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Mitral stenosis: "Persistent valvulopathy"

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Abstract

Mitral stenosis (MR) is essentially of rheumatic origin. AAR remains the predominant cause worldwide, representing a major public health issue in developing countries, while in industrialized countries, the prevalence of MR has decreased thanks to antibiotic prevention. Its clinical presentation has also changed, with an increase in the number of veiled forms, with valvular leaflets that are often rigid and calcified.

Doppler echocardiography provides a precise and comprehensive assessment of MR. It establishes the diagnosis, assesses the severity of the stenosis and its impact on the heart chambers (left atrium and right chambers) and pulmonary circulation . Finally, the feasibility of CMP, which is currently the method of choice when the anatomy is favorable.

In this article, we begin by describing the characteristic anatomical lesions of MR, then move on to methods of ultrasound assessment of its severity, anatomical criteria for accessibility to CMP, evaluation of procedural success and elements of ultrasound monitoring of a patient who has undergone CMP.

Keywords: Mitral stenosis; Doppler echocardiography; planimetry of the mitral valve; Percutaneous commissurotomy (CMP); transoesophageal echocardiography (TEE)

1. Introduction

Mitral stenosis is characterized by a narrowing of the mitral valve orifice, creating an obstruction to blood flow from the left atrium (LA) to the left ventricle (LV) during diastole. It is the most common rheumatic valvular disease and remains a major cause of morbidity and mortality in developing countries.

Diagnosis is initially based on clinical examination, supplemented by echocardiography, particularly with the advent of advanced imaging techniques (2D, 3D, 4D, and transesophageal echocardiography). These modalities allow for an accurate assessment of stenosis severity, its hemodynamic impact, and guide therapeutic management — whether mitral valve replacement (MVR) or percutaneous balloon valvuloplasty — in accordance with the 2021 ESC guidelines.

The prognosis depends on the disease's evolutionary stage, although many cases are revealed by thromboembolic complications.

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2. Anatomical lesions and etiologies

The characteristic anatomical lesions of rheumatic MR include (1) :

- Bi-commissural fusion
- Thickening of the valve leaflets, which in some patients may be calcified
- Remodelling of the sub-valvular apparatus, with varying degrees of cord fusion, shortening and retraction.

Other causes of MR are briefly described below:

- **Degenerative MR**: generally observed in the elderly, it is linked to calcareous envelopment of the base of the two leaflets, while their ends remain flexible and the commissures unfused (2)
- **Post-radiation MR:** lesions combining thickening and valvular rigidity, with the commissures remaining unfused (3)

Table 1 The main causes of mitral stenosis

Type of Mitral Stenosis (MS)	**Rheumatic MS**	**Degenerative MS**	**Post-radiation MS**
Leaflet mobility	Depends on the severity of the disease. Flexible at first, less mobile in advanced stages, especially in free edges.	Restrictive movement. Leaflet tips remain mobile.	Restricted movement at the aorto-mitral junction.
Calcification	Late, affecting leaflets and subvalvular apparatus.	Mitral annular calcification extending from the base to the tips of the leaflets.	Calcification of the anterior leaflet and mitro-aortic trigone.
Commissures	Fused	Open	Open
2D Planimetry	Reference method	Rarely possible	Difficult
3D Planimetry	Useful	Mainly useful in TEE	Useful at the mitral funnel
Pressure Half-Time (PHT)	Relatively reliable	Unreliable	Variable
Proximal Isovelocity Surface Area (PISA)	Reliable	Not validated	Unknown
Gradient	Reliable	Useful	Useful
Continuity equation	Reliable in the absence of aortic or mitral regurgitation	Unreliable, often the only method possible in TTE	Unknown

[MS: Mitral Stenosis TEE:Transesophageal Echocardiography, TTE: Transthoracic Echocardiography , PHT: Pressure Half-Time , PISA: Proximal Isovelocity Surface Area]

- **Congenital MR**, exceptional in adults
- **MR in carcinoid syndrome or drug toxicity** (ergot derivatives)(4).

