Imaging of Aortic Valve Disease

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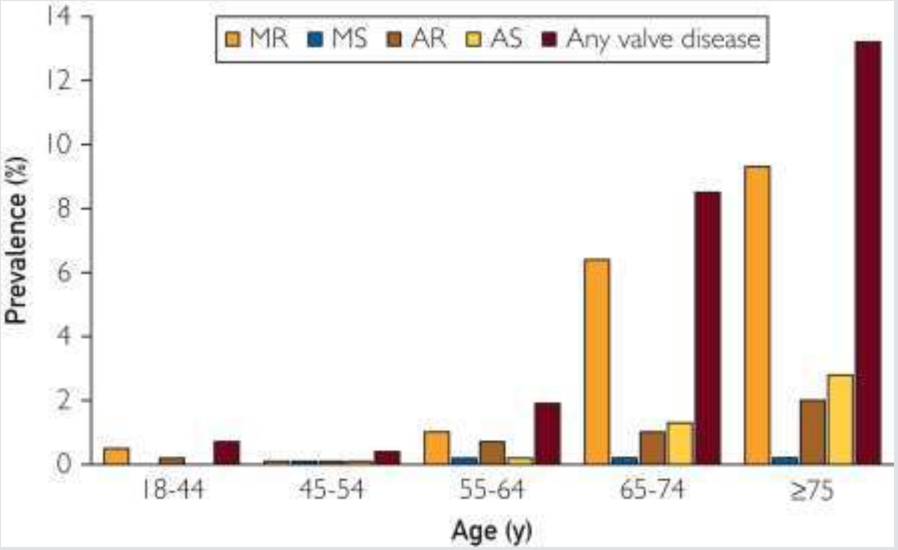
Why Aortic Valve Disease Matters



Kanwar A, Thaden JJ, Nkomo VT. *Mayo Clin Proc*. 2018;93(4):488–508

- Severe AS Approximately **3.4% of individuals aged ≥75 years old**
- Most common reason for valve intervention in the elderly
- Alarmingly, **up to 50% of severe AS cases remain undiagnosed** or are diagnosed too late for optimal outcomes
- Up to 30–40% of elderly patients with severe AS develop symptomatic HF
- If left untreated, symptomatic AS carries a **2-year mortality of up to 50–60%**
- **LF LG AS**, especially with preserved LVEF - **increased all-cause mortality (associated)**
- 1-year mortality rate **>50% without aortic valve replacement**

(Clavel MA et al., *J Am Coll Cardiol*, 2015).

(Osnabrugge et al., *JACC*, 2013; Vahanian et al., *Eur Heart J*, 2021).

(Lindman BR et al., *JACC*, 2013; Otto CM et al., *Circulation*, 2021).

- Chronic AR in the general population ~0.5–1.5%

  Dweck MR, et al. JACC Cardiovasc Imaging. 2019;12(1):102–117.

- Moderate/severe AR in patients with HFrEF: ~10–15% in hospitalized cohorts

  Oh J, et al. J Am Coll Cardiol. 2024;83(5_Supplement):1932.

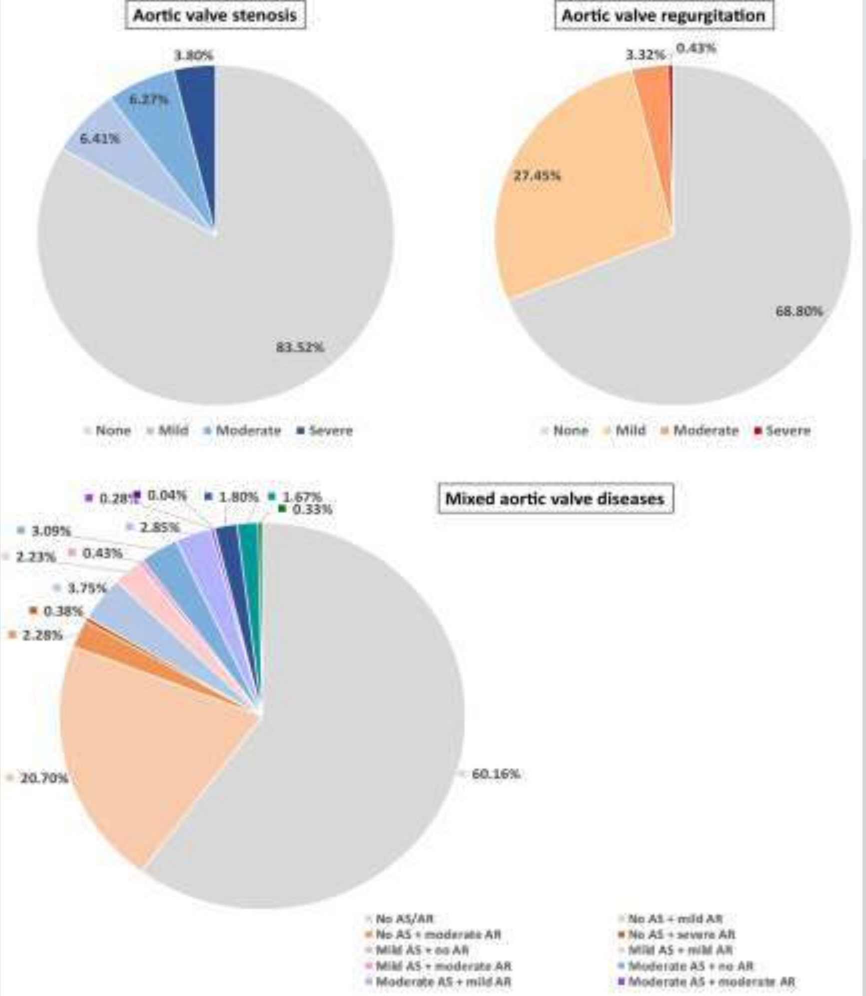
- Moderate/severe AR in HFpEF ~5% prevalence

  Barbato E, et al. ESC Heart Fail. 2023;10:14362.

