Challenges in the Assessment of Aortic Regurgitation

Eustachio Agricola, MD

Head of Cardiovascular Imaging Unit

Cardio-Thoracic-Vascular Department

San Raffaele Hospital, IRCCS, Milan

Aortic regurgitation assesment objectives

- ✓ MECHANISM
- ✓ QUANTIFICATION
- ✓ HAEMODYNAMIC CONSEQUENCES

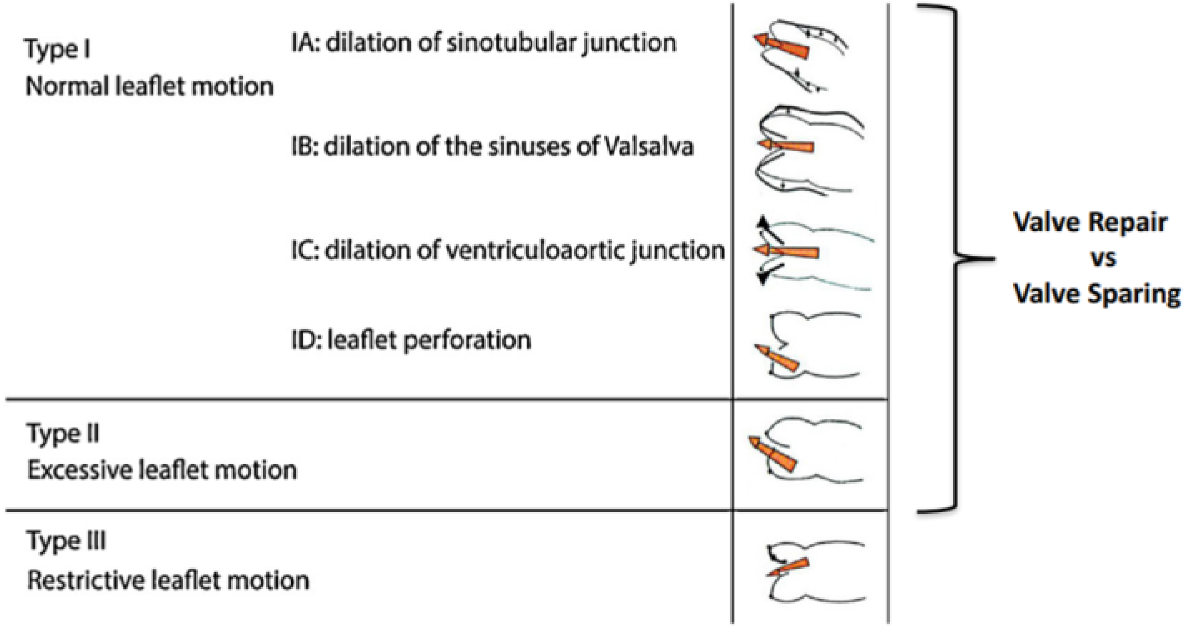
Aortic regurgitation assesment objectives

Table 6 Anatomical and functional classification of AR lesions

Dysfunction	Imaging findings
Type I: normal leaflet motion	• Ia: Sinotubular junction and ascending aorta dilatation • Ib: Sinuses of Valsalva and sinotubular junction dilatation • Ic: Annulus dilatation • Id: Cusp perforation or cusp fenestration without a primary functional aortic annular lesion
Type IIa: excessive leaflet motion due to cusp prolapse with eccentric AR jet	
(1) Cusp flail	(1) Complete eversion of a cusp into the LVOT in long-axis views
(2) Partial cusp prolapse	(2) Distal part of a cusp prolapsing into the LVOT (clear bending of the cusp body on long-axis views and presence of a small circular structure near the cusp free edge on short-axis views)
(3) Whole cusp prolapse	(3) Free edge of a cusp overriding the plane of aortic annulus with billowing of the entire cusp body into the LVOT (presence of a large circular or oval structure immediately beneath the valve on short-axis views)
Type IIb: free edge fenestration with eccentric AR jet	Presence of an eccentric AoR jet without definite evidence of cusp prolapse
Type III: restrictive leaflet motion due to poor cusps quality or quantity	• Thickened and rigid valves with reduced motion • Large calcification deposits/extensive calcifications of all cusps interfering with cusp motion

The degree of calcification of the aortic valve is scored by 2D echocardiography as follows:

- Grade1: no calcification
- Grade 2: isolated small calcification spots
- Grade 3: bigger calcification spots interfering with cusp motion
- Grade 4: extensive calcifications of all cusps with restricted cusp motion
- The degree of calcification can also be quantitated by CT.



Lancellotti et al. ESC/EACVI Position Paper, EHJ CVI 2022

(2) QUANTIFICATION OF AORTIC REGURGITATION

Table 7 Grading the severity of AR

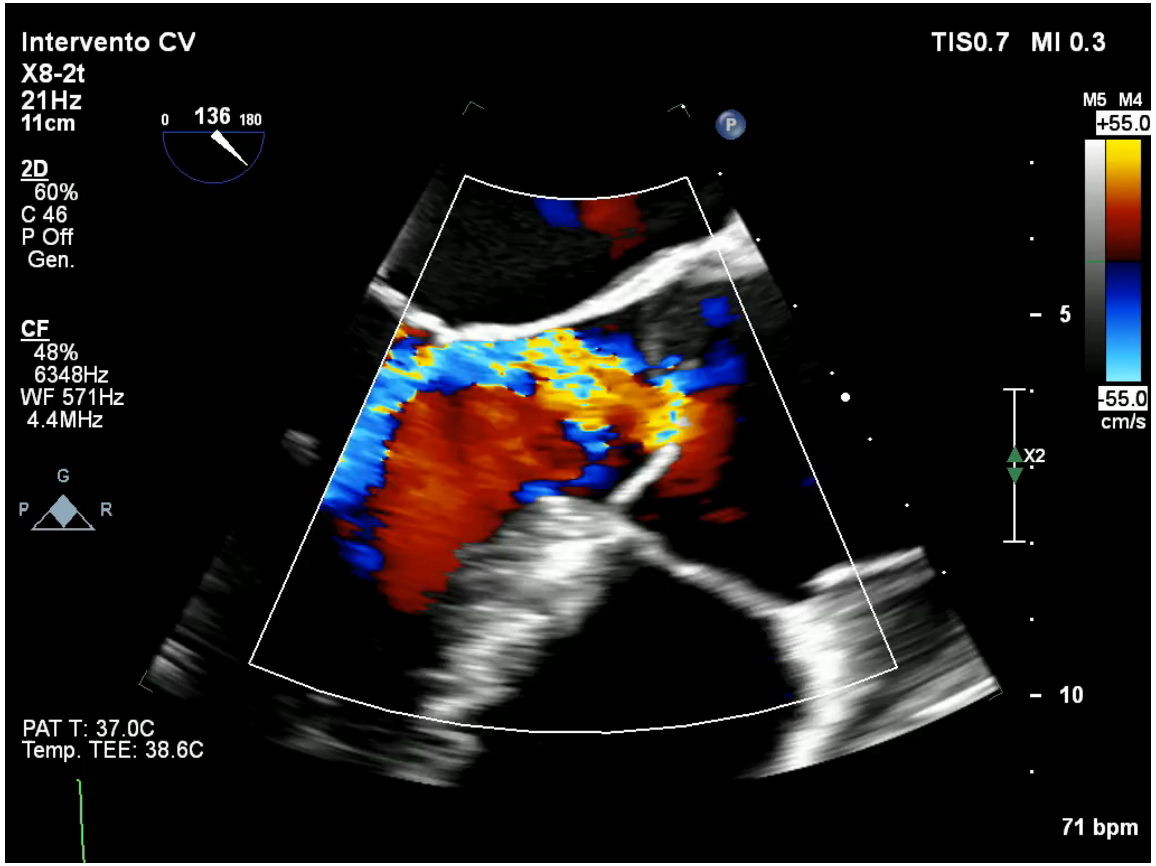
AR severity classes[a]	Mild	Moderate		Severe
AR severity sub-classes[a]	**Mild (Grade 1 or 1+)**	**Mild-to-moderate[a] (Grade 2 or 2+)**	**Moderate-to-severe[a] (Grade 3 or 3+)**	**Severe (Grade 4 or 4+)**
Qualitative parameters				
Aortic valve morphology	Normal/abnormal	Normal/abnormal	Abnormal/prolapse/moderate coaptation defect	Abnormal/**flail/large coaptation defect**
Colour flow AR jet width[b]	Small in central jets	Intermediate	**Large in central jet,** variable in eccentric jets	**Large in central jet,** variable in eccentric jets
Color flow convergence	None or very small	Intermediate	Intermediate	Large
CW signal of AR jet	Incomplete/faint	Dense	Dense	Dense
Diastolic flow reversal in descending aorta[c]	Brief, proto-diastolic flow reversal	Intermediate	Holodiastolic flow reversal (end-diastolic velocity 10 to <20 cm/s)	**Holodiastolic flow reversal** (end-diastolic velocity ≥ 20 cm/s)
Diastolic flow reversal in abdominal aorta[c]	Absent	Absent	Present	Present
Semi-quantitative parameters				
VC width (mm)	<3	3–6	3–6	**>6**
Jet width/LVOT diameter (%)	<25	25–45	46–64	≥**65**
Jet CSA/LVOT CSA (%)	<5	5–20	21–59	≥**60**
Pressure half-time (ms)[c,d]	>500	Intermediate, 500 to 200	Intermediate, 500 to 200	**<200**
Quantitative parameters				
EROA (mm^2)	<10	10–19	20–29	≥30
R Vol (mL)	<30	30–44	45–59	≥60
RF (%)	<30	30–39	40–49	≥50
CMR parameters				
RF (%)	<30	30–39	40–49	≥ 50
Structural parameters				
LV size[e]	Usually normal	Normal or dilated	Usually dilated	Usually dilated

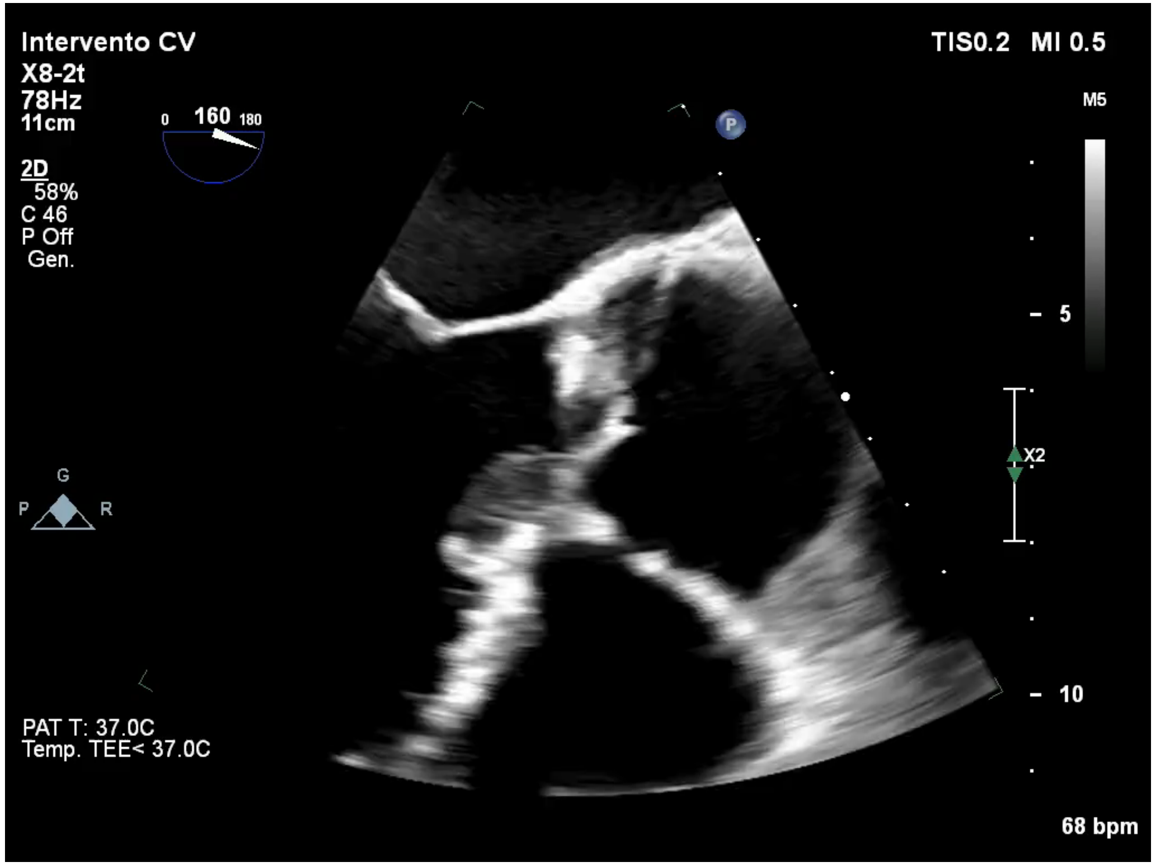
Lancellotti et al. ESC/EACVI Position Paper, EHJ CVI 2022

