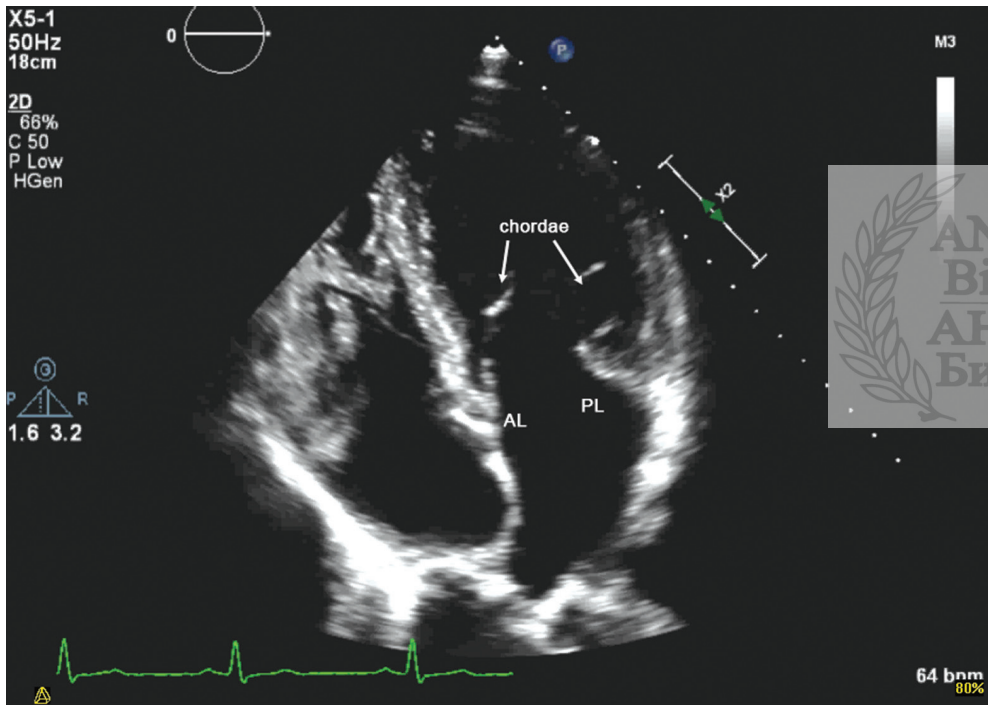


Figure 6. The apical four-chamber view with the anterior (AL) and posterior (PL) mitral valve leaflet.