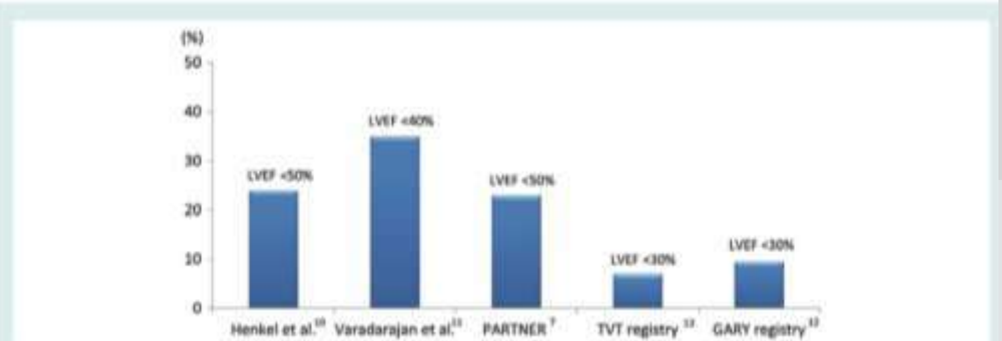
- AVD + HF associated with significantly worse outcomes

AS and MAVD → ↑ in-hospital mortality and ↑ CV death at 12 months

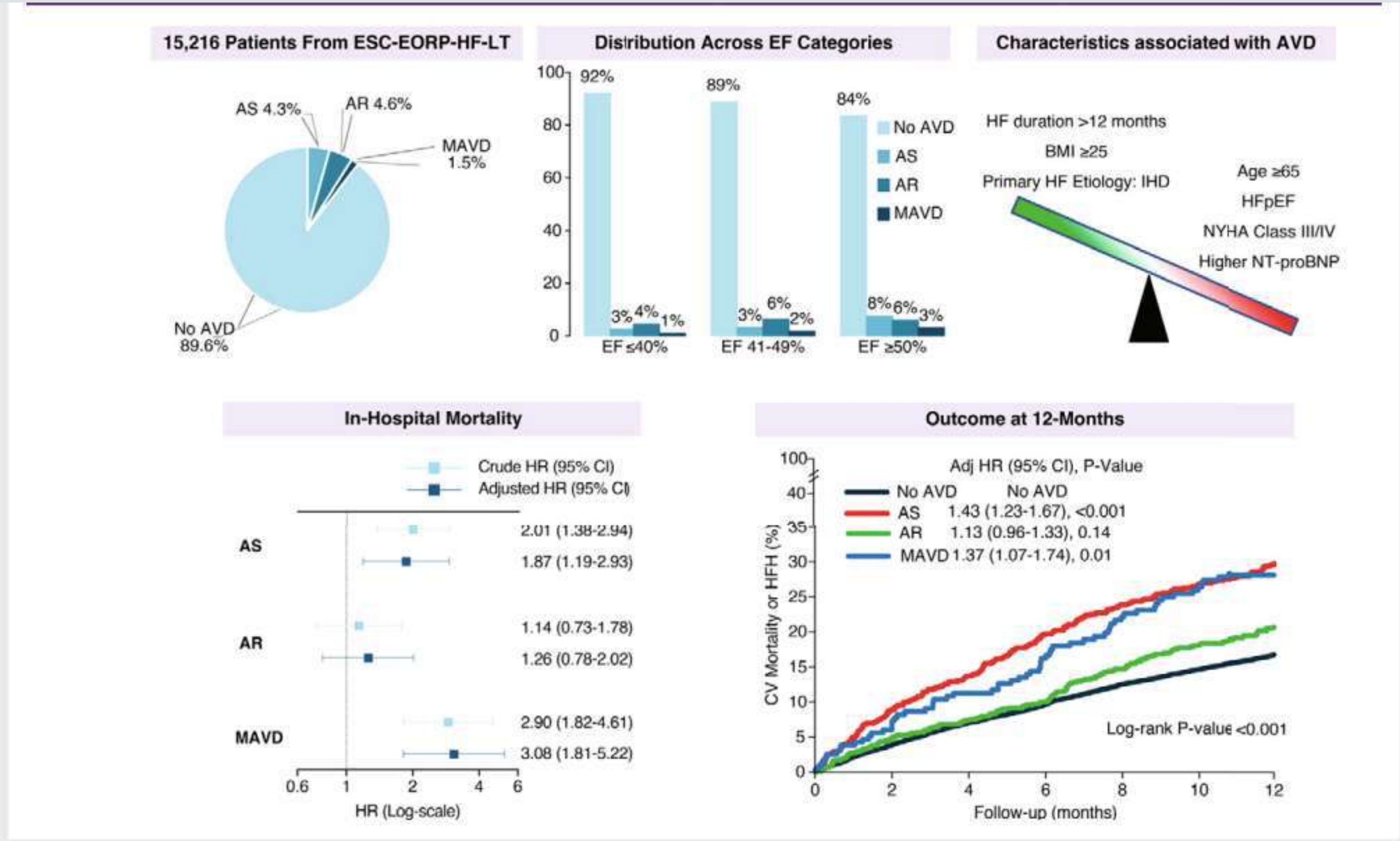
Barbato E, et al. ESC Heart Fail. 2023;10:14362.