CASE #1

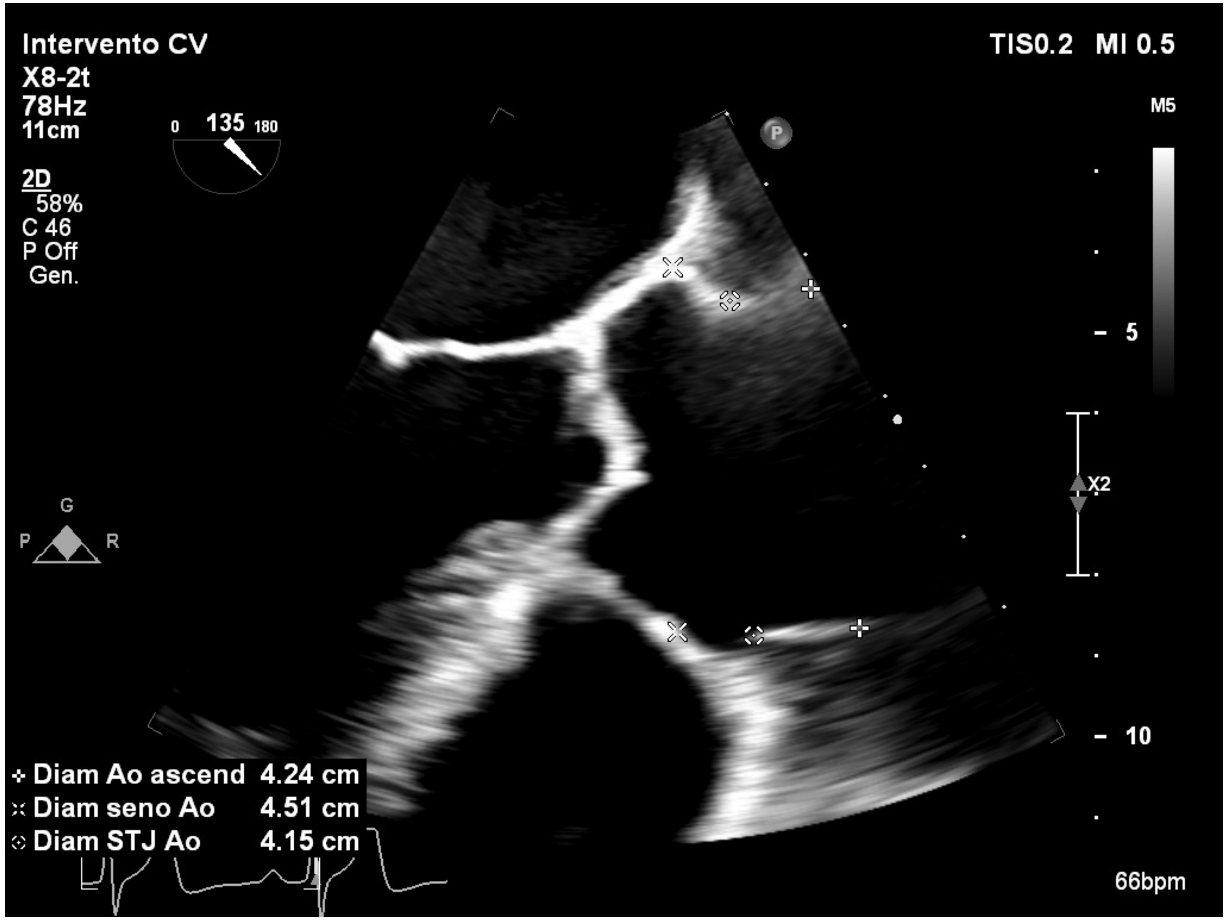
- T. F. (M, 58 yo)
- CVRF: uncontrolled arterial hypertesion.
- Past medical hystory: no significant comorbidities.
- Exertional dyspnoea since 3 months.

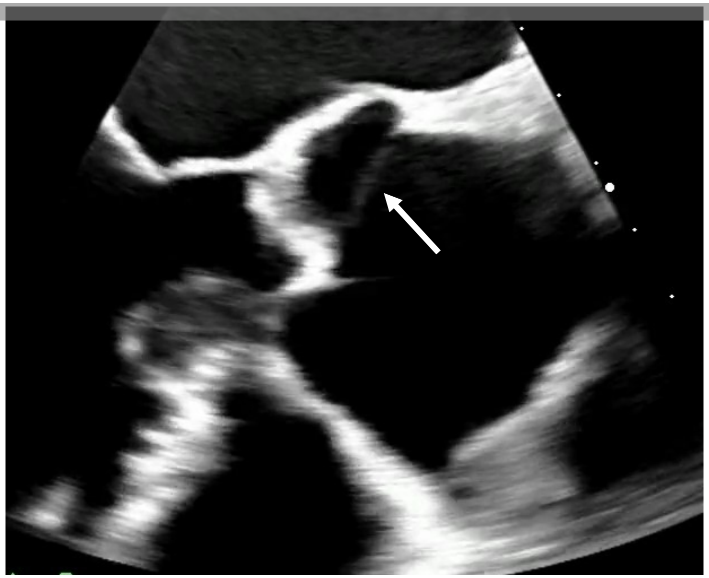
TRANSOESOPHAGEAL ECHOCARDIOGRAPHY





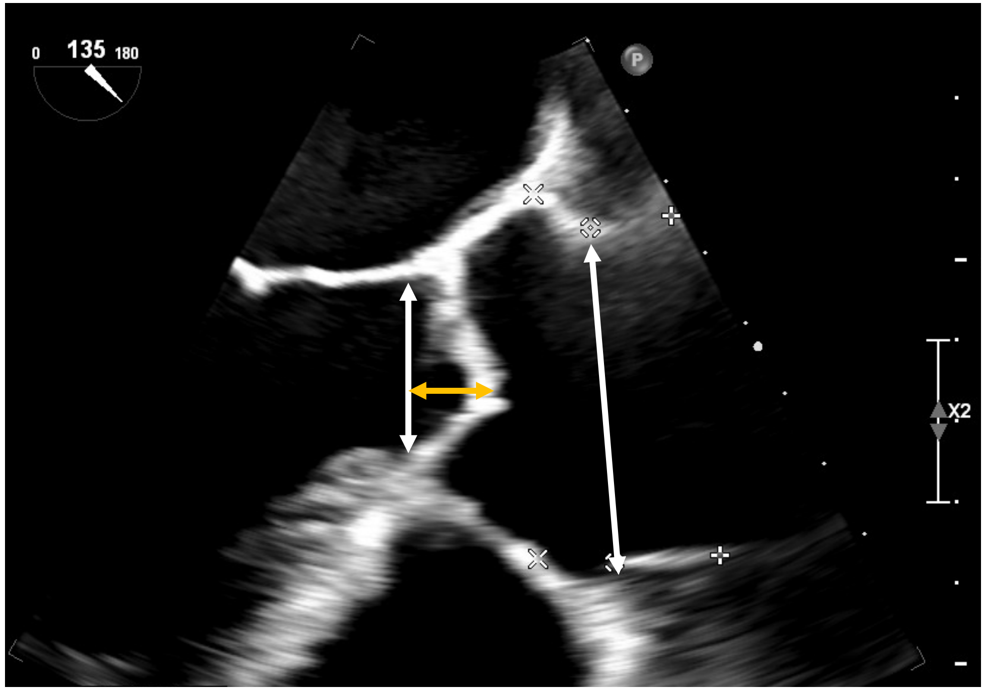
MECHANISM: type I AR with presence of aortic valve chordae tendineae





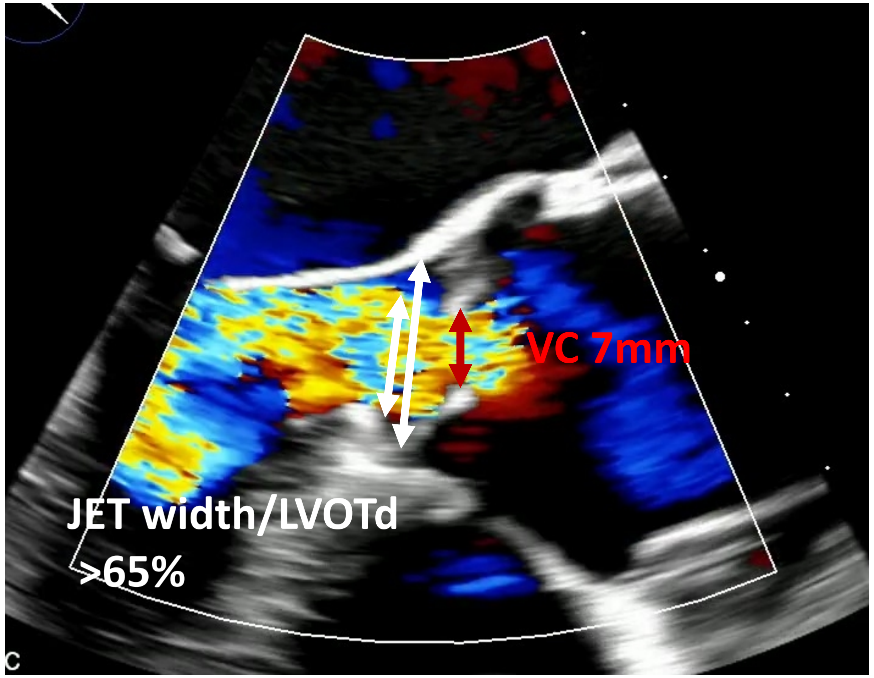
MECHANISM: aortic valve chordae tendineae

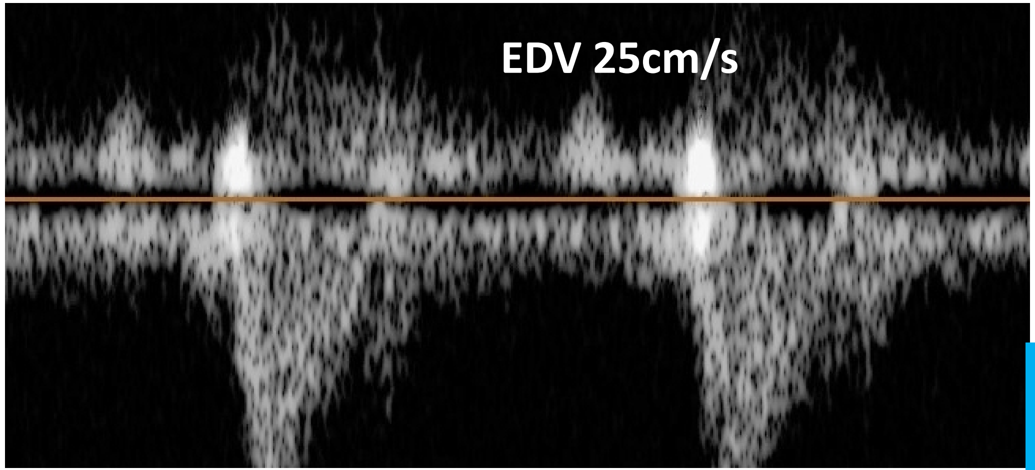
- Type I aortic valve regurgitation and cusp tethering due to aortic chordae («fenestrations») that contribute to the mechanism of functional regurgitation.
- Aortic valve chordae tendineae are **congenital remnants of cardiac development**, connecting aortic valve cusps to the wall of the ascending aorta, potentially causing aortic regurgitation especially in the presence of a dilated ascending aorta.