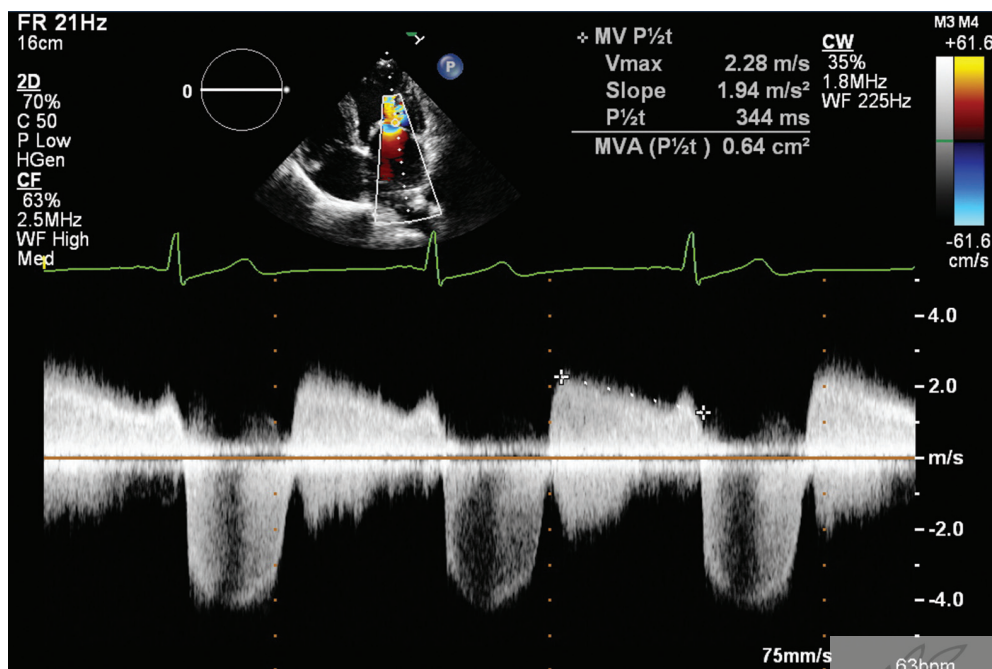


Figure 7. In apical four-chamber view mitral valve area (MVA) is calculated by pressure half-time method. The patient has severe rheumatic mitral valve stenosis. The continuous-wave Doppler signal of mitral regurgitation is dense and parabolic, indicating associated moderate mitral regurgitation.

Transesophageal echocardiography

When detailed assessment of the mitral valve is necessary or prior to surgical correction of the mitral valve, TEE is indicated. It provides better imaging of the mitral valve and its morphology. For detailed information on mitral morphology different views are used. The mitral valve is usually evaluated by transducer rotation from the four-chamber to the long-axis view. If needed, transgastric views can also be used. TEE is useful before surgery in mitral valve prolapse, flail mitral valve, to determine the mechanism of mitral regurgitation or to evaluate in more detail the mitral stenosis (Figure 8, 9) (8).

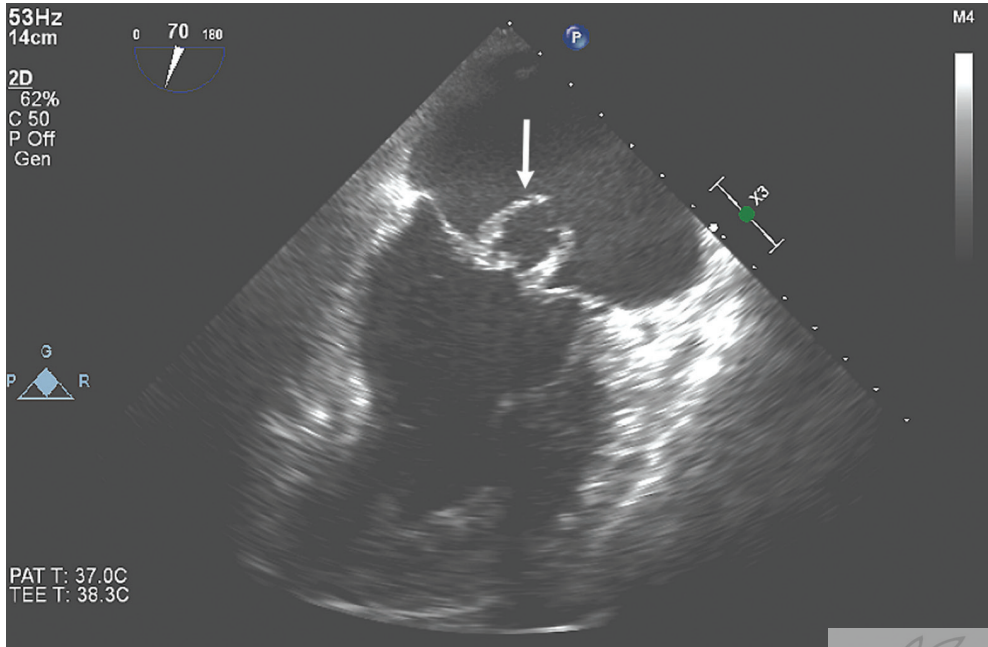


Figure 8. In TEE two-chamber view flail mitral leaflet is seen.