3. Assessing the severity of MR

Assessment of the severity of mitral stenosis is based on determination of the mitral valve area, the mean transmitral gradient and evaluation of the hemodynamic impact. The area can be assessed by several methods, planimetry being considered the reference method. mitral stenosis is said to be tight when the area is less than 1.5cm^2.each method has its advantages, but also its limitations, and it is important to combine them.

3.1. Planimetry of the mitral orifice

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Planimetry is the only method for anatomically measuring the mitral orifice. The mitral orifice is scanned from apex to base, and the measurement is taken at the apex of the mitral funnel. Planimetry is performed in zoom mode at maximum opening in mesodiastole, including the open commissures.

The difficulties are also related to the patient's echogenicity and the extent of calcifications (5).

- **2D planimetry**: the reference method for assessing mitral orifice surface area (figure 1) , using a zoom-mode approach during maximum opening in meso-diastole(6).
- **3D planimetry**: this method is particularly useful in transesophageal echocardiography (TEE)(figure3). It allows better visualization of abnormalities and thrombosis in the left atrium before CMP or after an embolic event (7). The disadvantage is the semi-invasive nature of the examination, even if it is performed systematically before any CMP.

3.2. Pressure half-time (PHT)

PHT (pressure half-time) is the time corresponding to the decrease in half of the atrioventricular gradient from its maximum value. the area is obtained by the formula 220/PHT. this method has been validated by Hatle et al. on 32 patients. its main advantage is its simplicity. the transmitral flow is collected in continuous Doppler and the half-pressure time is obtained by plotting the slope of the flow. In some patients, the slope is not rectilinear but biphasic, with a rapid proto-diastolic first slope and a steeper meso-diastolic second slope. It is the second slope that should be measured; the rapid slope corresponds to rapid filling after leaflet opening, and depends little on mitral obstruction.

The use of PHT must be particularly cautious in subjects over 60 and in those in AF, as the slope sometimes varies significantly from one cycle to the next. Other limitations of PHT are tachycardia, aortic insufficiency (which shortens PHT) and, to a lesser extent, mitral insufficiency. Because of the acute changes in A-V compliance, the PHT is not valid after CMP. However, a PHT of less than 130ms is highly indicative of a good procedural result, whereas a PHT of 130ms or more is inconclusive (8).

3.3. Equation of continuity

The equation of continuity is based on the conservation of flow at the level of the left ventricular hunting chamber and mitral orifice. Aortic flow is obtained at the level of the hunting chamber (πx diameter of the hunting chamber ^{2}x sub-aortic VTI measured in pulsed Doppler).mitral flow is calculated in a similar way (mitral surface area x mitral VTI measured in continuous Doppler). mitral surface area by continuity equation is relatively easy to obtain, but is invalid in the event of mitral or aortic leakage (9).moreover, as aortic and mitral flow rates are measured on different cycles, this method also fails in atrial fibrillation, especially if cycles are irregular.in this case, five to ten cycles should be averaged.

3.4. PISA (proximal isovelocity surface area):

PISA (proximal isovelocity surface area) is also based on the law of conservation of flow. Blood flow, as it approaches the stenosing orifice, forms isovelocity zones. The main hypothesis of PISA is that these zones of isovelocity are hemispherical at an appropriate distance from the orifice.PISA has been validated in various valvulopathies, including MR.It has few practical limitations, and can be used in cases of irregular rhythm or associated mitral or aortic leak.

It is reputed to be complicated, but can easily be mastered with minimal training and the observance of certain rules:

- Zoom in on the convergence zone
- Move the aliasing line upwards (in the direction of flow) to obtain a speed of between 20-30cm/s.
- Measure the radius of the convergence zone in protodiastole
- Measure the alpha angle formed by the mitral leaflets
- Measure the maximum anterograde mitral velocity in protodiastole

The mitral area (MA) is calculated using the following formula:

$$MA = \frac{2\pi r^2 \times Va \times (\alpha/180)}{\text{Mitral velocity}}$$

3.5. Transmitral gradient

Doppler is the reference method for measuring the mean transmitral gradient. A gradient greater than 10 mmHg is indicative of a tight MR (figure 4) .