Indexes of functional AR:
- STJ/Annulus ratio >1,6 (white arrows)
- eH > 11mm (yellow arrow)

QUANTIFICATION AND GRADING





Key point: When feasible, the measurement of the VC width is very useful to quantify AR. Intermediate VC values (3–6 mm) need confirmation by a more quantitative method, when feasible. The VC can often be obtained even in eccentric jets. In case of multiple jets, the respective values of VC width are not additive. The assessment of the cross-sectional area of VC by 3D echo can be helpful to better delineate the regurgitant orifice morphology and quantitate AR severity.

Key point: The colour flow area of the regurgitant jet, as a single parameter, is not appropriate to quantify the severity of AR. The colour jet width and its ratio to the LVOT diameter may be used to semi-quantitate AR severity. A more quantitative approach is required when more than a small central AR jet is observed.

LVEDVi 80ml/m2

Key point: The measurement of the diastolic flow reversal in the descending and abdominal aorta must systemically be performed, when assessable. It should be considered as the strongest additional parameter for evaluating the severity of AR.

Table 7 Grading the severity of AR

AR severity classes[a]	**Severe**
AR severity sub-classes[a]	**Severe (Grade 4 or 4+)**
Qualitative parameters	
Aortic valve morphology	Abnormal/**flail/large coaptation defect**
Colour flow AR jet width[b]	**Large in central jet,** variable in eccentric jets
Color flow convergence	Large
CW signal of AR jet	Dense
Diastolic flow reversal in descending aorta[c]	**Holodiastolic flow reversal** (end-diastolic velocity ≥ 20 cm/s)
Diastolic flow reversal in abdominal aorta[c]	Present
Semi-quantitative parameters	
VC width (mm)	**>6**
Jet width/LVOT diameter (%)	**≥65**
Jet CSA/LVOT CSA (%)	**≥60**
Pressure half-time (ms)[c,d]	**<200**
Quantitative parameters	
EROA (mm^2)	≥30
R Vol (mL)	≥60
RF (%)	≥50
CMR parameters	
RF (%)	≥ 50
Structural parameters	
LV size[e]	Usually dilated

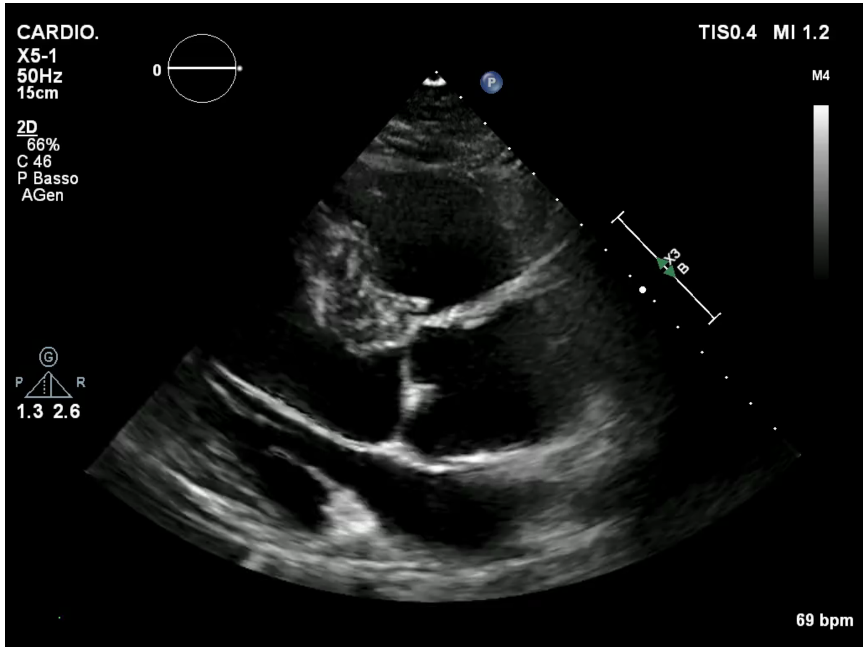
4 consistent data for <u>severe AR</u> according to multiparametric approach

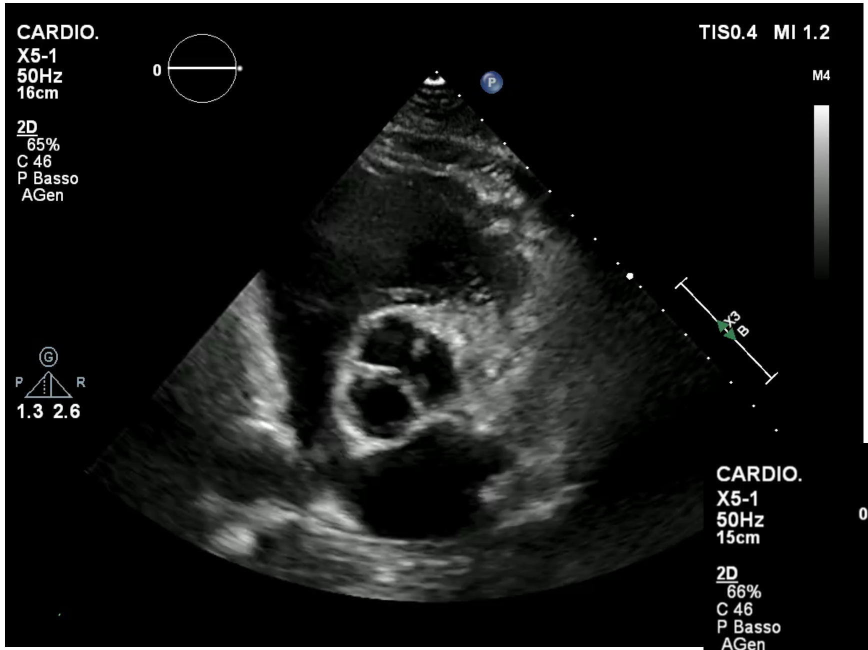
Lancellotti et al. ESC/EACVI Position Paper, EHJ CVI 2022

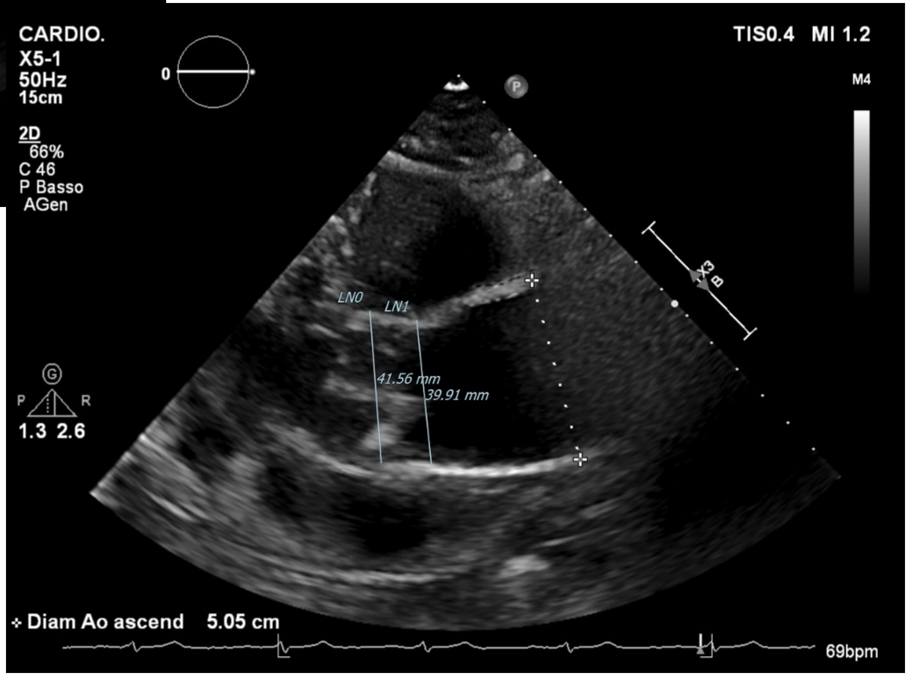
CASE #2

- M. S. (M, 42 yo)
- CVRF: none.
- Past medical hystory: none
- Exertional dyspnoea since 1 year.

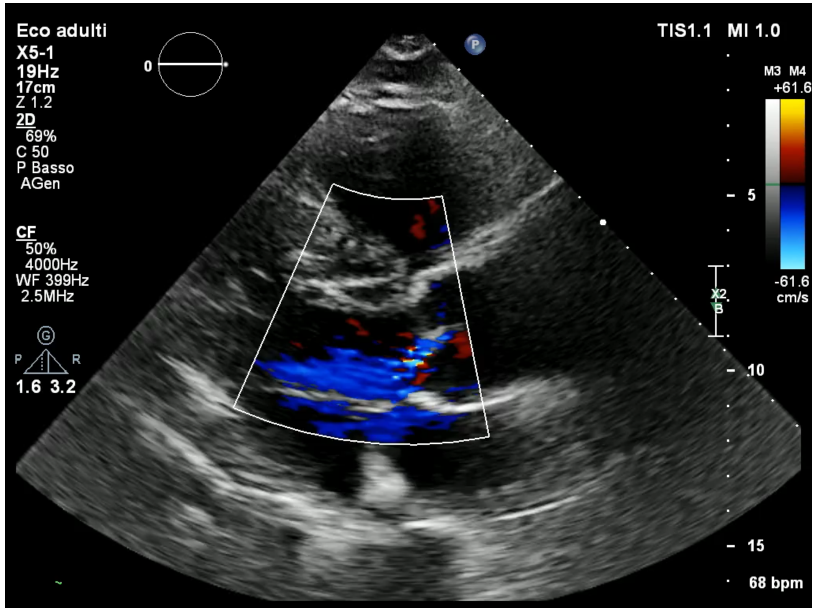
Transthoracic echocardiography – bicuspid AV

