Review Article

My Approach to PISA EROA in Mitral Regurgitation: A Critical Review

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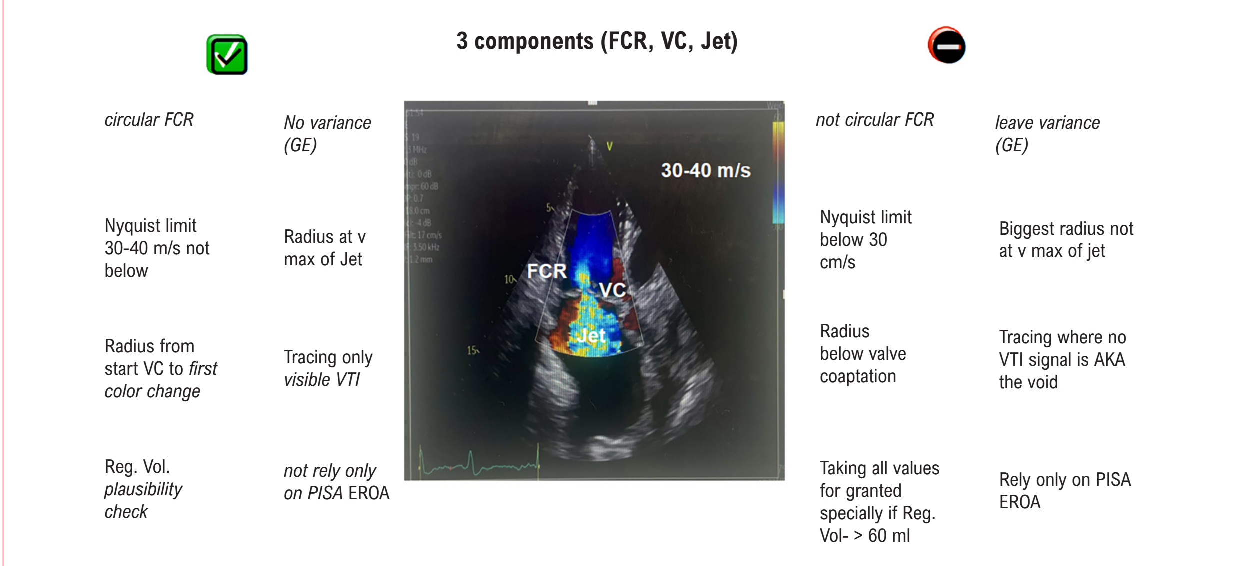
Central Illustration: My Approach to PISA EROA in Mitral Regurgitation: A Critical Review



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VC: vena contracta; FCR: flow convergent region; VTI: velocity time integral

Abstract

Mitral valve regurgitation is the most common valvular heart disease. In order to guide proper therapy, it is paramount to follow and use the guideline-recommended echocardiographic tools. The flow convergent method, which calculates the effective regurgitant orifice area and the regurgitant volume, plays an important role in the diagnostic workup and is widely used by echocardiographers and sonographers. Only by knowing the correct application and avoiding its pitfalls can we guarantee comprehensive and plausible values. This critical review will show in a step-by-step manner all critical moments by applying the Proximal Isovelocity Surface Area (PISA) and Effective Regurgitant Opening Area (EROA) method.

Keywords

Mitral Valve Insufficiency; Risk; Heart Valve Diseases.

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Introduction

Important to stay humble in echocardiography,[1] but confident. The measurement of the effective regurgitant orifice is recommended by the 2021 published ESC/EACTS guidelines for the management of valvular heart disease due to the evidence that routinely measured Effective Regurgitant Opening Area by Proximal Isovelocity Surface Area (EROA by PISA) is associated with all-cause mortality for EROA ≥ 20 cm^2.[2] In clinical practice we encounter different shapes of flow convergence zones based on different underlying mitral valve pathology. Often, the flow convergent region (FCR) is not hemispherical; therefore, the PISA EROA method tends to underestimate the EROA. Furthermore, we need to know several pitfalls when using the flow convergent method.