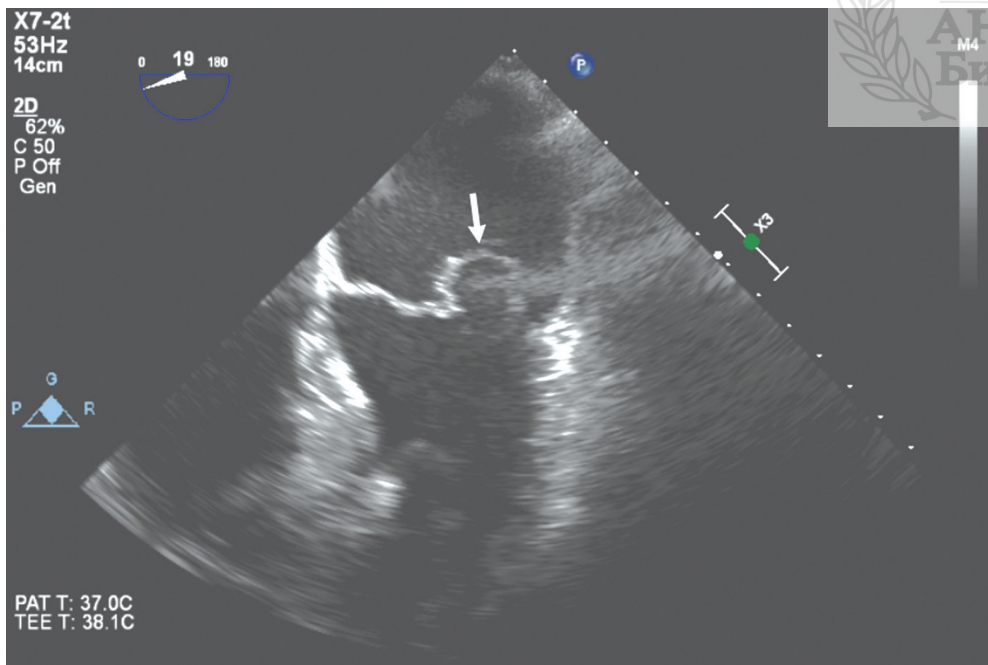


Figure 9. In TEE four-chamber view the mitral valve prolapse is seen.

Three-dimensional echocardiography

Three-dimensional echocardiography upgrades classical two-dimensional echocardiography. It gives “en face” view of the mitral valve. The valve is visualized either from left atrium or left ventricle. The view of the mitral valve from the left atrium (“surgeon’s view”) facilitates communication with the surgeons since the view is the same as in the operating theatre (9, 10).

To visualize the mitral valve “3D ZOOM” mode is used (Figure 10). For evaluation of subvalvular apparatus and surrounding structures “full volume 3D” is used. Image acquisition is made during breath-hold to avoid stitching artefacts. Colour Doppler can also be used (9, 10).

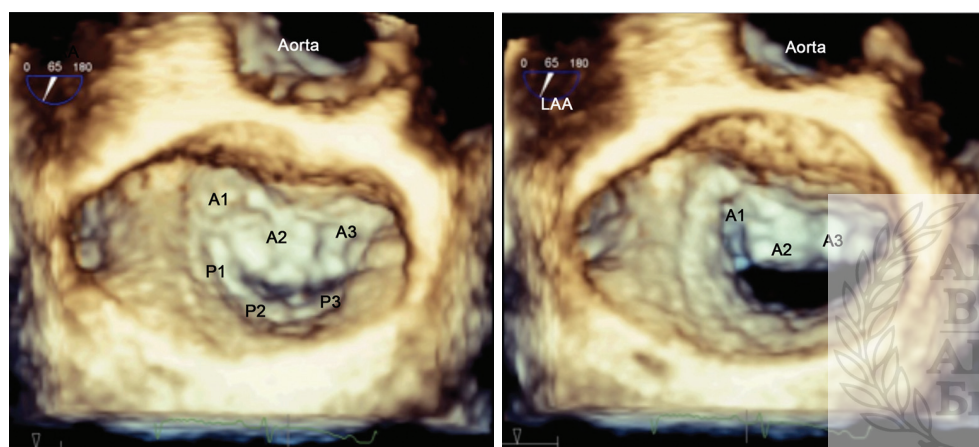


Figure 10. Three-dimensional TEE of closed (left) and open (right) mitral valve with its scallops in a ZOOM mode from the left atrium in a “surgeon’s view”. LAA – left atrial appendage

Mitral valve disease

In the Western countries, mitral valve disease is the second most common valvular heart disease after aortic valve disease (11). Disease of the mitral valve can result in mitral valve regurgitation, stenosis or combined lesion (7).