This is a less useful parameter, since it depends not only on mitral surface area, but also on heart rate, rhythm, cardiac output and the existence of an associated leak. It could also be influenced by the extent of sub-valvular damage, although this aspect seems less established.

The correlation coefficient between gradient and surface area is of the order of 0.5/0.6. However, it remains an important prognostic factor, independent of mitral surface area.

3.6. Importance of impact

The impact on the cavities (OG and right cavities) and the measurement of systolic pulmonary artery pressure (PAPs) are important elements to consider.

OG volume should be measured in biplane mode (4and 3cav), using the area-length method and vertical length. OG volume greater than 60ml/m^2 indicates significant dilatation, and is associated with high sensitivity and thromboembolic risk. Thus, current recommendations for anticoagulant treatment in the absence of AF atcd or thromboembolic events are a diameter greater than 50mm, but patients with a left atrial volume greater than 60ml/m^2 could benefit from preventive anticoagulant treatment.

A resting PAPs elevation of over 50 mmHg indicates a significant impact and, in the absence of symptoms, even constitutes an indication for CMP or conventional surgery. Similarly, dilatation of the right heart chambers and functional IT are frequently associated.

Table 2 Classification of the severity of mitral stenosis

RM	**Moderate**	**Severe**	**Very Severe**
MV area (cm^2)	> 1.5	1 - 1.5	< 1
Mean gradient (mmHg)	< 5	5 - 10	> 10
PASP (mmHg)	< 30	30 - 50	> 50
PHT (ms)		> 150	> 200
IVS (mm)		< 8	

(**RM** : Rheumatic Mitral stenosis ,**MV area** : Mitral Valve area,**PASP :** Pulmonary Artery Systolic Pressure, **PHT** : Pressure Half-Time ,**IVS** : Interventricular Septum)

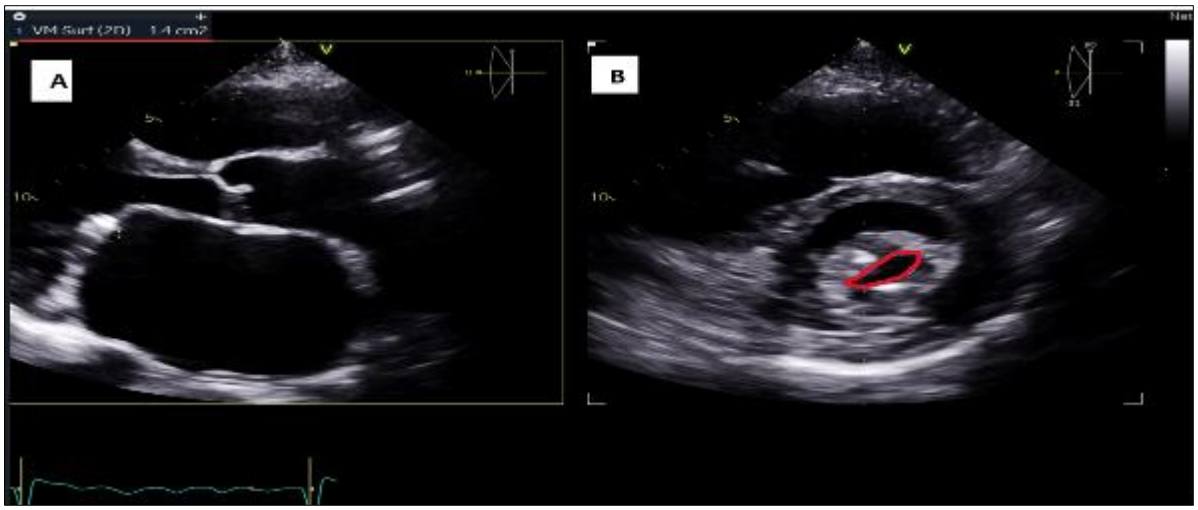

Figure 1 Long-axis (A) and short-axis (B) parasternal incidences in biplane mode for planimetry of the mitral orifice. The measurement is taken in short-axis parasternal incidence using the zoom at the apex of the mitral funnel