The PISA EROA method can calculate regurgitant volume according to the continuity principle. The regurgitant flow rate can be calculated by multiplying the hemispheric surface area of the FCR by the velocity that characterizes the hemispheric surface; it was first described by G. Bargiggia et al. in 1991 in a cohort of 52 patients with secondary but also primary mitral regurgitation (MR).[3]

The flow through this isovelocity surface can then be calculated as the area of the surface ($2x \pi r^2$) times the aliasing velocity.

This implies that the PISA EROA or flow convergence method can only be used with hemispherical surfaces. Therefore, it cannot be applied to elliptical, flat or most eccentric jets without a clear hemispherical flow convergence zone.

$2x \pi r^2$ refers to a circular structure and only circular.

The velocity to identify the concentric hemispheric isovelocity surface area was obtained by zero shifting to 38 cm/s.[1]

1st important message here is:

- *Use only hemispherical FCR only (PISA shell = FCR)*
- *Use zero shifting to 36 cm/s (30-40 cm/s), not below Lancelotti et al. recommended Nyquist limit to ∼15–40 cm/s,[4] although all images in the recommendation have been done with Nyquist around 30 cm/s*

At which time frame does the radius have to be measured? The radius must be measured at the moment of v max of the MR velocity time integral (VTI), not at its maximum extension (Figure 1)!

A careful interpretation of measured values of regurgitant volume by the PISA method is pivotal. The amount of systolic back flowing volume in the left atrium cannot exceed the left ventricular total stroke volume (left ventricular end-diastolic volume [LVEDV] – left ventricular end-systolic volume [LVESV] = left ventricular total stroke volume [LVSV]) as there is needed to be left enough forward stroke volume (fSV) leaving the left ventricle via the Left Ventricular outflow tract (forward LVOT SV) to maintain adequate cardiac output above cardiac shock parameter in chronic MR.

2nd important message here is:

- *Measurement of radius at MR VTI Vmax (timing)*
- *Reg. volume by PISA is always in context to LV volumetry*

The correct interpretation of the measured regurgitant volume values by the flow convergent method (PISA EROA) is strictly linked to the volumetric plausibility check using the LV volumes obtained by 2D or 3D Simpson and the fSV obtained with Doppler echocardiography via LVOT.

Both measurements are error-prone.

Correct LV volumetry depends on the exact tracing of the inner endocardial border, excluding the trabecula, with attention to the trace between compacted and compacted myocardium.[5]

Correct measurement of LVOT diameter (LVOTd) is pivotal to obtaining LVOT SV. Another important point is correct VTI tracing with attention to modal velocity. It is helpful to reduce the gain setting and see the aortic valve closing artifact to ensure the correct positioning of the sample volume in LVOT.

It might be helpful to position the pulse wave Doppler sample volume at the level of the aortic valve and withdraw carefully until the first drop of velocity with a clear closing valve artifact without any valve opening click visible.

3rd important message here is:

- *LV endocardial border tracing between compacted and noncompacted myocardium*
- *LVOT VTI tracing with reduced gain (better visualization of modal velocity)*
- *LVOT VTI tracing without aortic valve opening click*

There are two main known methods for putting the PIAS EROA regurgitant volume in context with the LV volumetry. First, the Doppler volumetric method uses the 2D measurement of the mitral valve annulus and the LVOTd with consecutive measurements of the respective inflow VTI using the pulse wave Doppler; the only use of Doppler volumetric method is not recommended as is time-consuming,[3] therefore we recommend the second method, the volumetric method combined with the Doppler echocardiography to calculate LVOT SV.[6]

The evaluation of LV EF via the Simpson rule or 3D is an integrative part of every standardized comprehensive echocardiography. This combination is recommended as part of standardized comprehensive echocardiography, as the measurement of LV function using either the 2D Simpson