Mitral stenosis

Mitral stenosis is caused by rheumatic heart disease in more than 90% of cases. Other causes like mitral annular calcification, infective endocarditis, carcinoid heart disease, or others are rare and usually do not progress to severe stenosis. Nowadays, in the Western countries mitral stenosis is rare (11-13).

Commissural fusion is the most characteristic feature of rheumatic heart disease. It results in doming of the leaflets in diastole (hockey-stick appearance of the anterior leaflet), which is best seen in parasternal long-axis view (Figure 11). The doming results from the restricted mobility of the leaflet tips due to commissural fusion, while the base and mid-section of the leaflets remain relatively mobile. Subvalvular apparatus is also affected with thickening, shortening, fusion, fibrosis and calcification of the mitral chordae (7, 12, 13).

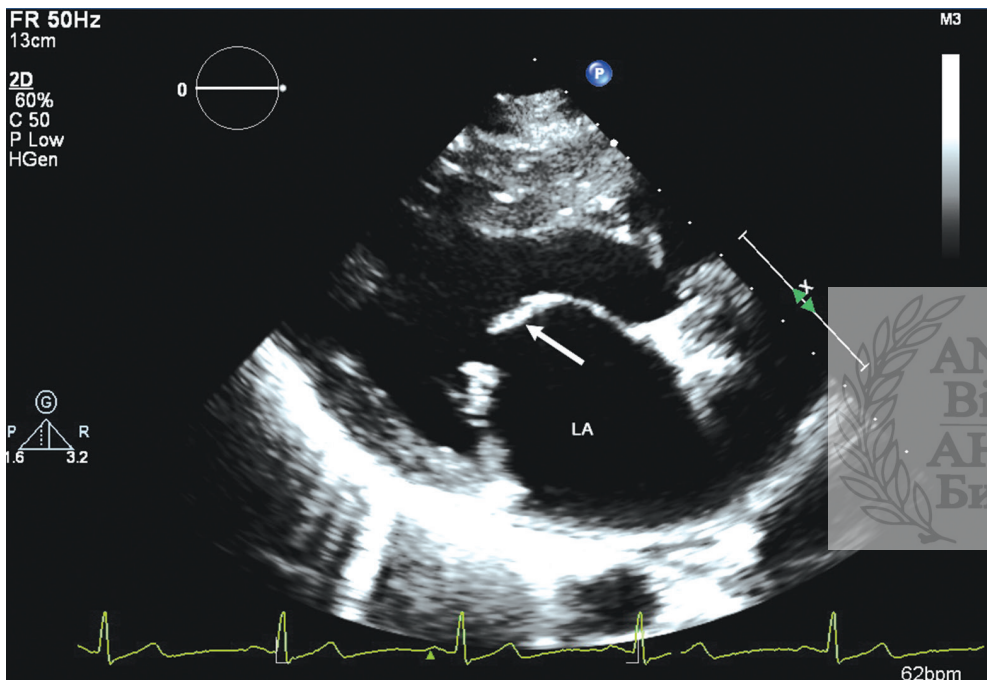


Figure 11. In the parasternal long-axis view of a patient with severe rheumatic heart disease the doming of the mitral valve is shown. Anterior mitral valve leaflet has hockey-stick appearance (arrow). The tips of the leaflets are thickened. Left atrium (LA) is enlarged.