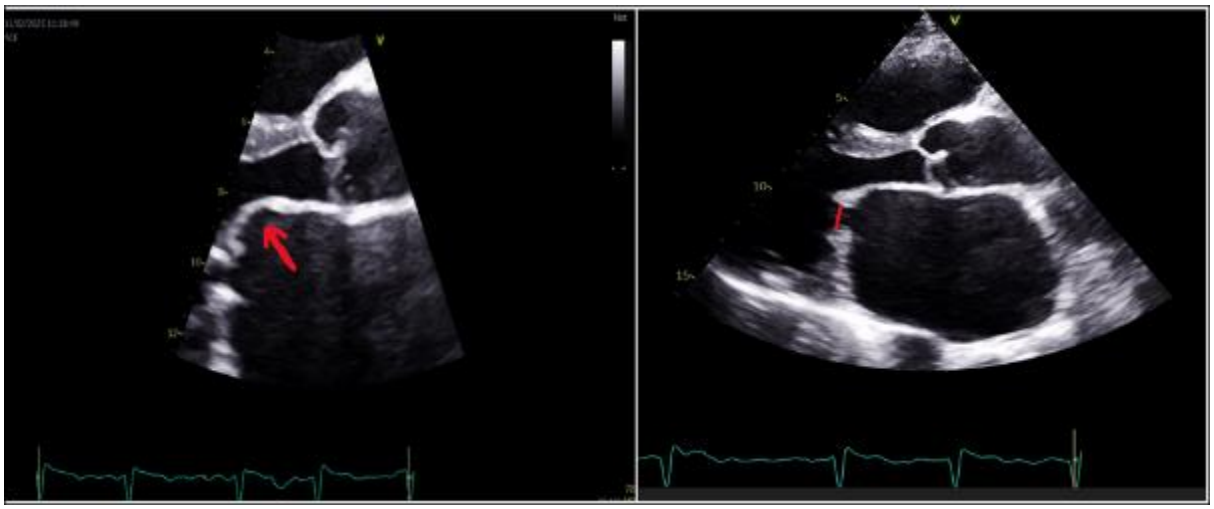

Figure 2 Parasternal long-axis view showing the knee aspect of the large mitral valve and allowing measurement of the inter-valvular distance