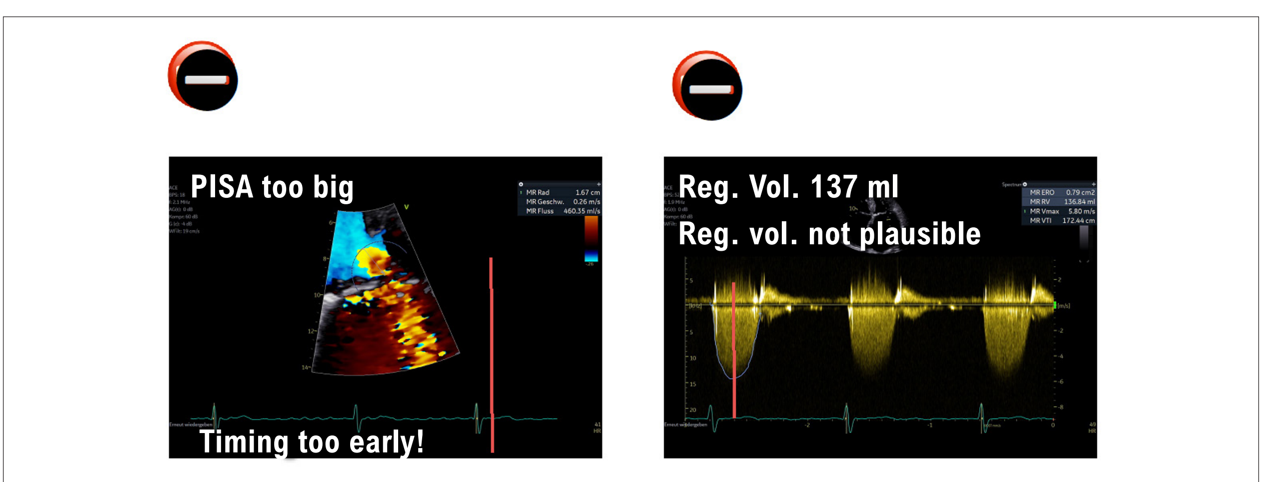

Figure 1 – *Timing of measurement of FCR radius. PISA: Proximal Isovelocity Surface Area.*

method or 3D is requested information of echocardiographic exam. Together with the LV function, we also obtain the end-diastolic and end-systolic volumes and, therefore, the total LV stroke volume (LVEDV – LVESV = total SV). This parameter is important in guideline-directed decision-making in many pathologies as the cut-off value for intervention.

The calculation of the LVOT SV is also an important part of the echocardiographic exam, as information about the effective fSV is required to determine the flow status and is part of the calculation of the aortic valve area.

As we rely on these parameters mentioned above in certain pathologies, we should also be able to use and rely on them in the context of regurgitant lesions to countercheck the PISA EROA regurgitant volume.

How to use the PISA method

- Apply only if all three components of MR are visible (PISA shell, VC, Jet)
- No variance (GE)
- Zoomed mode best in simultan mode (2D and color Doppler)
- Color Doppler FPS 31 (sector: small & high)
- Best Nyquist 30-40 cm/s (not below); Nyquist limit to ~15–40 cm/s (4) seems too low!
- Vena contracta at Nyquist 50-60 cm/s
- Not the biggest radius, but at the moment of v max of MR VTI
- Radius from first color chance to beginning of VC (usually at the level of the valve tips or shortly below) (5)

VTI tracing only of a visible part does not extrapolate (systolic timing) (Figure 3)

VTI tracing with aliasing above baseline cannot be used (Figure 3)

Always double-cross-check calculated reg. volume from PISA EROA

- Always look at LV and LVOT stroke volume (mathematics is not an opinion) (Figure 4)

PISA Reg. Vol. + LVOT SV = LV stroke volume

4th important message here is:

- *Always without variance (GE)*
- *Radius measurement not below Vena contracta*
- *Never the biggest radius to measure, but at the correct timing*

Due to different phenotypes in MR, it is difficult to determine the correct depiction of the beginning of the isovelocity flow convergence for the correct radius.

In atrial secondary MR (aSMR), the leaflets are distanced due to mitral ring enlargement; in ventricular secondary MR (vSMR), due to asymmetrical or symmetrical tethering, the leaflets are configured as a funnel.

In aSMR, it seems to be easier to detect the correct beginning of the isovelocity flow convergence. In contrast, in vSMR, it is more difficult to detect the correct beginning of the vena contracta as a starting point for the radius.