Typical changes in mitral stenosis can usually be accurately assessed by two-dimensional TTE, if detailed visualization is necessary TEE or three-dimensional echocardiography can be performed. By colour-flow Doppler a turbulent flow across the mitral valve in diastole can be detected (7, 12, 13).

The severity of mitral stenosis is assessed by MVA and pressure gradients (7, 12, 13). Echocardiographic classification of mitral stenosis severity is presented in Table 1.

Table 1. Echocardiographic classification of mitral stenosis severity

	Mild	Moderate	Severe
MVA (cm ²)	>1.5	1.0–1.5	<1.0
Mean pressure gradient (mmHg) ^a	<5	5–10	>10
Systolic PAP (mmHg)	<30	30–50	>50

MVA—mitral valve area, PAP—pulmonary artery pressure; ^a—in sinus rhythm at heart rates 60–80 bpm

There are several methods to calculate MVA. By *planimetry* MVA can be directly traced in parasternal short-axis view (Figure 5). This is the method of reference; however it requires adequate image quality. The measurement should be done at mid-diastole at the tips of the leaflets. In atrial fibrillation, average of 5 consecutive beats should be used (7, 12, 13).

MVA can be calculated from by *pressure half-time (PHT) method* with the formula: $MVA = 220/PHT$. PHT is obtained by tracing the slope of the E-wave from the continuous wave Doppler signal in apical four-chamber view (Figure 7) (7, 13).

MVA can also be calculated by *continuity equation*, where stroke volume of the mitral valve equals stroke volume of the aortic valve:

$$MVA = CSA_{LVOT} \times VTI_{LVOT} / VTI_{MV}$$

(CSA – cross sectional area ($CSA = \pi \times r^2$), VTI – velocity time integral, LVOT – left ventricular outflow tract, MV – mitral valve, r – LVOT diameter)

Transmitral pressure gradient is obtained by tracing the continuous wave Doppler signal through the mitral valve in apical four-chamber view (Figure 12). Mean pressure gradient is determined using simplified Bernoulli equation (7, 12, 13).

When evaluating mitral stenosis, systolic pulmonary artery pressure from tricuspid regurgitation should also be estimated. In patient with significant mitral stenosis, left atrium is typically enlarged (7, 12, 13).

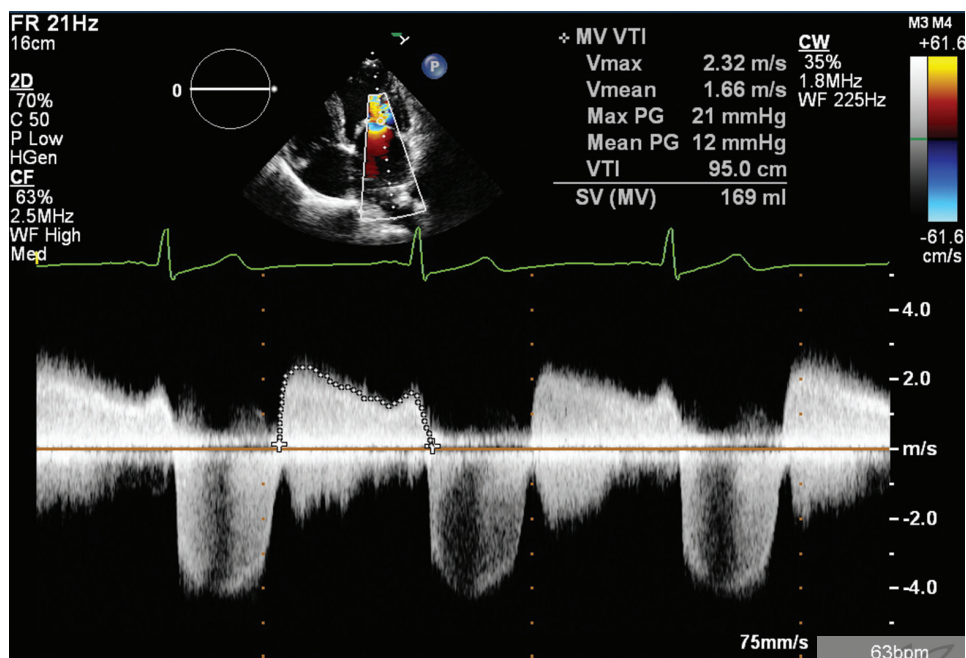


Figure 12. The assessment of mean pressure gradient in a patient with severe rheumatic mitral stenosis.