European J of Heart Fail, Volume: 26, Issue: 8, Pages: 1832-1846, First published: 19 June 2024, DOI: (10.1002/ejhf.3337)



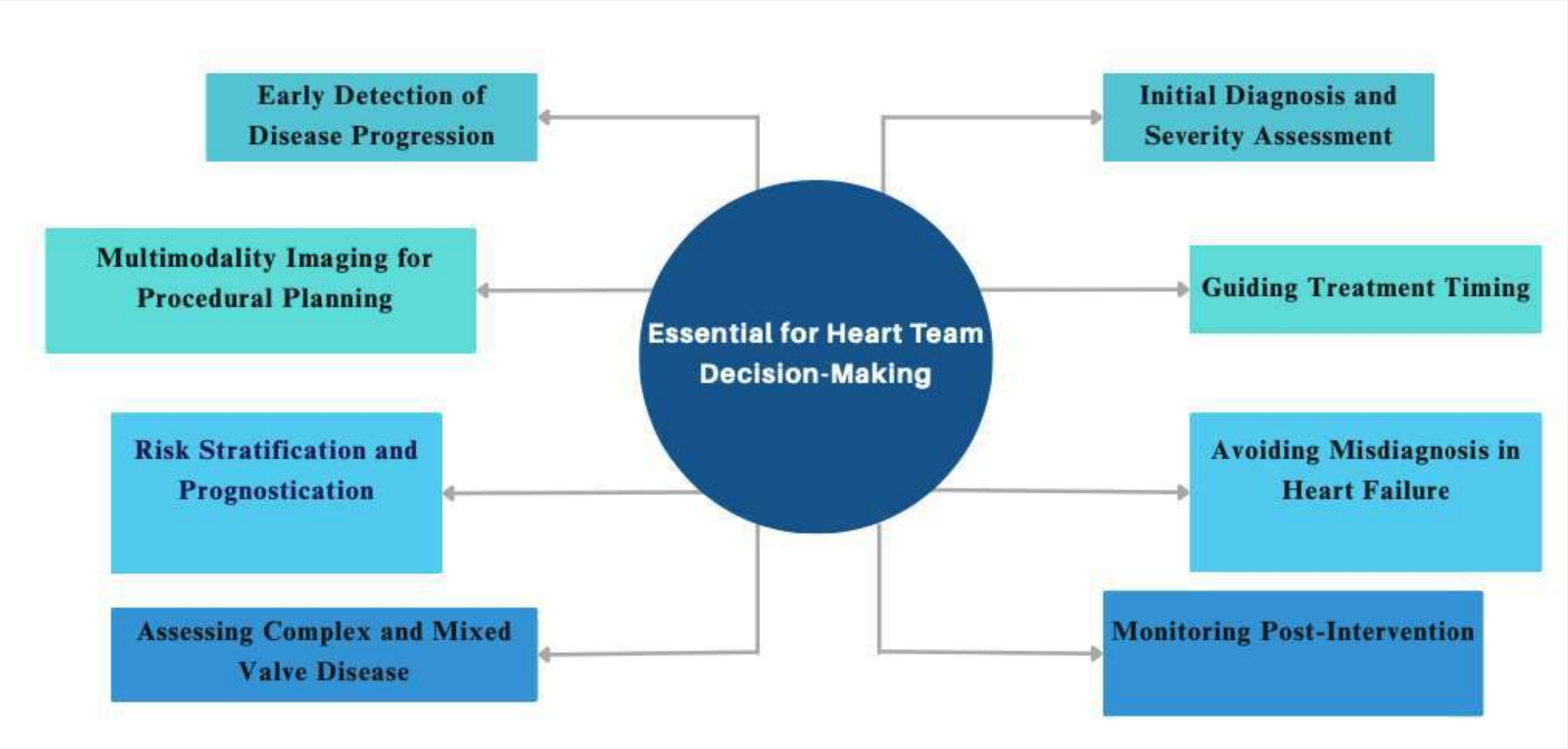
Aortic Valve Disease in the ESC Heart Failure Long-Term Registry



- In the ESC Heart Failure Long-Term Registry (>15,000 patients), ~10% had moderate to severe AVD, especially in HFpEF and HFmrEF patients

- AS and MAVD were linked to worse outcomes, including higher mortality and HF hospitalization

Why Imaging of Aortic Valve Disease Important?



(Vahanian et al., Eur Heart J, 2021)

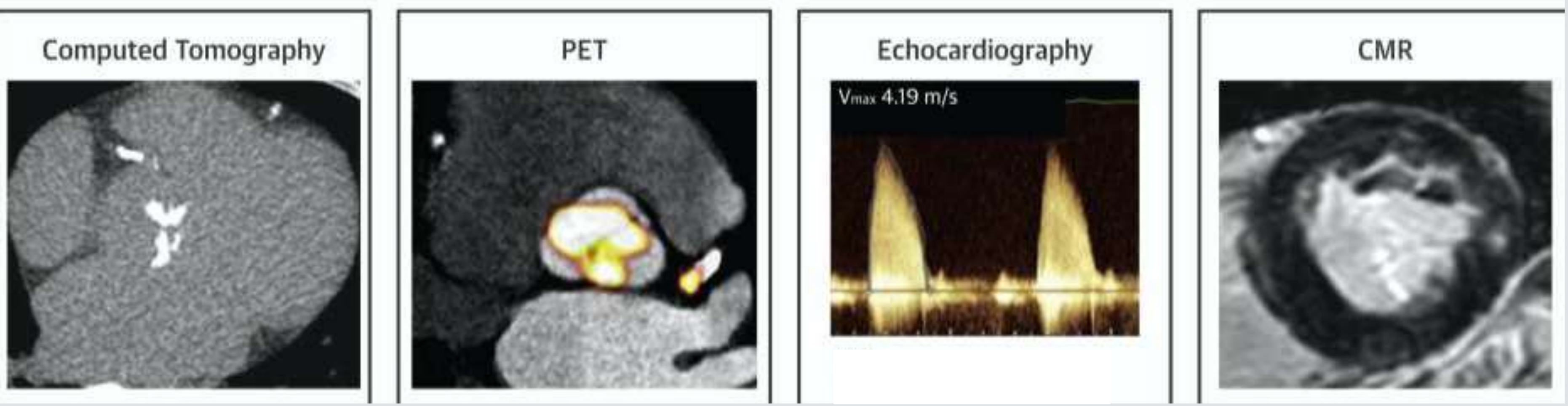
(Otto et al., Circulation, 2020)

(Makkar et al., JACC, 2022; VARC-3, J Am Coll Cardiol, 2021)

Which Imaging Method?