Uretzky et al.[7] found that only 52% of patients with definitely severe MR following the ASE algorithm by echocardiography had severe MR by cardiac magnetic resonance (CMR).

The notion that "Echocardiography overestimates MR" supports the rationale for using CMR for exact quantification.

It is widely accepted that CMR will almost always downgrade MR severity.

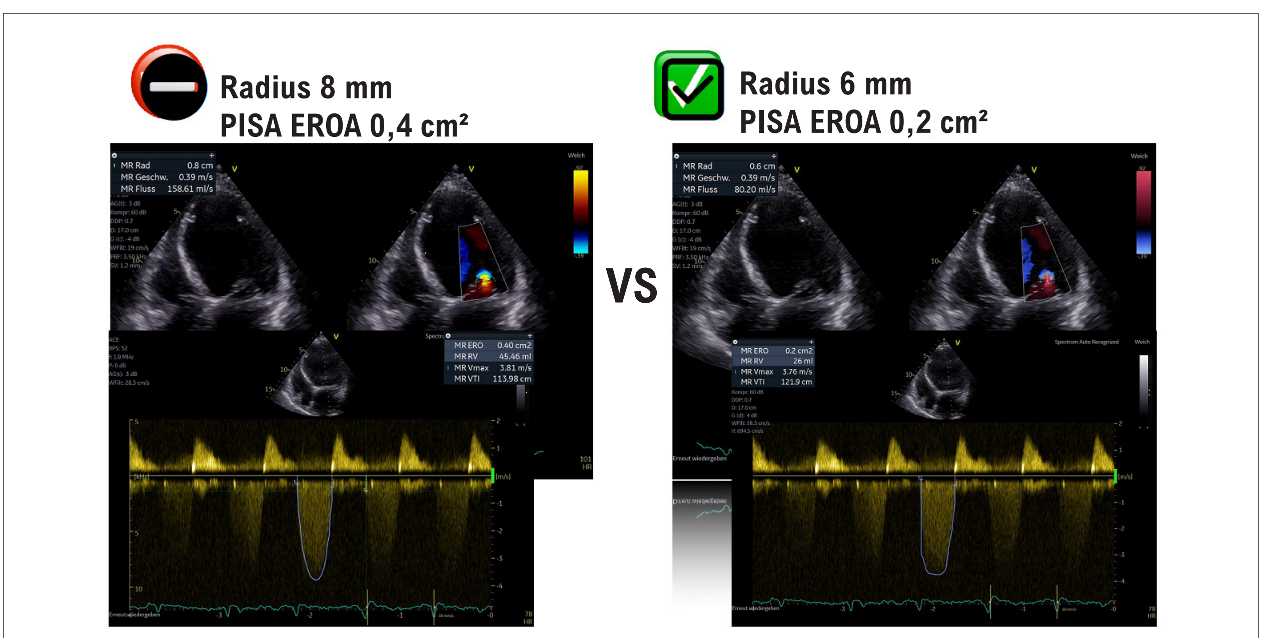

Figure 2 – *Measurement of radius and its influence on EROA and regurgitant volume. PISA: proximal isovelocity surface area; EROA: effective area of regurgitant opening*