Mitral regurgitation

Mitral regurgitation is classified as primary (organic) and secondary (functional). Organic mitral regurgitation is caused by disease of the mitral valve. Functional mitral regurgitation is caused by geometrical changes of the subvalvular apparatus due to left ventricular remodelling while the valve itself is structurally normal (7, 10, 13).

Etiology of mitral regurgitation is diverse. Organic mitral regurgitation is most commonly caused by degenerative disease (myxomatous changes, Marfan, etc.), followed by rheumatic valve disease, ruptured papillary muscle due to myocardial infarction and infective endocarditis. Functional mitral regurgitation is caused by left ventricular dilatation and systolic dysfunction due to ischemic heart disease or dilated cardiomyopathy (7, 10, 13).

To determine the mechanism of mitral regurgitation Carpentier's classification is used (7):

Type I: normal leaflet motion with leaflet perforation (infective endocarditis) or annular dilatation

Type II: leaflet prolapse – leaflets are excessively mobile and the free edge of one or both leaflets is displaced beyond the mitral annular plane

Type III: restriction of leaflet motion; IIIa – restricted motion in diastole and systole due to shortening of chordae or leaflet thickening (as in rheumatic heart disease) and IIIb – restricted motion in systole (functional mitral regurgitation in ischemic or non-ischemic cardiomyopathy).

To grade the severity of mitral regurgitation several echocardiographic methods are used (Table 2) (11).

Table 2. Grading of the severity of organic mitral regurgitation

Parameters	Mild	Moderate	Severe
Qualitative			
MV morphology	Normal/abnormal	Normal/abnormal	Flail leaflet/ruptured PM
Colour-flow jet	Small, central	Intermediate	Very large central or eccentric adhering the LA wall
PISA	No or small	Intermediate	Large
CW signal of MR jet	Faint/parabolic	Dense/parabolic	Dense/triangular
Semi-quantitative			
VC width (mm)	<3	Intermediate	≥7
Pulmonary vein flow	Systolic dominance	Systolic blunting	Systolic flow reversal
Mitral inflow	A wave dominant	Variable	E wave dominant (>1.5 cm/s)
VTI_{MV}/VTI_{AV}	<1	Intermediate	>1.4
Quantitative			
EROA (mm ²)	<20	20–29; 30–39 [*]	≥40
RVol (ml)	<30	30–44; 45–59 ^{**}	≥60

* plus LV and LA size and systolic pulmonary artery pressure; PM – papillary muscle, MV – mitral valve, AV – aortic valve, CW – continuous wave, EROA – effective regurgitant orifice area, RVol – regurgitant volume, VC – vena contracta, MR – mitral regurgitation, VTI – velocity time integral, ^{*} – moderate regurgitation is classified to mild-moderate and moderate-severe.

For ischemic mitral regurgitation EROA > 20 mm² and RVol > 30 ml is considered significant.

The initial screening for mitral regurgitation is done by colour-flow Doppler (Figure 13). The method has many limitation and is not recommended for severity quantification. If the jet is central and its area <20% of left atrial area, the regurgitation is considered mild (7, 11).

The intensity of continuous-wave Doppler signal of mitral regurgitation is related to mitral regurgitation severity (Figure 7). In severe regurgitation the signal is dense and has a full envelope (7, 11).