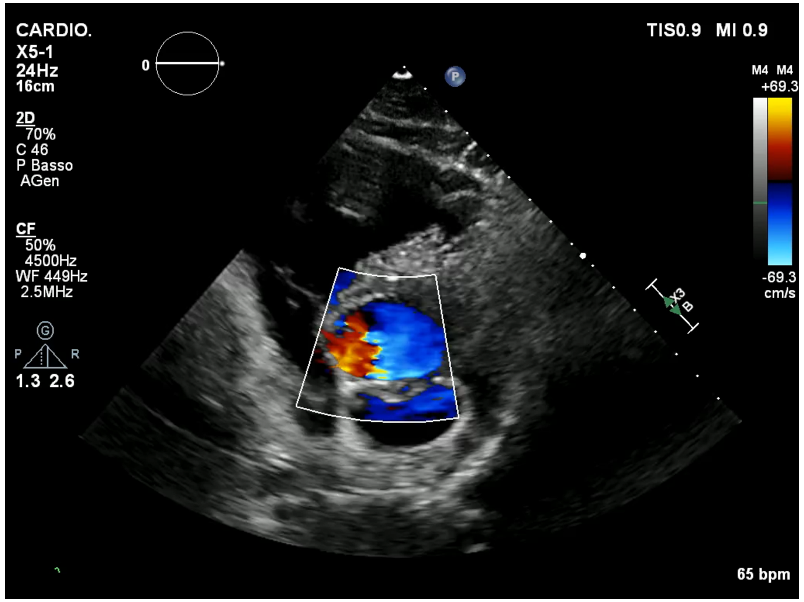


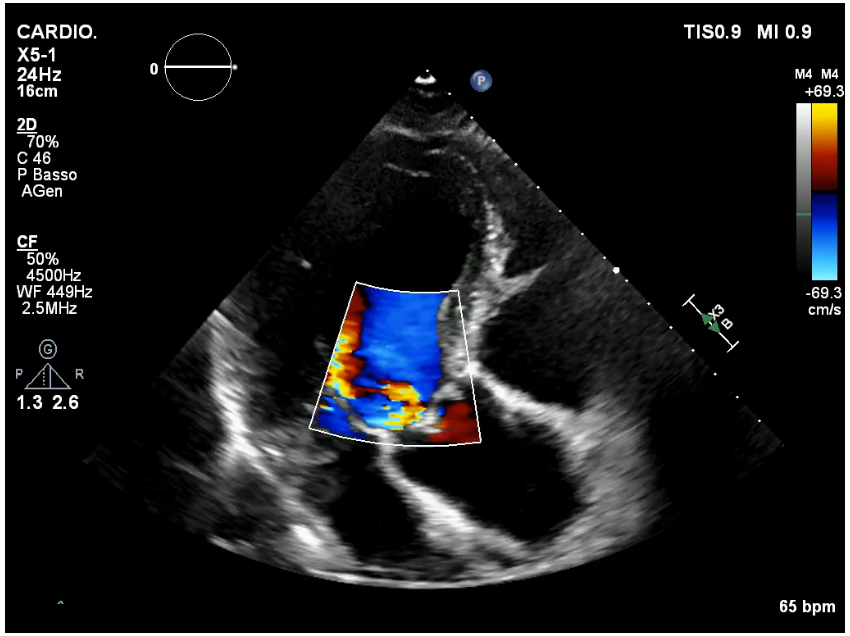


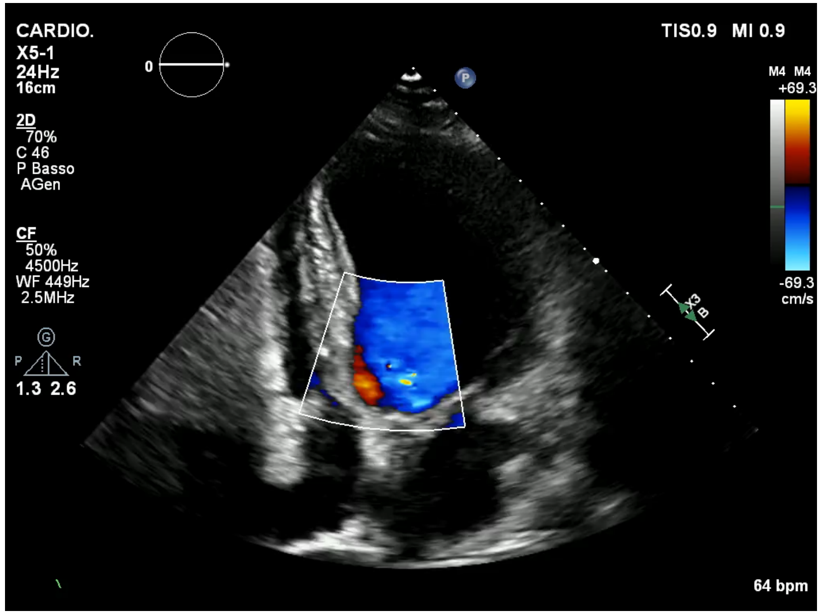


Transthoracic echocardiography – bicuspid AV









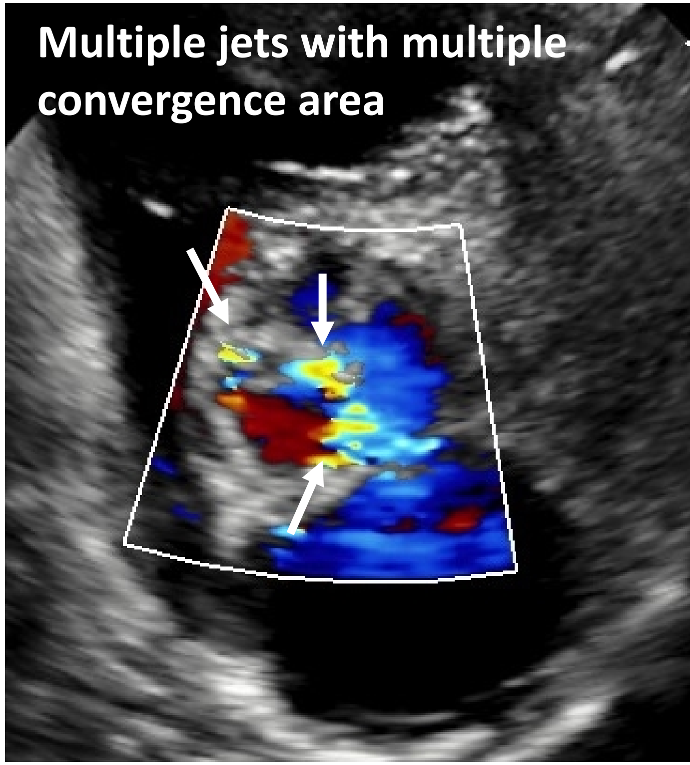
✓ Quantification problems: multiple and commissural jets

✓ Mechamism

Type III ?

"Classical" semiquantitative and quantitative parameters are less reliable indicators of severity:

- **Jet width/LVOT diameter** → underestimation of the severity due to multiple jets
- **Area of jet in Short axis** → underestimation or overestimation depending on the transverse alignment
- **CW jet recording** → may be difficult and often "faint"
- **Vena Contracta width**→ not useful. In case of multiple jets, the respective values of VC width are not additive.
- **EROA-PISA** → not useful. No wide convergence is often visible in multiple jets



Quantification problems: multiple and commissural jets

PROBLEM SOLVING #1: HAEMODYNAMIC IMPACT

- **LV size and function**→ suspect severe AR in pts with LV dilatation and/or dysfunction in the absence of other causes
- **Flow reversal in aorta** → specific for severe AR but less sensitive

PROBLEM SOLVING #2: VALVE MORPHOLOGY

- In case of a remodelled valve (bicuspid, fibrotic cusps, prolapse etc..) always suspect significant AR in case of multiple jets.

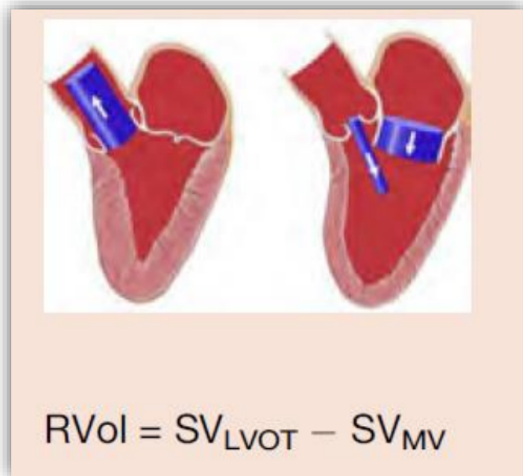
PROBLEM SOLVING #3: VOLUMETRIC QUANTITATIVE APPROACH

- Regurgitant volume and regurgitant fraction using 2D and 3D TTE

PROBLEM SOLVING #4: transesophageal echocardiography and/or CMR

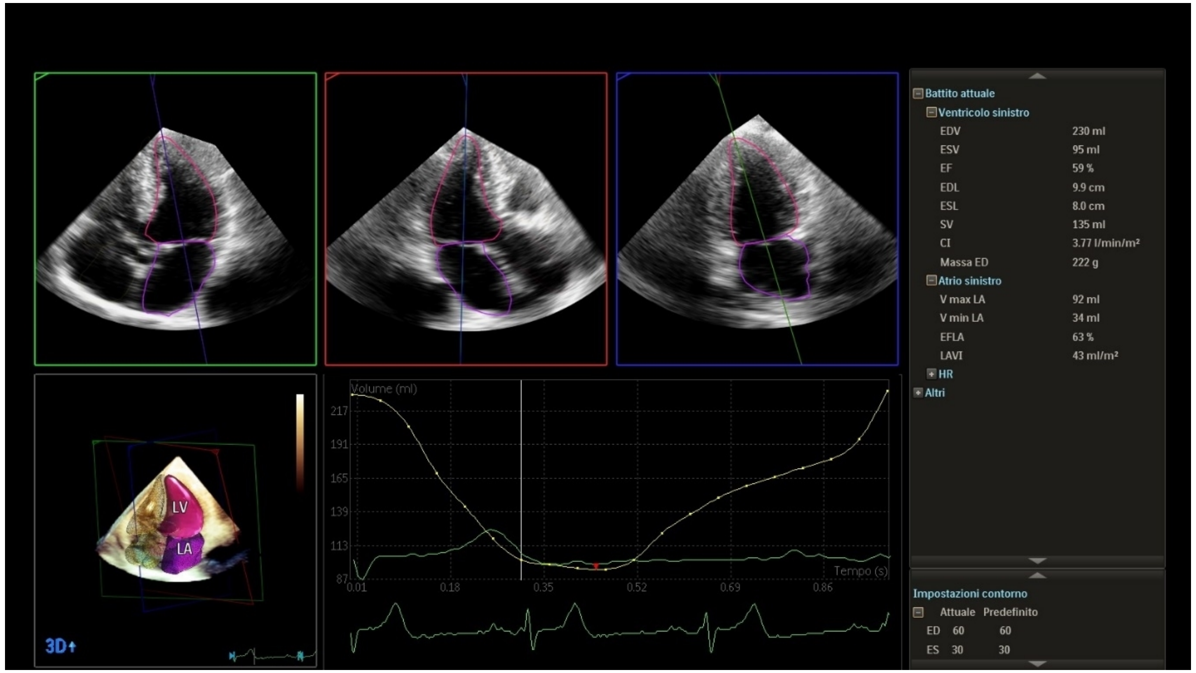
- If no consistent data on severity are acquired with the above-mentioned solutions, **TEE** is mandatory to assess morphology, mechanism and severity. Although large outcome **CMR** studies are lacking, CMR is the alternative method of choice for quantitative assessment of AR using the phase-contrast technique.