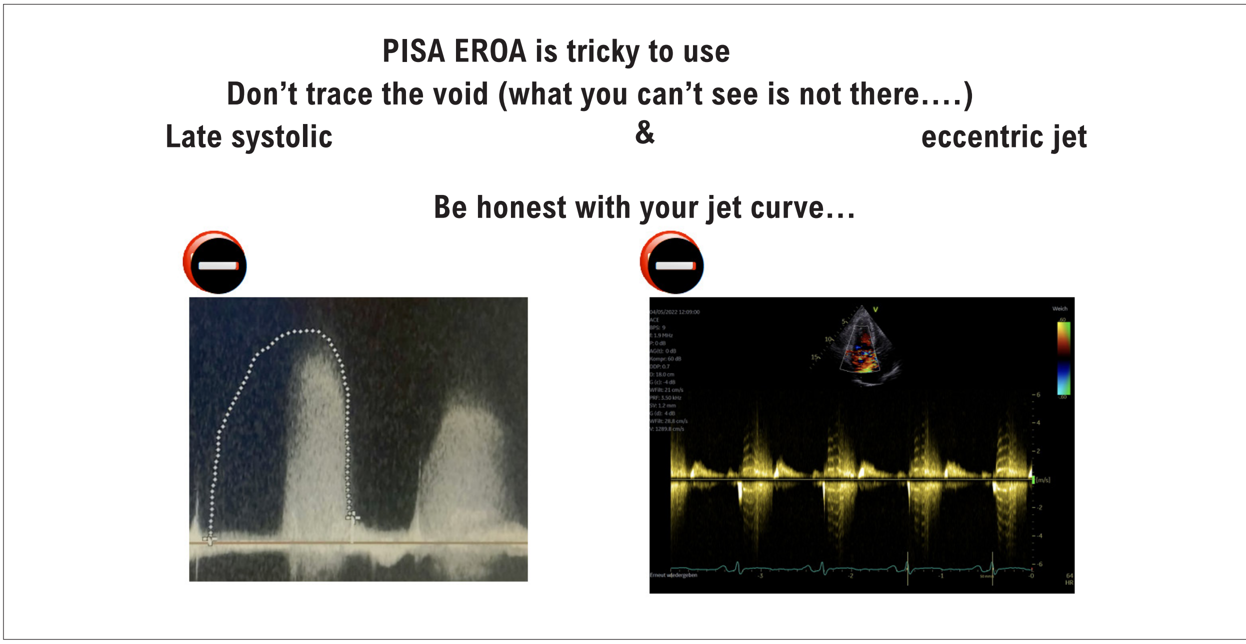

Figure 3 – *Correct tracing of MR VTI. PISA: Proximal Isovelocity Surface Area; EROA: Effective Regurgitant Opening Area.*

However, it should be noted that echocardiography as a method does not overestimate MR; the issue lies with the echo tool used. The flow convergence method has many pitfalls and needs to be integrated with the LV volumes and the LVOT fSV to demonstrate adequate cardiac output.

In chronic MR, we often calculate values of cardiac output and cardiac index below 2.2 liter/min/m², which defines cardiogenic shock. A possible explanation could be the consecutive adaptive optimized oxygen extraction to maintain adequate oxygen supply in chronic reduced fSV due to chronic MR.

PISA EROA should never be used as a standalone method to grade the severity of chronic MR despite the focus on the PISA EROA method in the current guidelines and its adaption in clinical use when it comes to quantifying the severity of chronic MR in decision making.

We need to cross check the obtained measurements with the volumetric method.

Furthermore, we need to evaluate all consecutive changes due to chronic regurgitation.

Chronic MR results in remodeling of the left ventricle and the left atrium and hemodynamic changes. These changes are well described in the 2021 ESC/EACTS guidelines, which define the severity and moment of valve intervention.[8,9]

Therefore, these parameters must be integrated within the comprehensive echo report to underline the severity grade of chronic MR.

LV Dilatation	LVEDS ≥ 40 mm
LV EF	≤ 60%
LA Dilatation	Left atrial volume index ≥ 60 ml/m²
E- Wave inflow	E wave > 1,2 m/s
Dimensionless velocity index	MV VTI/LVOT VTI > 1,4
Systolic pulmonary artery pressure	> 50 mmHg at rest
Vena contracta	≥7 (≥8 mm for biplane)
Lung vein inflow	blunted or reversal

5th important message here is:

- *Chronic MR needs a multiparametric approach*
- *Remodeling is seen and must be reported*
- *Make your exam plausible*
- *Note reduced CI in chronic MR*

Clinical decision-making in chronic MR regarding intervention, surgical or interventional, must be based on standardized comprehensive multiparametric echocardiography as a first-line diagnostic tool.

Therefore, we advocate reporting not only PISA EROA but all parameters showing the clinical adaption of the heart in terms of structural changes.

All measured or calculated parameters must be as plausible as possible; in clinical echocardiography, we can accept an error of 10% in our parameters.