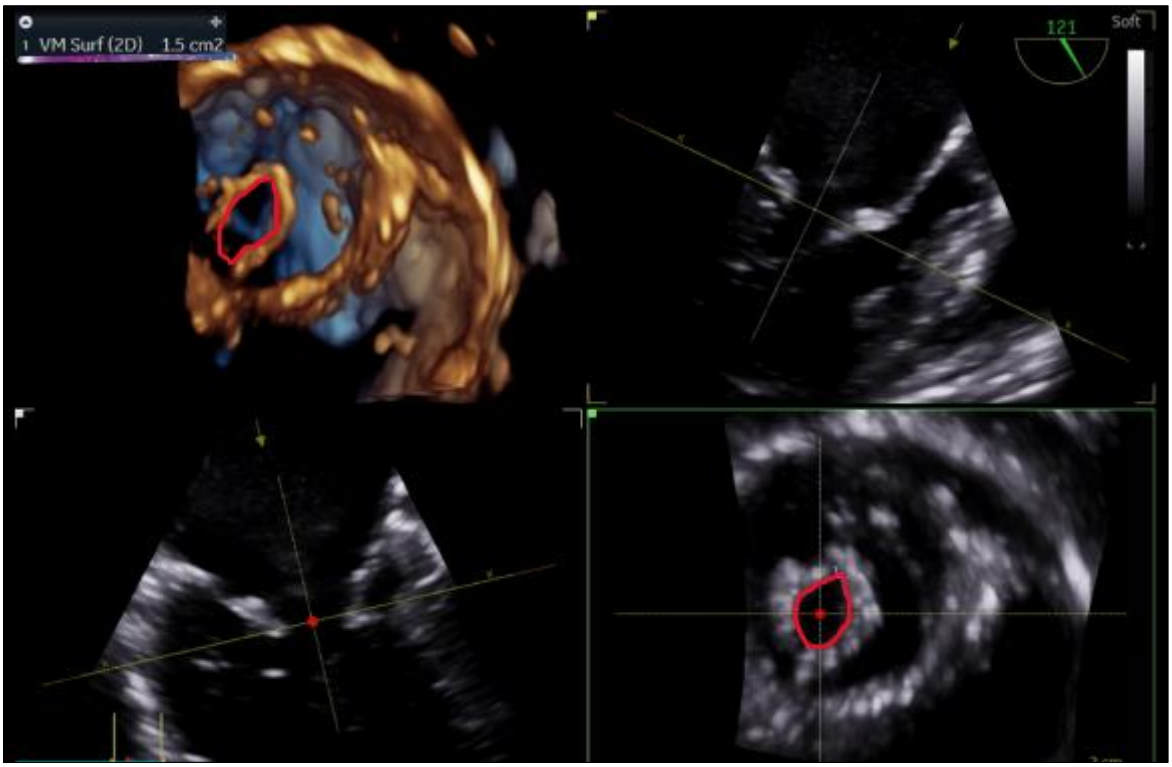

Figure 3 3D planimetry of the mitral valve (SVM=1.5cm^2) using transoesophageal echocardiography (TEE)