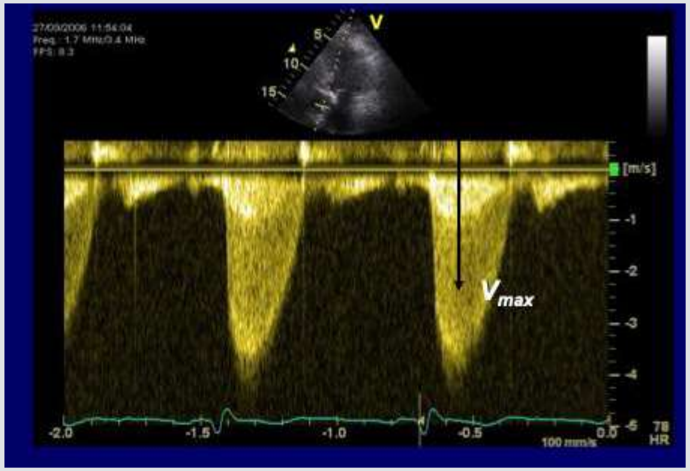
- Transthoracic Echocardiography
- Transesophageal Echocardiography
- Dobutamine Stress Echocardiography
- Cardiac Computed Tomography

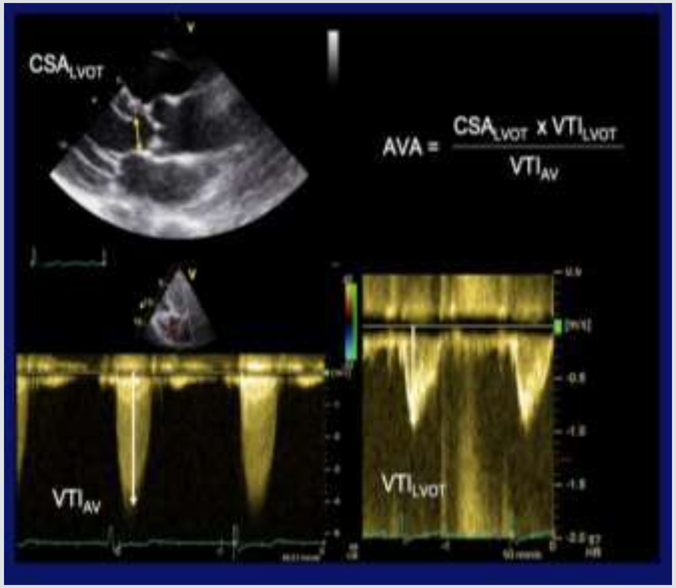
- Cardiac Magnetic Resonance Imaging (CMR)
- 4D Flow CMR
- Speckle Tracking Echocardiography (Strain Ima
- Tissue Doppler Imaging (TDI)
- Vector Velocity Imaging



Aortic Stenosis

	Mild AS	Moderate AS	Severe AS
Vmax (m/s)[a]	2.0–2.9	3.0–3.9	≥4.0
Mean gradient (mmHg)[a]	<30	30–49	≥50
AVA (cm^2)	>1.5	1.0–1.5	<1.0
AVAi (cm^2/m^2 BSA)	≥1.0	0.6–0.9	<0.6

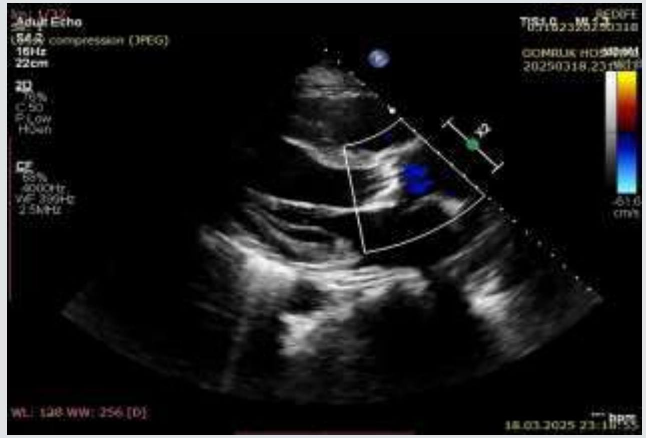




10.1093/eurheartj/ehq249

Transthoracic Echocardiography

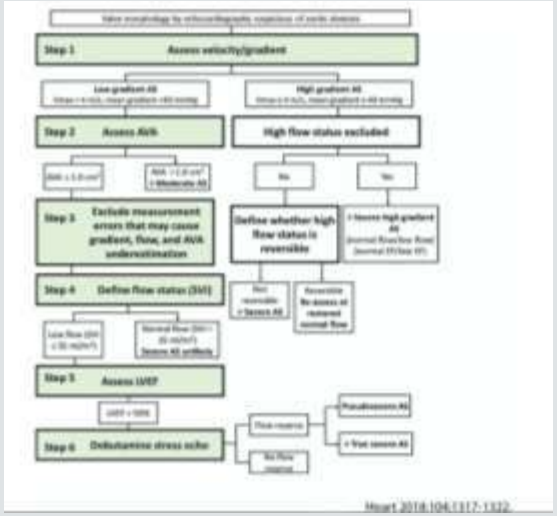
- First-line
- Non-invasive
- Widely available



- Valve morphology
- Severity
- Mechanism of the valvular lesion
- Haemodynamic consequences

General Approach by Echo

1. **Assess Aortic Valve Morphology** — Calculate Aortic Valve Area (AVA)
2. **Measure LVOT Diameter** — Calculate Dimensionless Index (Doppler Velocity Index, DVI)
3. **Assess LV Function** — Assess Stroke Volume Index
4. **Acquire LVOT Flow (PW Doppler)** — Identify Flow-Gradient Pattern
5. **Acquire Aortic Valve Jet (CW Doppler)** — Classify into:
   - Normal-flow high-gradient
   - Low-flow low-gradient
   - Normal-flow low-gradient