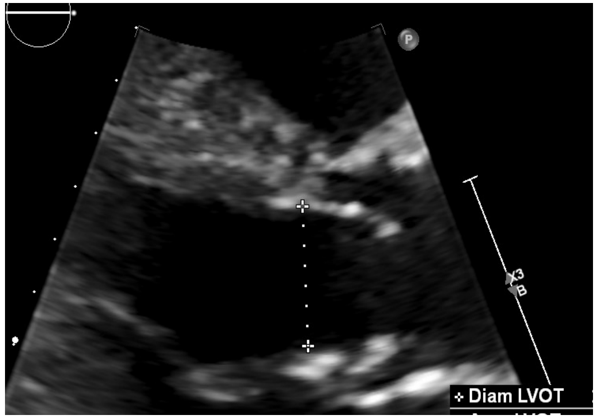
Quantification: stroke volume method

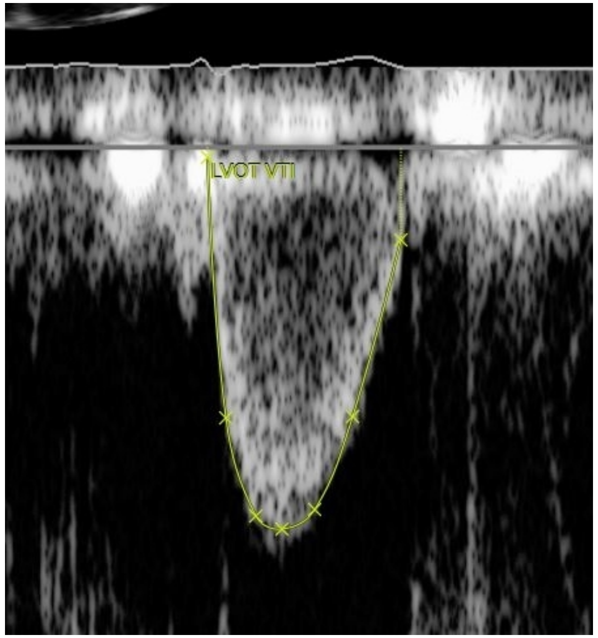


OR

$$RVOL = SV_{LVOT} - SV_{RVOT}$$

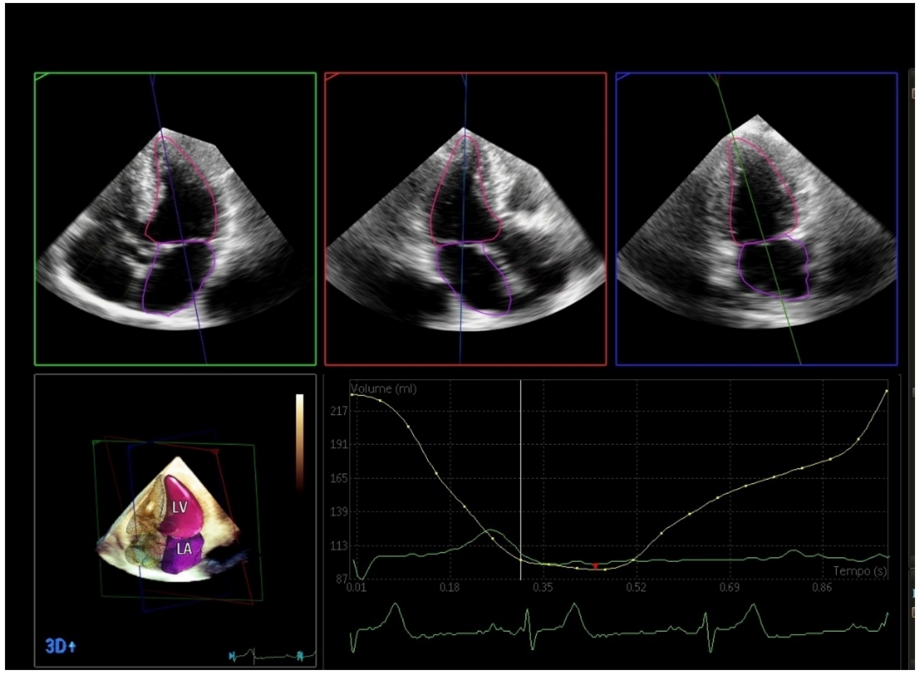


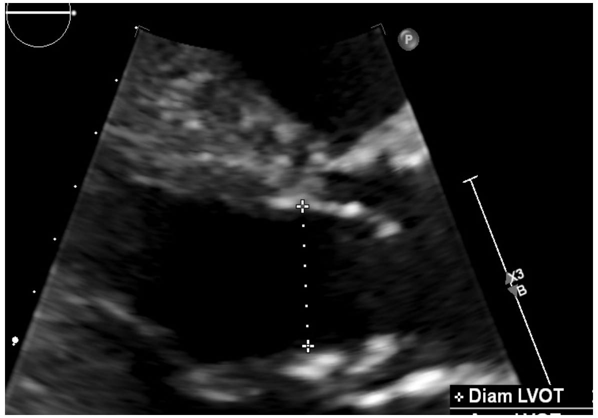


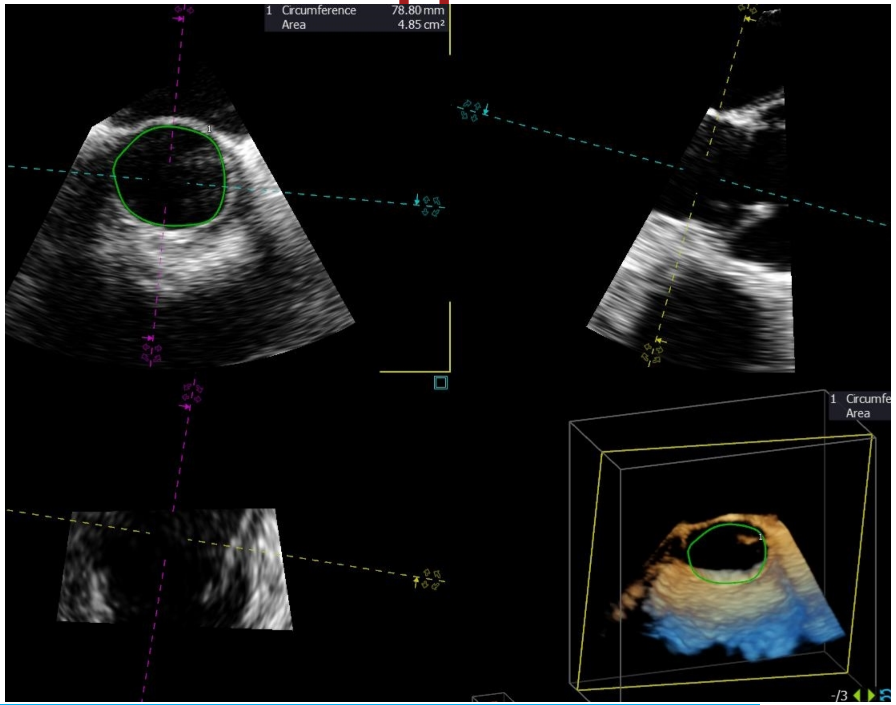


Quantification: stroke volume method

Always check for consistency with at least two volumetric approaches!!







Consistency between 2D and 3D measures is important to avoid drawbacks and correctly estimate RVol and RF:

- 3D volumetric SV: 134 ml

- 3D Doppler SV: 3D LVOT area: 4,85cm2; LVOT TVI 28cm → **3D LVOT SV: 136ml**

- **2D Doppler SV :** 2D LVOTd: 24 mm → LVOT area: 4,5 cm2; LVOT TVI: 28 cm; 2D LVOT SV: 126 ml

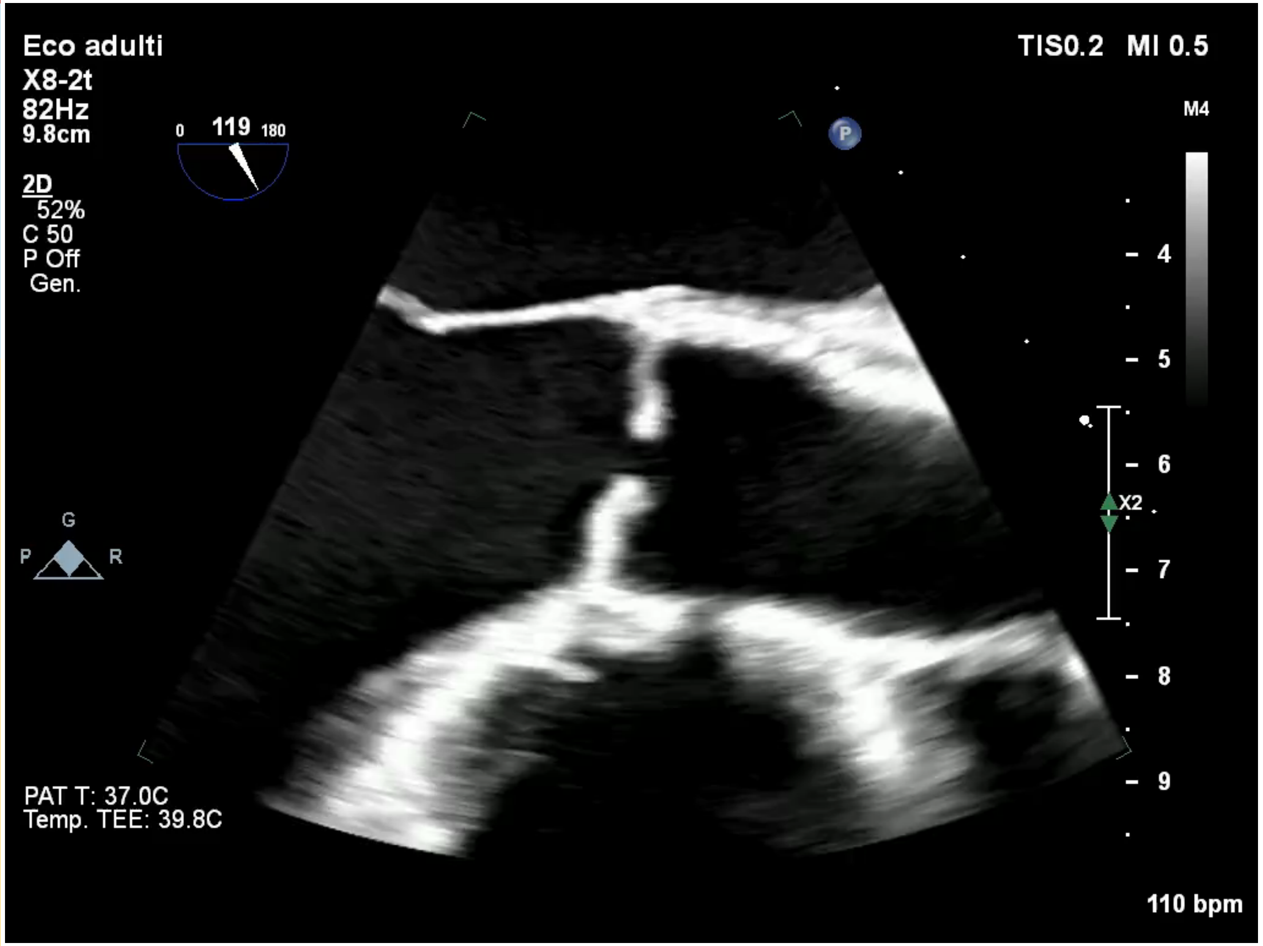
Accept little underestimation of 2D SV due to underestimation of LVOTd and chamber dimensions.

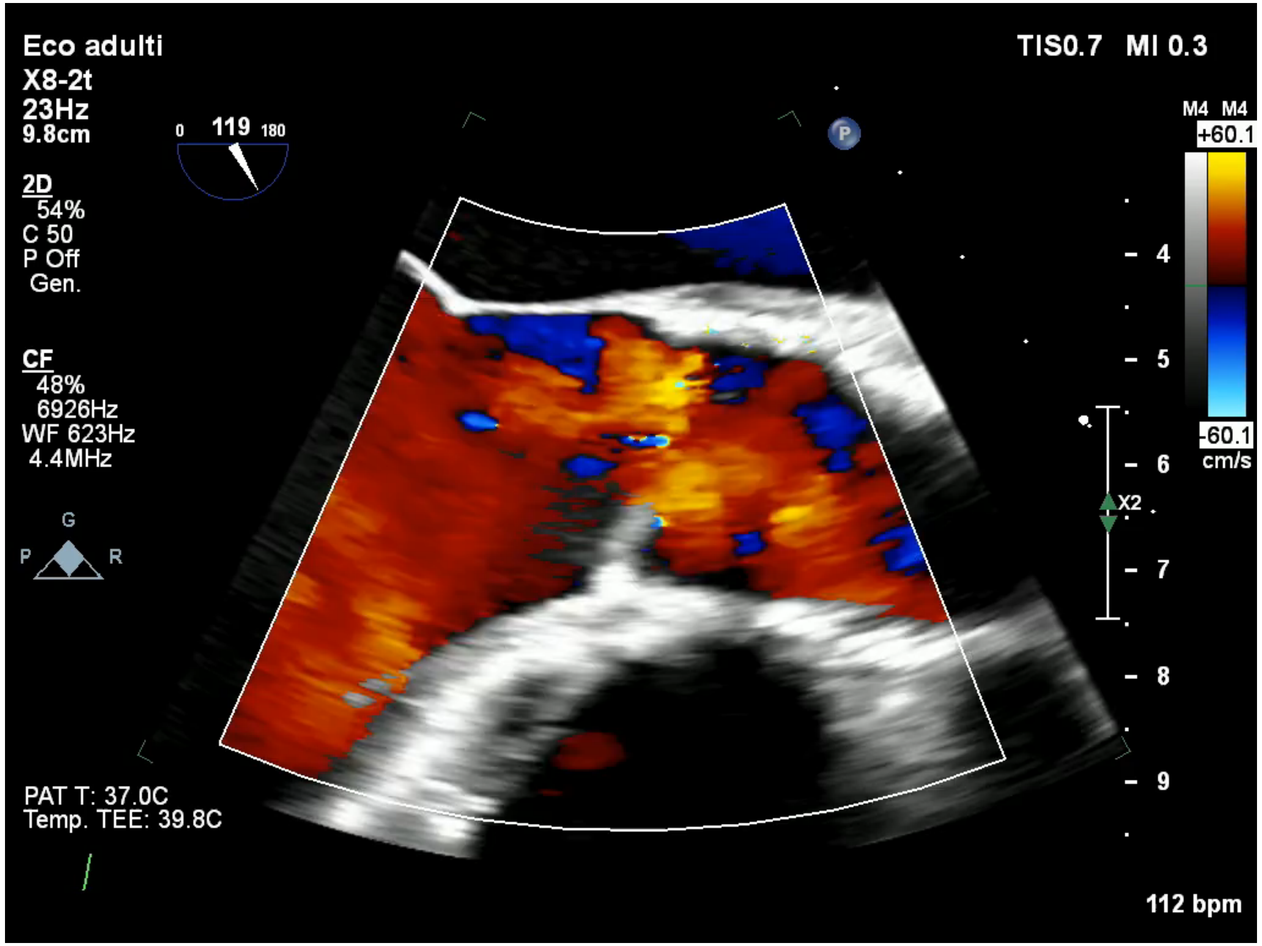
3D RVentricle SV: 73ml → 3D Rvol: 62ml; 2D Rvol 53ml