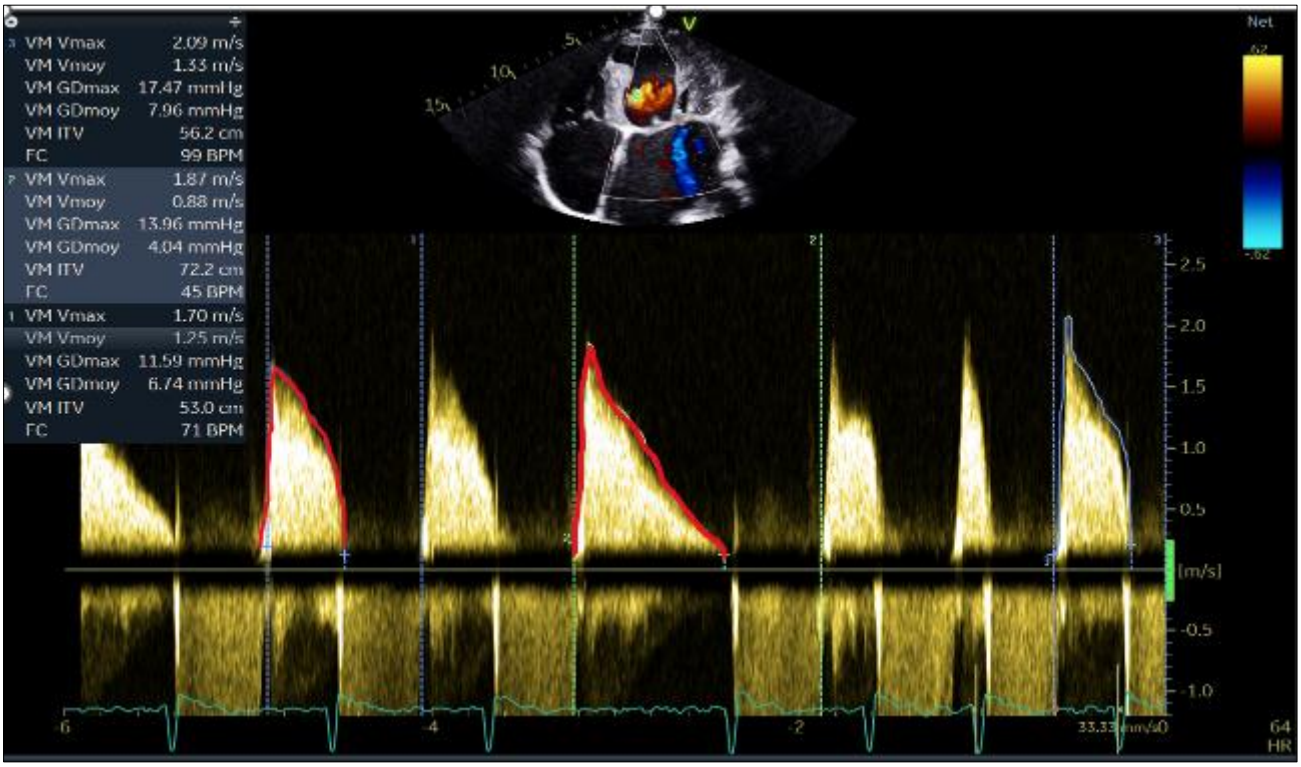

Figure 4 Measuring the mean trans-mitral gradient with continuous Doppler

4. Stress ultrasound

As in other valvulopathies, stress ultrasonography is a very useful objective and dynamic tool for unmasking false asymptomatic patients, and in cases of discrepancy between MR severity and dyspnoea.

It provides an objective, quantitative assessment of patients' functional capacity, unmasking neglected or underestimated exertional dyspnea, or dyspnea that is not felt due to self-limitation of patients' physical activity. Ultrasound also enables gradient and PAPs to be monitored throughout exercise.

The 2021 European guidelines do not specify thresholds for mitral gradient and PAPs during exercise. On the other hand, the 2009 US guidelines suggest CMP intervention for asymptomatic MR in the presence of a gradient greater than 15mmHg and a PAPs greater than 60mmHg during exercise, but these recommendations should be applied with caution due to their low level of evidence.

5. Management

The decision to treat mitral stenosis is a collegial one, taking into account the patient's condition, the degree of valve damage and the presence or absence of other valvulopathies .

Table 3 Contraindications for Percutaneous Mitral Commissurotomy (PMC)

Absence of commissural fusion
Left atrial or left atrial appendage thrombus
Mitral regurgitation ≥ grade 2
Severe or bi-commissural calcifications
Associated valvular disease requiring intervention
Complex coronary artery disease requiring bypass surgery

Percutaneous commissurotomy (PCM) remains the first-line treatment (Grade I-B) for symptomatic tight mitral stenosis, in the absence of other surgical indications (coronary or valvular), contraindications (Table 1) and favourable anatomical criteria.

5.1. Accessibility to percutaneous mitral commissurotomy(PMC)

The decision to proceed with PMC is based on favorable anatomical criteria. The ideal anatomical shape is characterized by a valve with bicommisural fusion, soft leaflets and a mobile subvalvular apparatus with little or no calcification. The Cormier and Wilkins scores are important tools for determining the feasibility of a PMC(10).

Cormier and/or **Wilkins** scores are particularly useful in intermediate forms. A valve is considered favorable when the Cormier score of 1-2 and a Wilkins score of less than 8 (11,12).

Table 4 Cormier score

Class	**Description**
Class 1	Flexible anterior leaflet, minimally altered subvalvular apparatus, thin chordae > 10 mm in length.
Class 2	Flexible, non-calcified anterior leaflet, highly altered subvalvular apparatus, thickened chordae < 10 mm in length.
Class 3	Presence of valvular calcifications (confirmed by fluoroscopy), regardless of the degree of subvalvular alteration.