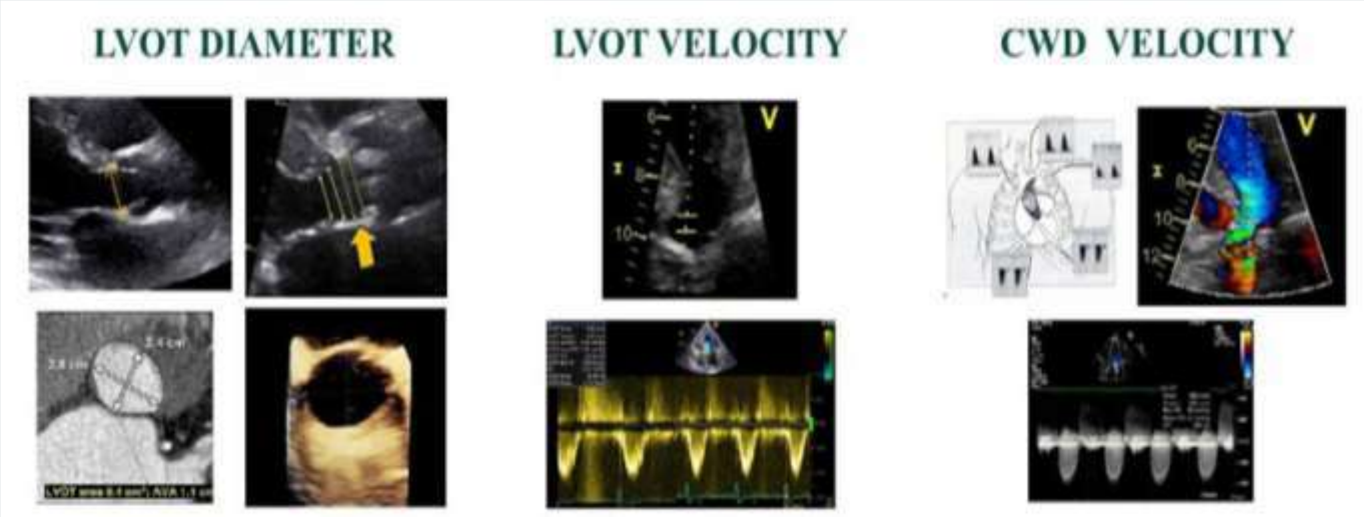


Sources of Errors

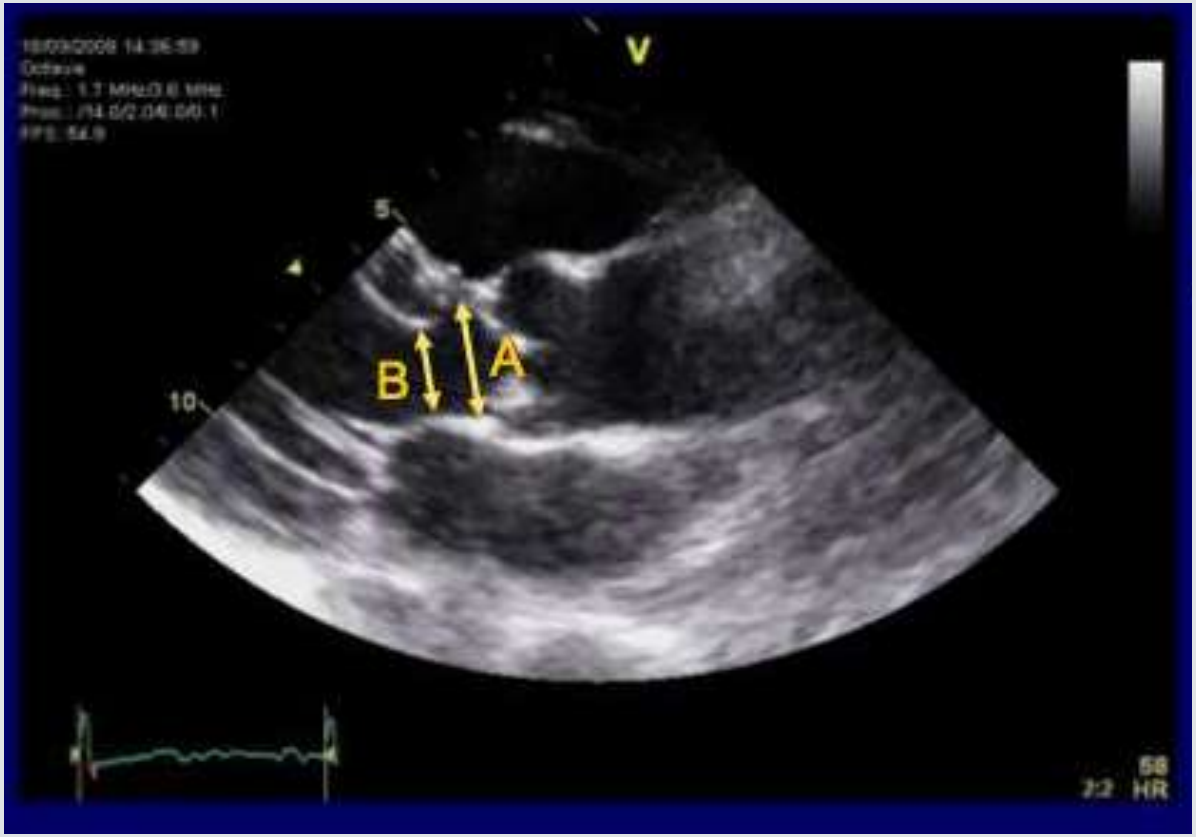
- LVOT Measurement Errors

○ Continuity formula assumes circular LVOT, but in reality, it's often oval

○ Measured in 2D PLAX view — leads to underestimation of LVOT area → underestimation of AVA



- Poor Acoustic Windows
- Misalignment of Doppler Beam
- Low-Flow States
- Pressure Recovery Phenomenon
- Suboptimal Valve Visualization
- Limited Utility in Mixed Valve Disease
- Lack of Functional Assessment
- Operator Dependence