CASE #3

- H. L. R. (M, 43 yo)
- CVRF: arterial hypertension.
- Past medical hystory:
  - Marfan syndrome.
  - Type A aortic dissection treated in 2020 with David intervention.
- Worsening exertional dyspnoea since 1 year. (NYHA III)

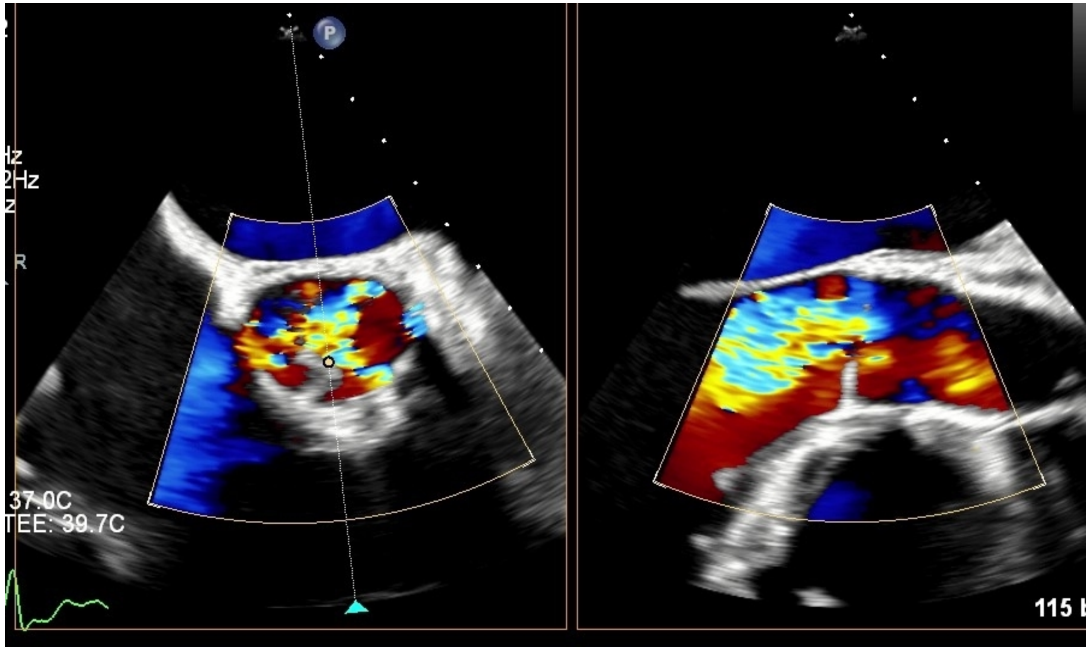
TRANSOESOPHAGEAL ECHOCARDIOGRAPHY



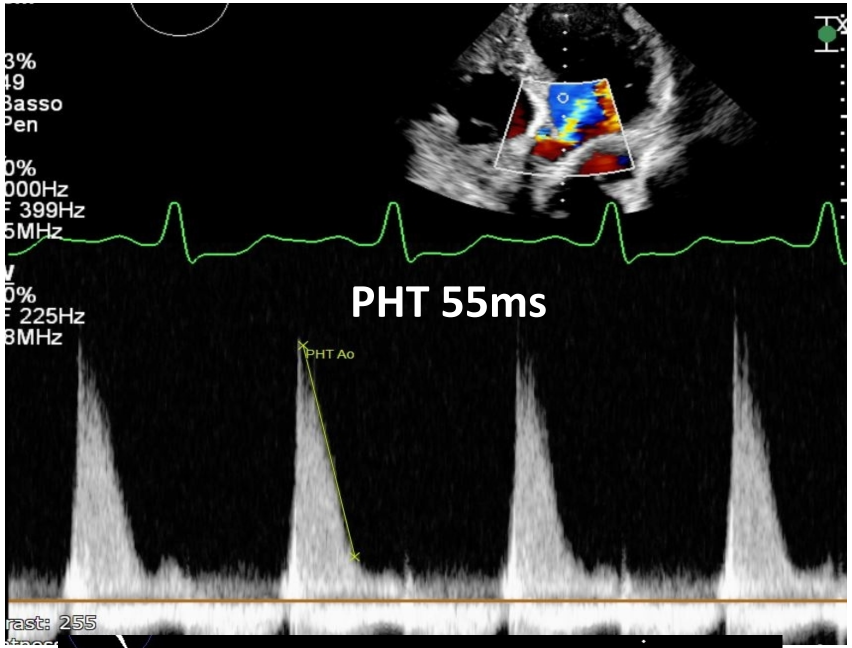


MECHANISM: Typ I :altered leaflet coaptation with central gap

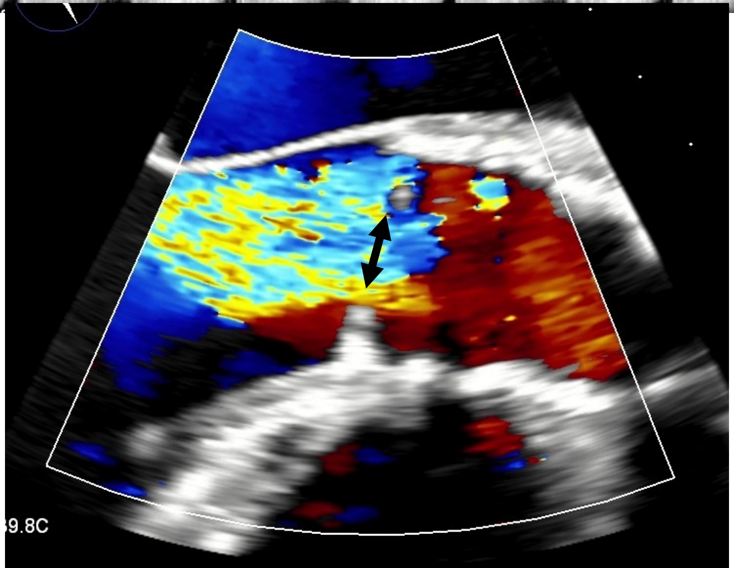
- Failure of David surgery
- Large central coaptation gap extending to the commissures due to dilated annulus and failure of cusp resuspension.



QUANTIFICATION: semiquantitative approach



Key point: The CW Doppler density of the AR jet does not provide useful information about the severity of AR. The assessment of the pressure-half time requires good Doppler beam alignment. A careful probe angulation is often needed. Because of the influences by LV and aortic chamber compliance and pressures, pressure half-time can only serve as a complementary finding for the assessment of AR severity.