Clinical decision-making in chronic MR is based on the 2021 ESC/EACTS Guidelines for the management of valvular heart disease.[7] The severity grading of MR follows, therefore, the recommendations for the echocardiographic assessment of native valvular regurgitation published by European Association of Cardiovascular Imaging in 2013.[2]

Considering the clinical symptoms of the patients and the new development of atrial fibrillation is of paramount importance in evaluating and quantifying the severity of chronic MR.

Recurrence of cardiac decompensation due to severe MR with or without atrial fibrillation should be evaluated carefully as well in the decision-making process for intervention if MR is only moderate at the moment of echocardiographic examination. In this context, exercise echocardiography can be helpful in unmasking severe MR. Recently published data suggest that handgrip stress during echocardiography can be helpful[9] in identifying severe MR as the driving force to symptoms.

It is pivotal to consider medical therapy that focuses on optimal guideline-directed medical therapy (GDMT) and the hemodynamic state at the moment of the echocardiographic exam (blood pressure as a maker of afterload, heart rate, and heart rhythm).

Conclusion

- *Use hemispherical convergent zone only (PISA shell = flow convergence zone)*
- *Use zero shifting to 36 cm/s (30-40 cm/s) better not below Lancelotti et al. recommended Nyquist limit to ~15–40 cm/s,[4] although all images in the recommendation have been done with Nyquist around 30 cm/s*
- *Measurement of radius at MR VTI v max (timing)*
- *Reg. Volume by PISA is always in context to LV volumetry*
- *LV endocardial border tracing between compacted and noncompacted myocardium*
- *LVOT VTI tracing with reduced gain (better visualization of modal velocity)*
- *LVOT VTI tracing without aortic valve opening click*
- *Always without variance (GE)*
- *Radius measurement not below Vena contracta*
- *Never the biggest radius to measure but at the correct timing*
- *Chronic MR needs a multiparametric approach*
- *Remodeling is seen and must be reported*
- *Make your exam plausible*
- *Note reduced CI in chronic MR*

Author Contributions

Conception and design of the research, acquisition of data, analysis and interpretation of the data, writing of the manuscript and critical revision of the manuscript for intellectual content: Merke N.

Potential Conflict of Interest

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Study Association

This study is not associated with any thesis or dissertation work.

Ethics Approval and Consent to Participate

This article does not contain any studies with human participants or animals performed by any of the authors.