CSA: geometrical assumptions

A: LVOT 23 mm → AVA: 1.2 cm²

B: LVOT 18 mm → AVA: 0.96 cm²

Ng et al. Circ Cardiovasc Imaging 2010

- This image clearly shows how **small measurement errors in the LVOT diameter** can significantly affect the calculated aortic valve area

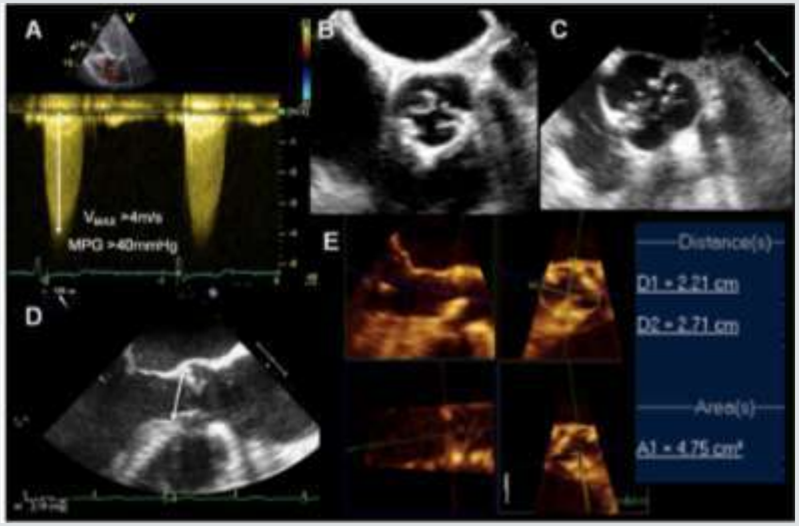
- This may result in **misdiagnosis** and **inappropriate management** of aortic stenosis

- This table shows how imaging techniques differ in AVA accuracy
- It compares their assumptions about LVOT shape and how that affects cross sectional area measurement and reliability

Technique	LVOT Shape Assumption	CSA Accuracy	AVA Reliability
2D Echo	Circular	Often underestimated	May overestimate AS severity
3D Echo	No assumption — planimetry	More accurate	Better AVA classification
Cardiac CT	Gold standard	Highest	Used in TAVI planning

Transoesophageal Echocardiography

- High-resolution imaging when **TTE is suboptimal**
- Better visualization of **valve morphology**, calcification and annulus
- Can help confirm **AVA** using improved LVOT/VTI assessment



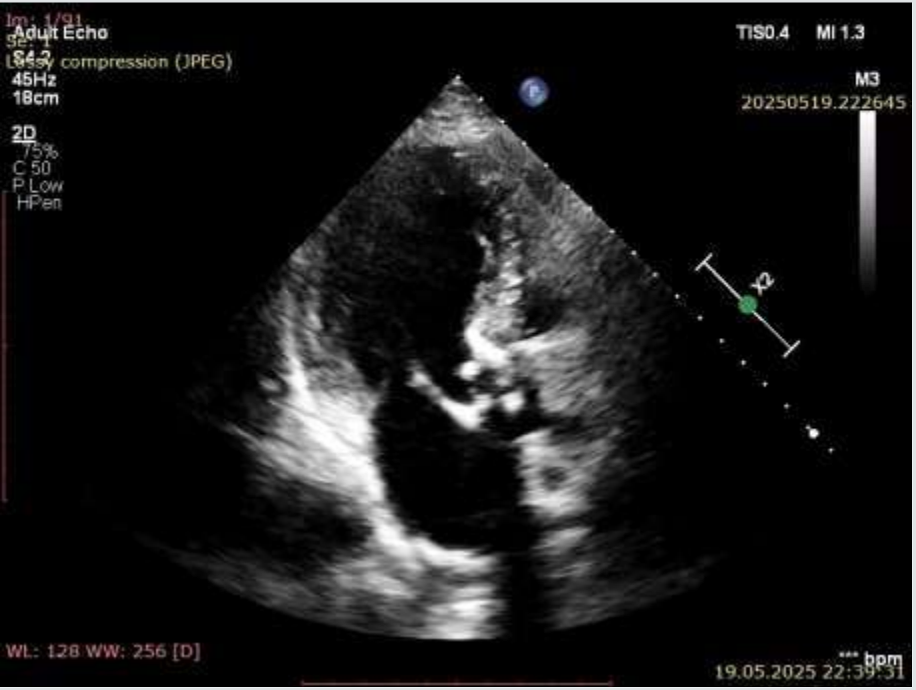
Used **intra-operatively during TAVI/SAVR** for:

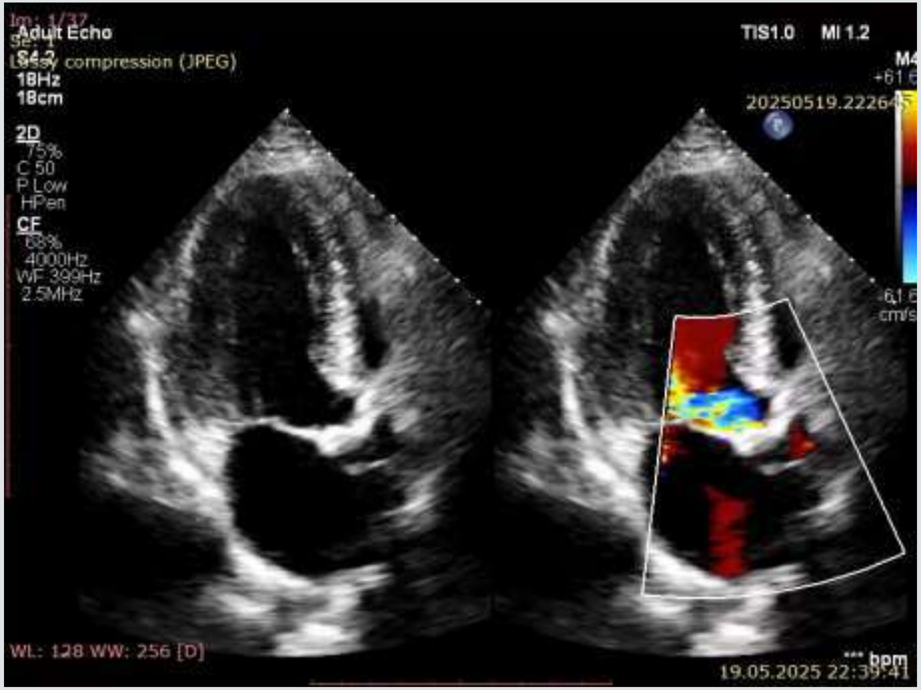
•Valve deployment guidance

•Assessing **paravalvular leak** and complications

Differentiates AS from **LVOT obstruction or subaortic membrane**

- Limitations: semi-invasive, not ideal for all patients





In this patient as seen from echo views:

- We obtained a serious gradient (Pmax/mean-80/55 mm Hg)

- Observed a membrane-like structure in the subaortic area

Due to the mobility of the structure mimicking a membrane, we requested a transesophageal echocardiographic evaluation.

During the TOE, we concluded that:

The structure was a calcified nodule protruding into the LVOT from a Type 1 malaligned bicuspid aortic valve

Difficult situation: AS and heart failure, how to diagnose ?

Low flow – low gradient situation

AVA: severe AS

Gradient: no severe AS

Low Flow Low Gradient AS

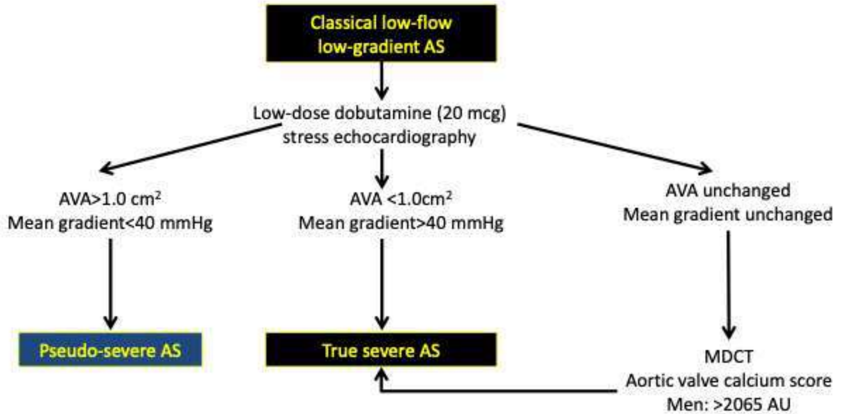
DEFINITION:

- Valve area < 1.0 cm^2 (< 0.6 cm^2/m^2)
- **WITH** LV systolic dysfunction (LVEF< 40%)
- **AND** Transaortic MPG < 40 mm Hg

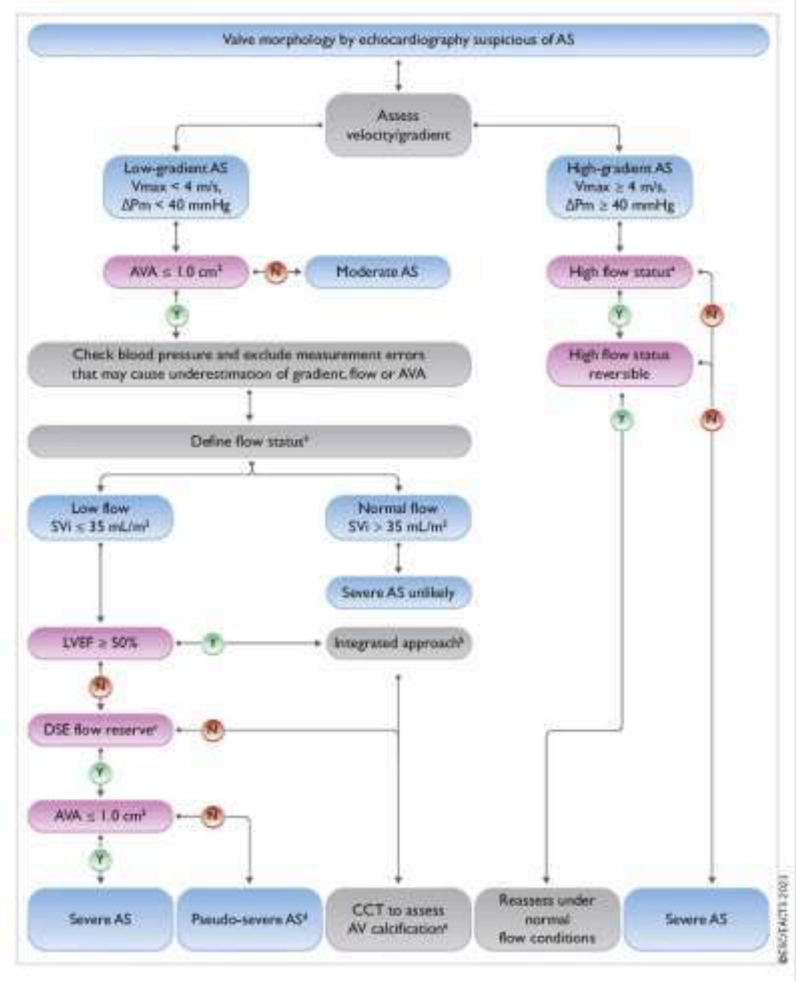
ESC/ EACTS Guidelines. Eur Heart J. 2012; 33: 2451-96
AHA/ACC Guidelines on VHD. Circulation. 2014; 129: e521-e643

Algorithm for severe AS diagnosis in HF

Low-flow, low-gradient severe AS
AVA <1.0cm^2 (<0.6cm^2/m^2)
(LV stroke volume index<35 mL/m^2)
Mean gradient<40 mmHg
LVEF <50%



Modified from Bax et al. Eur Heart J 2014



Dobutamine Stress Echo Roles in LF-LG AS

- Differentiate True Severe vs Pseudo-Severe AS
- Assess Contractile (Flow) Reserve
- Guide Management Strategy
- Prognostication