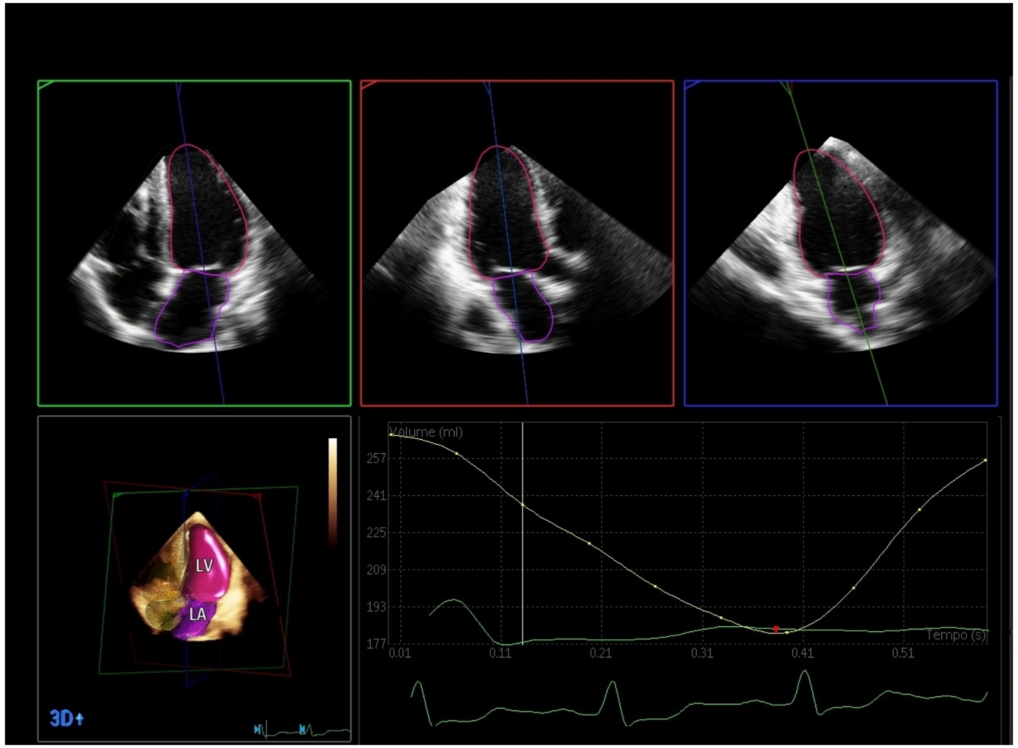
VC 8mm
JET width/LVOTd: 65%

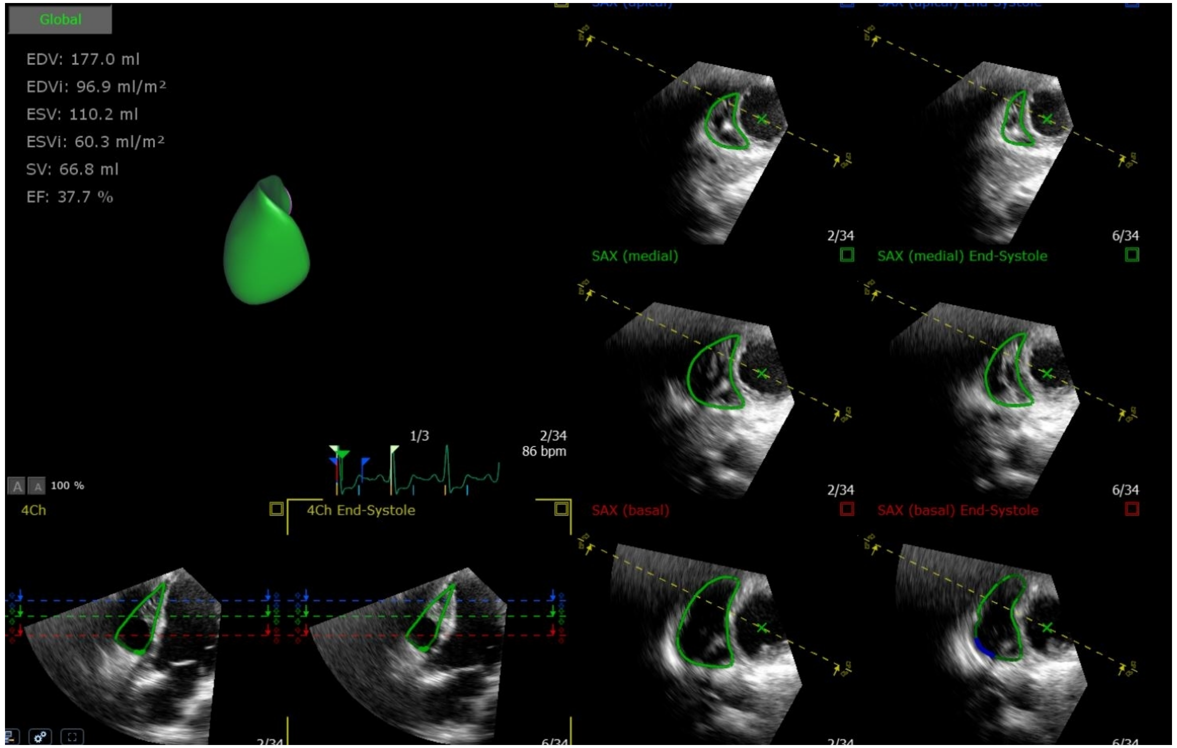
Table 7 **Grading the severity of AR**

AR severity classes[a]	Severe
AR severity sub-classes[a]	**Severe (Grade 4 or 4+)**
Qualitative parameters	
Aortic valve morphology	Abnormal/**flail/large coaptation defect**
Colour flow AR jet width[b]	**Large in central jet,** variable in eccentric jets
Color flow convergence	Large
CW signal of AR jet	Dense
Diastolic flow reversal in descending aorta[c]	**Holodiastolic flow reversal** (end-diastolic velocity ≥ 20 cm/s)
Diastolic flow reversal in abdominal aorta[c]	Present
Semi-quantitative parameters	
VC width (mm)	**>6**
Jet width/LVOT diameter (%)	**≥65**
Jet CSA/LVOT CSA (%)	**≥60**
Pressure half-time (ms)[c,d]	**<200**
Quantitative parameters	
EROA (mm^2)	≥30
R Vol (mL)	≥60
RF (%)	≥50
CMR parameters	
RF (%)	≥ 50
Structural parameters	
LV size[e]	Usually dilated

Lancellotti et al. ESC/EACVI Position Paper, EHJ CVI 2022

QUANTIFICATION- 3D TTE volumetric approach: do we always need it?



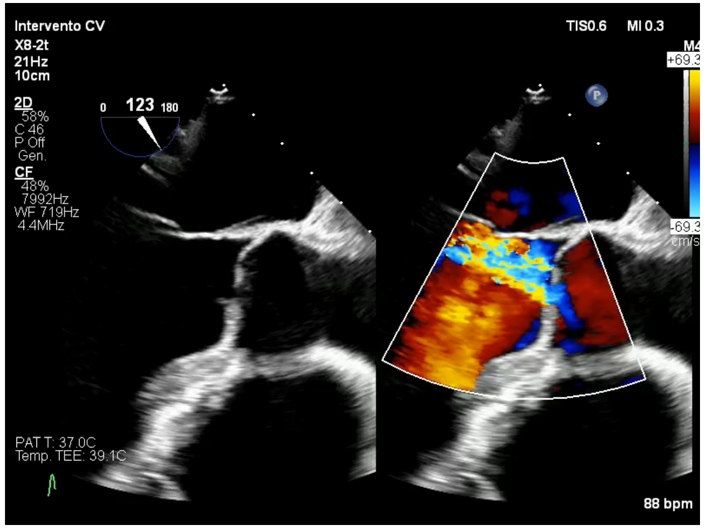


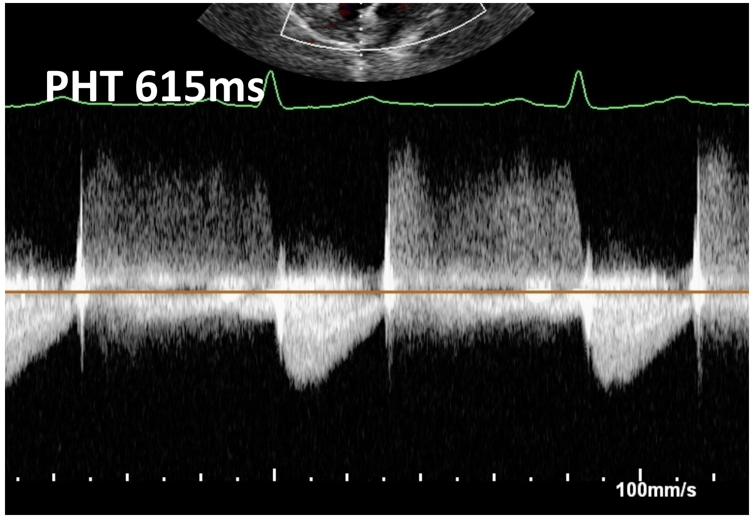
Severe biventricular systolic dysfunction and dilatation (LVEF 35%, RVEF 38%).
3D LV volumetric SV: 128mL
3D RV volumetric SV: 67 mL
RVol: 61ml; **RF**: 47%.

In the present case no doubt were present about AR grading and 3D volumetric approach can be time consuming, subject to several drawbacks and only applicable in case of <u>isolated valvular disease</u>.
To be used in case of discordant grading according to multiparametric approach.

QUANTIFICATION: Pressure half time

Limits of PHT in chronic severe AR!!





Pressure half time depends on the compliance of the receiving chamber and hence it can be reduced by elevated left ventricular diastolic pressure.

It can be prolonged (“pseudo-normal”) in chronic severe AR in case of dilated ventricles with preserved compliance.

In addition, PHT is highly dependent on peripheral resistance. Vasodilator therapy can reduce the pressure half time in aortic regurgitation.

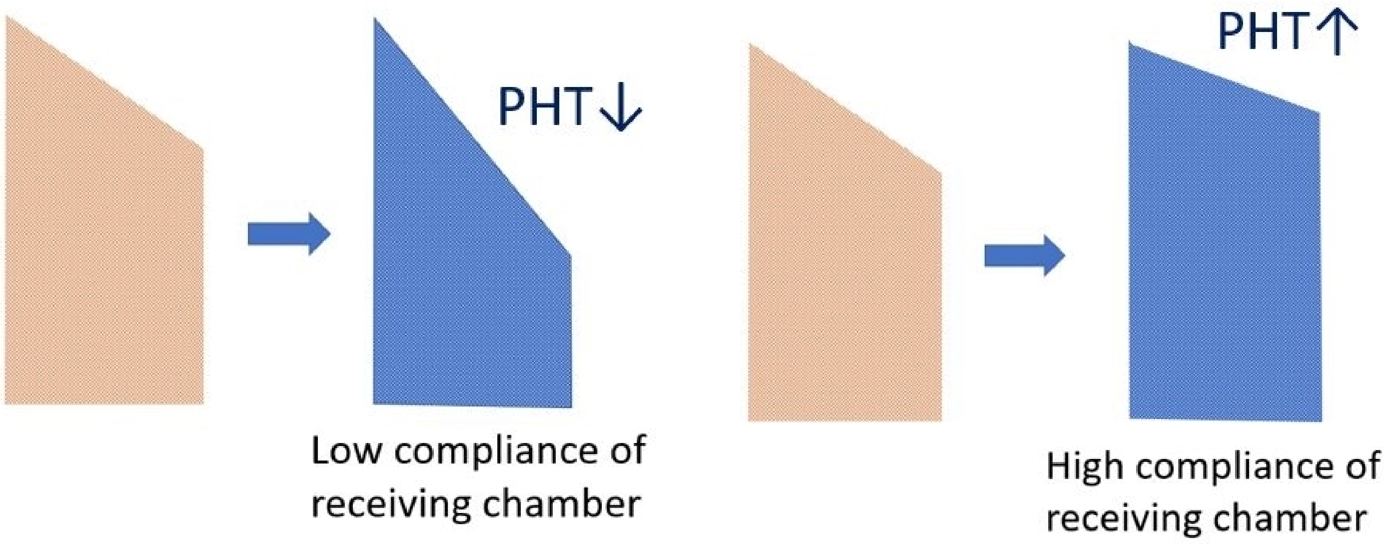
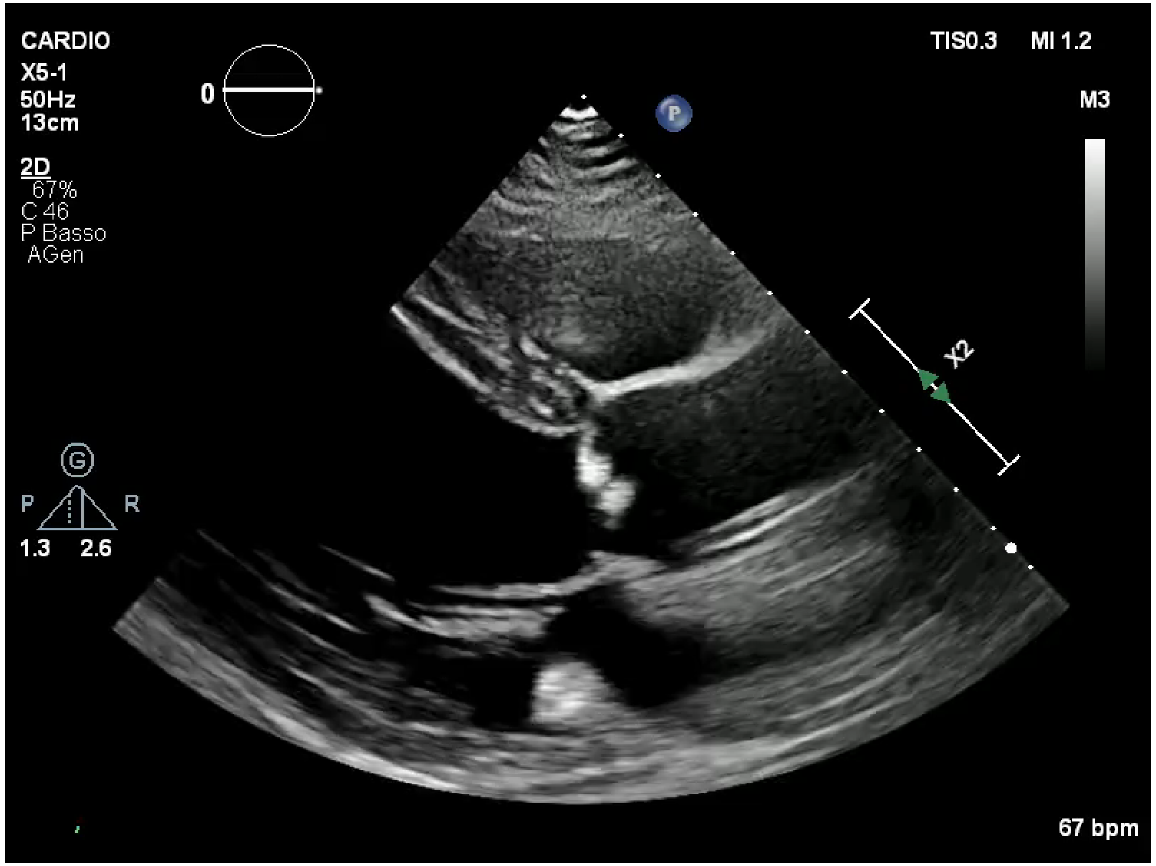