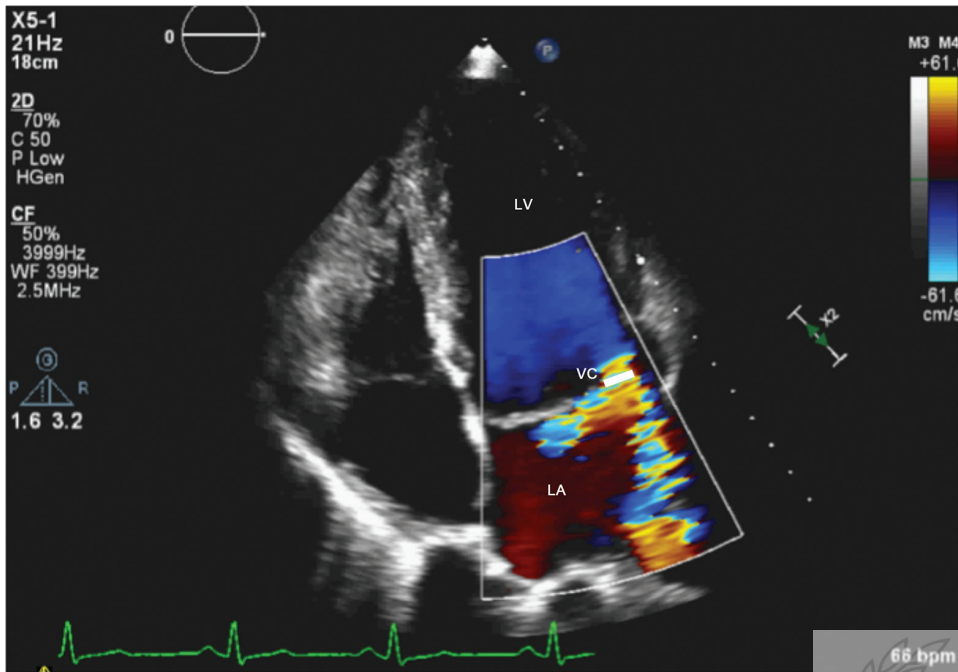


Figure 13. In apical four-chamber view colour-flow Doppler of the mitral regurgitation is seen. The regurgitant jets extends to the lateral wall of the left atrium (LA). VC – vena contracta, LV – left ventricle

The size of vena contracta, the narrowest portion of the regurgitant jet downstream from the regurgitant orifice, is the semi-quantitative measure of mitral regurgitation severity (Figure 13). It is recommended to measure it in two orthogonal planes (7, 11).

PISA (proximal isovelocity surface area) is the most recommended quantitative method to evaluate mitral regurgitation in central jets (Figure 14). Regurgitant volume and orifice area are derived from PISA. It is optimally measured in an apical four-chamber view, using narrow sector, minimal depth and zoom mode. The Nyquist limit should be set at 20 to 40 cm/s. With additional measurement of maximal velocity and velocity time integral of the regurgitant jet, effective regurgitant orifice area (EROA) and regurgitant volume are calculated (7, 11):

$$\text{EROA (cm}^2\text{)} = \text{PISA} \times v_a / v_{\text{max MR}}$$

$$\text{RVol (ml)} = \text{EROA} \times \text{VTI}_{\text{MR}}$$

(v_a – aliasing velocity, $v_{\text{max MR}}$ – maximal velocity of mitral regurgitation, Rvol – regurgitant volume, VTI_{MR} – velocity time integral of mitral regurgitation; $\text{PISA} = 2 \pi r^2$)