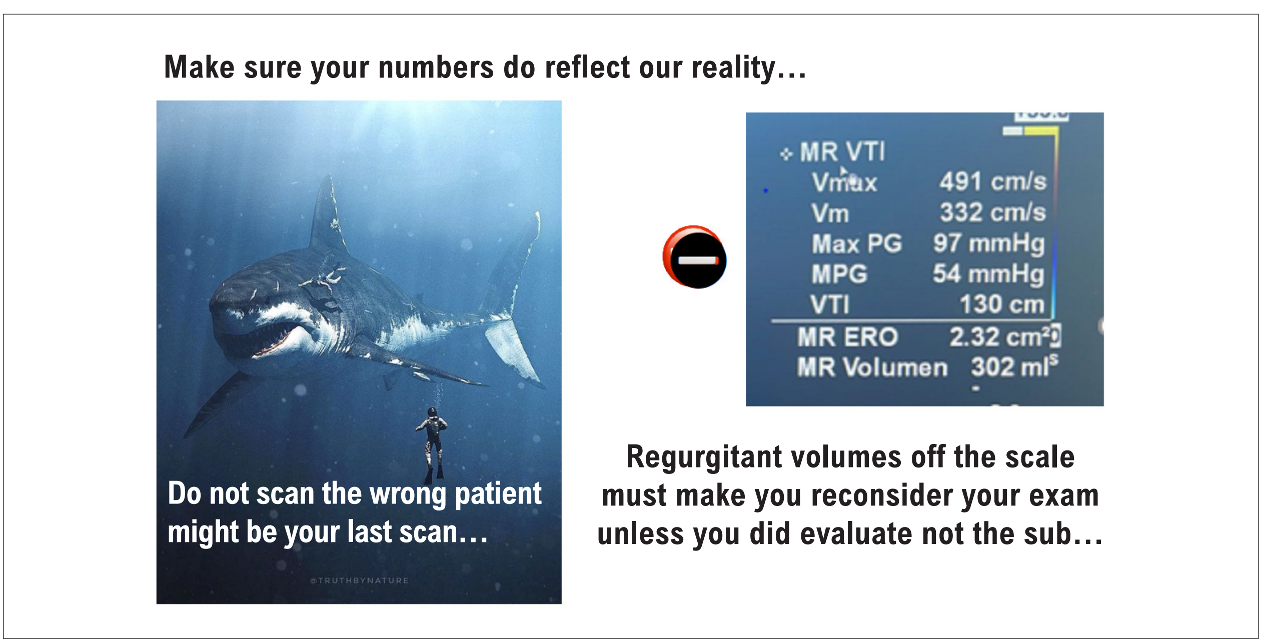

Figure 4 – *Value plausibility. MR: mitral regurgitation; VTI: Velocity Time Integral; MPG: mean pressure gradient; ERO: effective regurgitant orififice; PG: pressure gradient.*

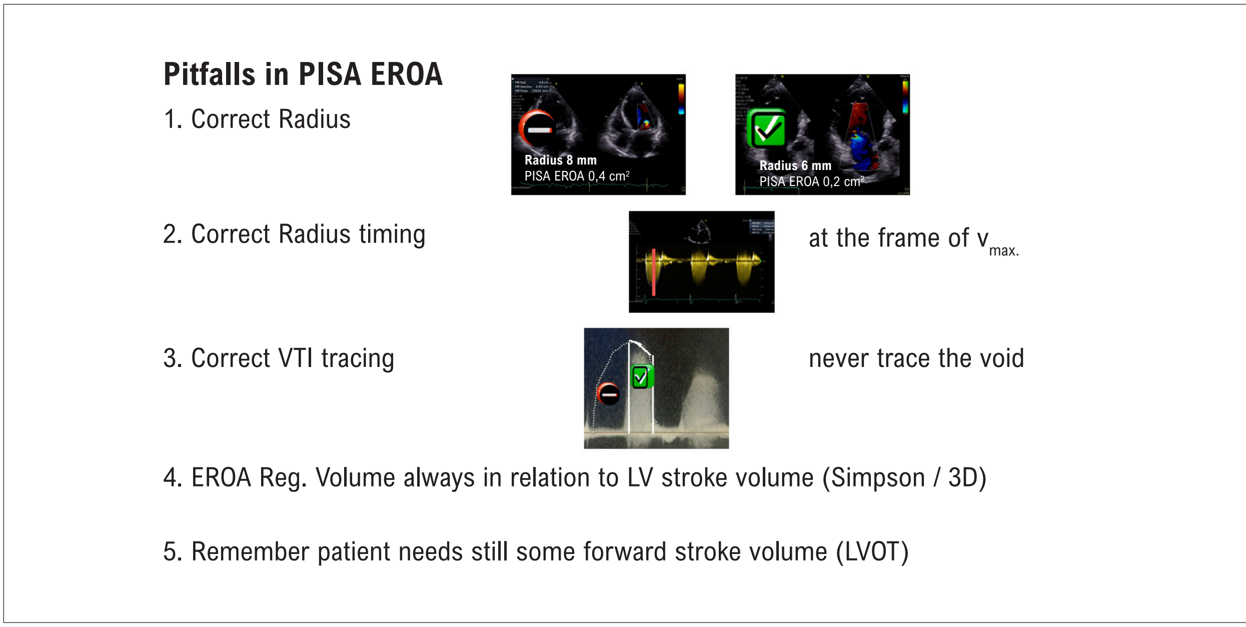

Figura 5 – *Summary. PISA: Proximal Isovelocity Surface Area; EROA: Effective Regurgitant Opening Area; LV: left ventricle; VTI: Velocity Time Integral; LVOT: left ventricular outflow tract.*

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