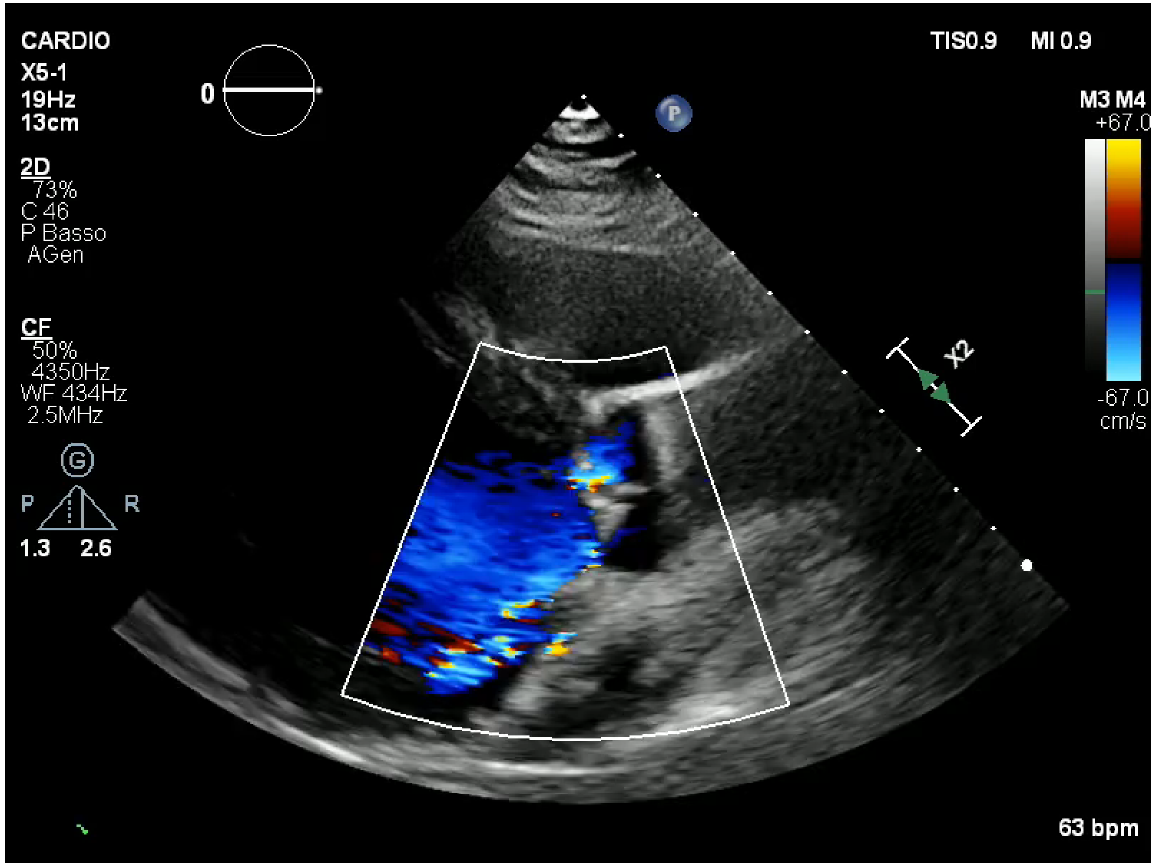
Image from: Pressure half time in aortic regurgitation – All About Cardiovascular System and Disorders (johnsonfrancis.org)

CASE #5

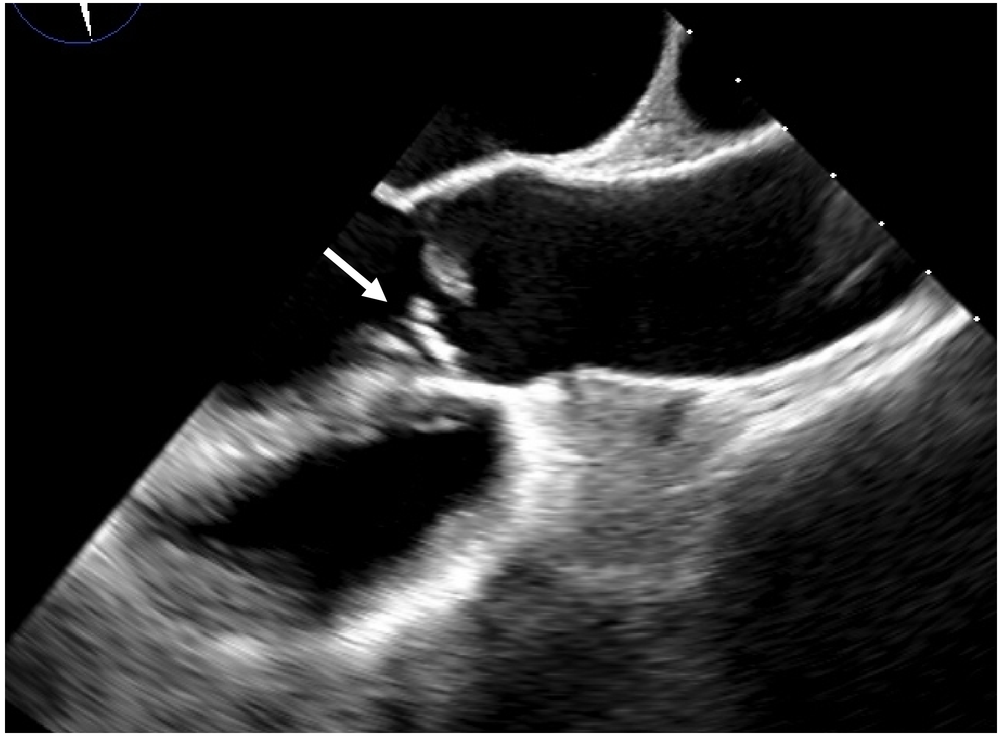
- B.S. (M, 52 yo)
- CVRF: Active smoker.
- Past medical hystory:
  - nothing relevant
- II/VI systolic murmur discovered during f-up for sport activity

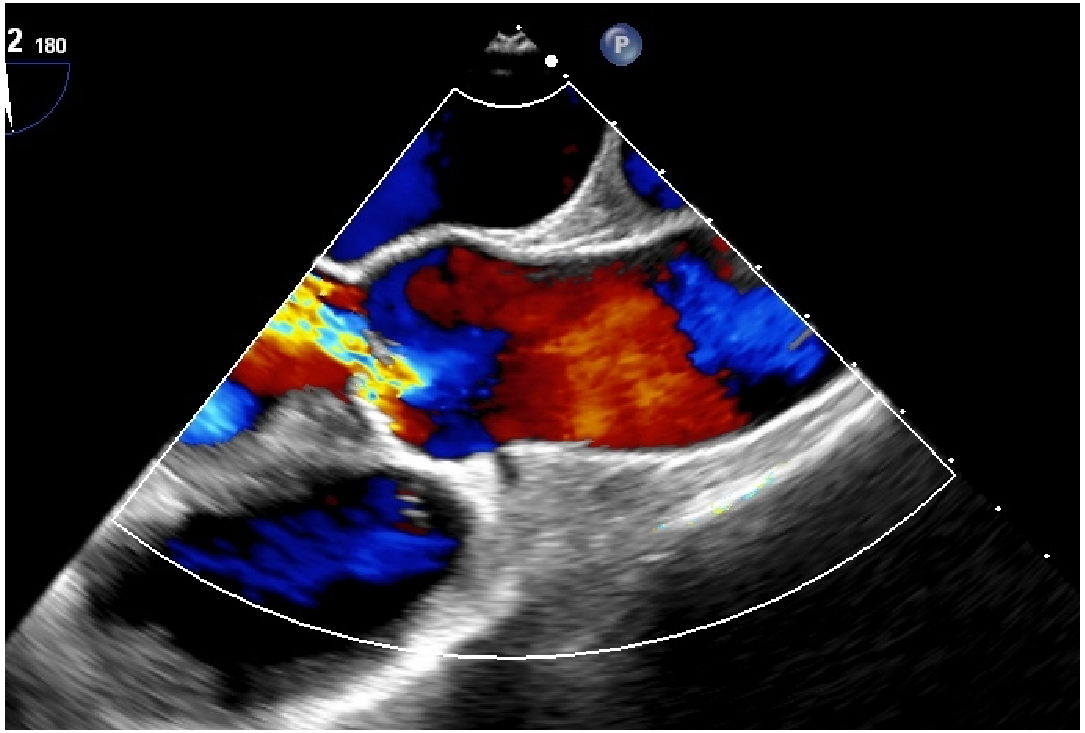
ECHOCARDIOGRAPHY





MECHANISM: Type II: conjoint cusp flail





Eccentric jet: difficult in quantification

Reliable indicators of severity

• Vena Contracta width→ only if clearly visible

EROA-PISA:

• Regurgitant volume and regurgitant fraction → but time consuming, single VHD and maximal precision needed

• Flow reversal in aorta → specific but less sensitive

• LV size → haemodynamic consequences → always suspect significant AR if dilated LV without other causes

Less reliable indicators of severity:

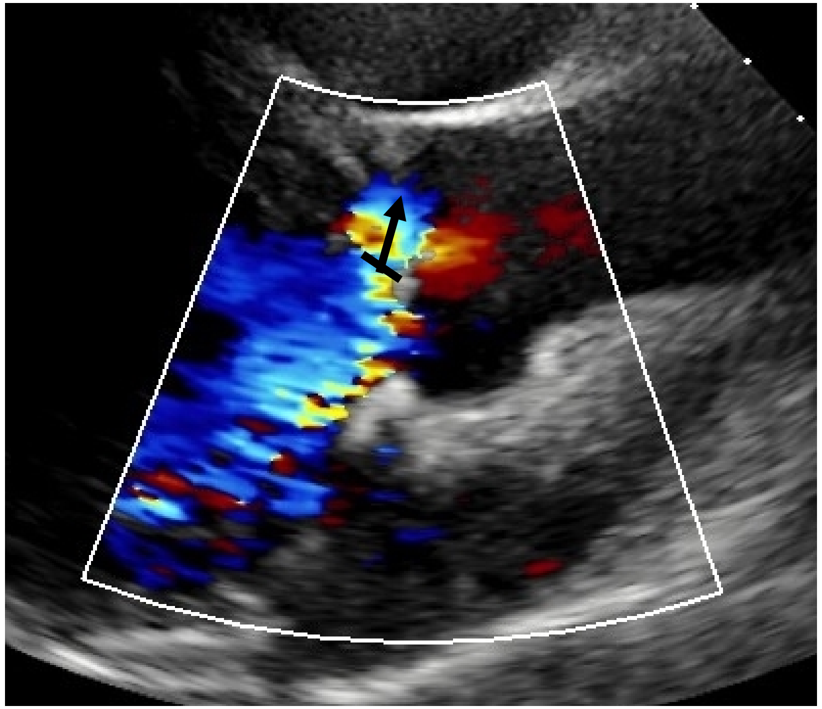
• Jet width/LVOT diameter → often underestimates the severity

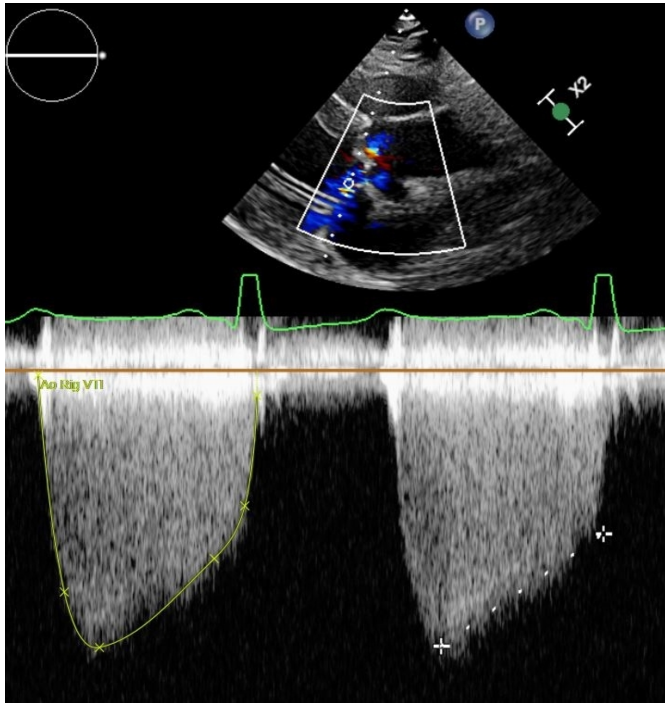
• Area of jet in Short axis → underestimation or overestimation depending on the transverse alignment

• CW jet recording → may be difficult and often “faint”

Quantification problems: severly eccentric jet

EROA PISA IN PLAX!





Key point: When feasible, the PISA method is highly suggested to quantify the severity of AR. It can be used in both central and eccentric jets. In eccentric AR jets, the parasternal long-axis view must preferentially be used to evaluate the flow convergence zone. An EROA $\geq 30\ mm^2$ or a R Vol ≥ 60 mL indicates severe AR. A RF greater than 50% indicates severe AR, even if EROA and R Vol are in the moderate range.