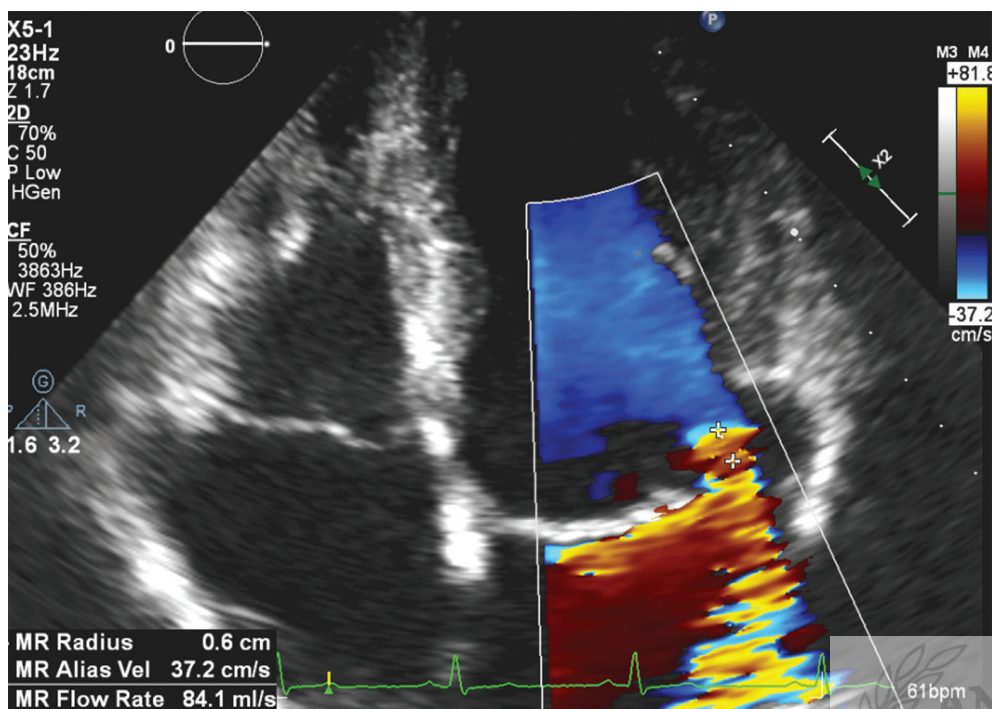


Figure 14. The measurement of PISA radius of the mitral regurgitation.

For complete assessment of the mitral regurgitation, size of left atrium and ventricle, left ventricular function and systolic pulmonary artery pressure must be evaluated (7, 11).

In conclusion, echocardiography is a key imaging modality in assessment of the mitral valve. With different techniques, morphology and function of the mitral valve can be reliably assessed. Novel modalities, like three-dimensional echocardiography, are especially useful when planning surgical correction.

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EHOKARDIOGRAFIJA MITRALNOG ZALISKA



Sažetak

Mitralni zalistak je složena anatomska i funkcionalna struktura, sastavljena od mitralnih listića, mitralnog prstena, srčanih niti zaliska, papilarnih mišića i susjednog miokarda. Normalna funkcija svih dijelova aparata mitralnog zaliska je od suštinskog značaja za normalnu funkciju mitralnog zaliska. Različite bolesti i sindromi mogu da izazovu disfunkciju mitralnog zaliska, odnosno mitralnu regurgitaciju i mitralnu stenožu. Ehokardiografija je ključni dijagnostički postupak za pregled mitralnog zaliska. Transtorakalna ehokardiografija je osnovna pretraga u procjeni mitralnog zaliska. Kada je potrebna detaljna evaluacija mitralnog zaliska preporučuje se transezofagealna ehokardiografija zbog prednosti bolje rezolucije i dodatnih pogleda. Dvodimenzionalna ehokardiografija je korisna u procjeni morfologije mitralnog zaliska, veličine srca i funkcije. Trodimenzionalna ehokardiografija je posebno korisna prije hirurških zahvata, jer daje bolji pogled na složenu strukturu mitralnog zaliska iz “perspektive hirurga”. Za otkrivanje moguće disfunkcije mitralnog zaliska koristi se kolor-dopler ehokardiografija. Za pravilnu procjenu stupnja regurgitacije mitralnog zaliska i stenoze, obavezna je pulsna i kontinuirana dopler ehokardiografija. Pregled mitralnog zaliska zahtijeva temeljitu ehokardiografsku istragu s različitim ehokardiografskim modalitetima, uz upotrebu novih ehokardiografskih metoda, kao što je trodimenzionalna ehokardiografija.

Ključne riječi: ehokardiografija, mitralni zalistak, mitralna regurgitacija, mitralna stenoza