Table 5 Wilkins score

Valve Mobility	**Subvalvular Apparatus**	**Leaflet Thickening**	**Calcifications**
Highly mobile valve with restriction localized to the free edge	Minimal thickening just below the leaflets	Nearly normal leaflet thickness (< 5 mm)	Small area of bright echoes

Reduced mobility of the mid and basal portions	Thickening of chordae affecting less than one-third of their length	Significant thickening of the leaflet tips	Scattered areas of bright echoes
Moderate limitation of diastolic movements	Thickening of the entire chordae	Significant thickening of the whole leaflet (5–8 mm)	Increased density reaching the mid portion of the leaflets
Severe limitation of diastolic movements	Severe thickening and shortening of the chordae	Severe leaflet thickening (> 8 mm)	Diffuse increased density

Success criteria: appearance of commissural opening on ultrasound during the procedure , area >1.5cm^2 and mitral insufficiency <2/4.

A detailed ultrasound evaluation is crucial to guide curative treatment. However, the presence of unfavorable clinical criteria (elderly patient, history of commissurotomy, NYHA stage IV dyspnea, permanent ACFA, severe PAH) points to a surgical strategy requiring case-by-case discussion in the Heart Team.

Significant rheumatic MR (< 1.5 cm^2): valve surgery by plasty (surgical commissurotomy) or valve replacement is recommended (grade IC), if clinical or anatomical criteria preclude CMP.

Medical treatment may include beta-blockers, diuretics and anticoagulants for patients with atrial fibrillation (AF) or a history of embolic events (13). Management of antibiotic prophylaxis with Extencillin remains essential to prevent subsequent episodes of AAR and MR (14).

5.2. Immediate and remote evaluation of CMP

Ultrasound evaluation of a patient who has undergone CMP should specify mitral valve area, mean transmitral gradient, degree of commissural opening (fused, partially or completely open), existence, degree and mechanism of any mitral leak, PAPs and absence of pericardial complications (15).

5.3. Management in the event of non-cardiac surgery

Non-cardiac surgery can be safely performed in cases of insignificant MR (area >1.5cm^2) and in asymptomatic individuals with significant MR and PAPs below 50mmHg.

In symptomatic patients or those with PAPs above 50mmHg, valve intervention (surgery or percutaneous mitral commissurotomy) is recommended prior to scheduled intermediate- or high-risk non-cardiac surgery (grade I)(16)

5.4. MS and pregnancy

Mitral stenosis is the most poorly tolerated valve disease during pregnancy, because the tachycardia of pregnancy shortens diastole, which increases the gradient for a given degree of stenosis. Unlike other valvulopathies, the majority of patients are asymptomatic before pregnancy. asymptomatic before pregnancy with narrowing will become severely symptomatic during symptomatic during pregnancy (dyspnoea NYHA class III or IV). In addition the onset of signs of heart failure during pregnancy carries a risk of serious hemodynamic serious haemodynamic complications at the time of delivery, leading to a high peripartum mortality rate high peripartum mortality in developing countries.

Pregnancy should be avoided, and intervention should be recommended prior to pregnancy in the presence of MR and valve area <1.5cm^2 (especially if <1cm^2).

CMP should be considered in very symptomatic women (NYHA class III and VI) and/or if the PPs exceeds 50mmHg despite optimal treatment.

CMP should preferably be performed after the 20th week of pregnancy, and in experienced centers. Cesarean delivery is recommended in case of tight MR (17).

5.5. Follow-up and repeat examinations

Asymptomatic people with clinically significant MR should be followed up once a year with a clinical consultation and echocardiography. intervals are wider (2-3years) in moderate MR. follow-up of people after successful CMP is similar to that of asymptomatic people.monitoring should be closer if asymptomatic restenosis occurs.

6. Conclusion

Ultrasound analysis is essential to determine whether the MR is tight and whether the valve anatomy is compatible with CMP. Planimetry, although the reference method, must be complemented by other evaluation techniques, such as PHT and PISA, for a more accurate assessment. CMP remains the technique of choice in patients with severe MR and favorable anatomy, and regular post-procedural monitoring is crucial to assess long-term results.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interests to be disclosed.

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