Usefulness of dobutamine echocardiography in distinguishing severe from nonsevere valvular aortic stenosis in patients with depressed left ventricular function and low transvalvular gradients

C R deFilippi [1], D L Willett, M E Brickner, C P Appleton, C W Yancy, E J Eichhorn, P A Grayburn

Affiliations + expand

PMID: 7810504 DOI: 10.1016/s0002-9149(00)80078-8

This landmark study was among the first to show that **dobutamine stress echocardiography** effectively distinguishes **true severe from pseudo-severe aortic stenosis** in patients with **reduced LVEF,** guiding appropriate surgical decisions

	True AS		Pseudo AS	
	Rest	Dobutamine	Rest	Dobutamine
CO L/min	3.5	5.0	3.5	5.0
Gradient mm Hg	25	40	25	25
AVA cm^2	0.7	0.8	0.7	1.0

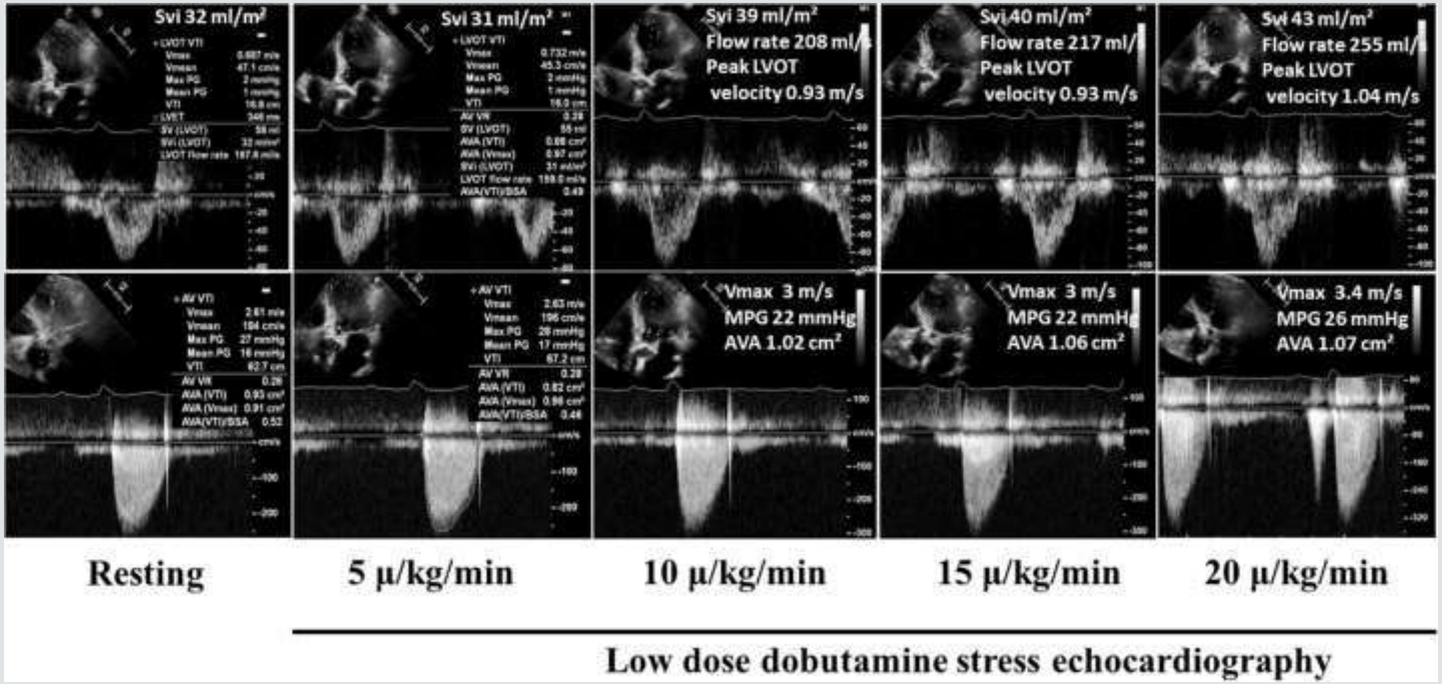
Abbreviation: CO, Cardiac output.

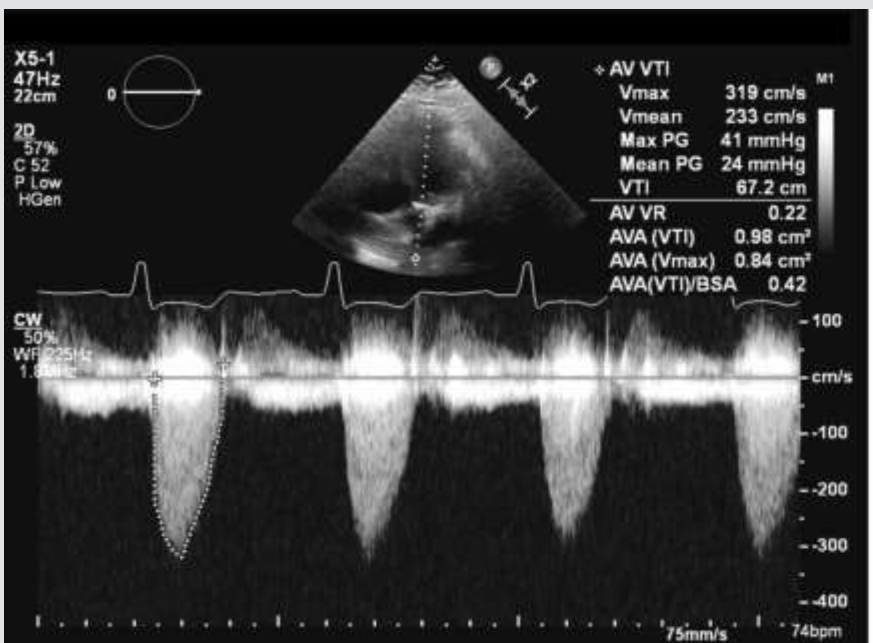
True AS

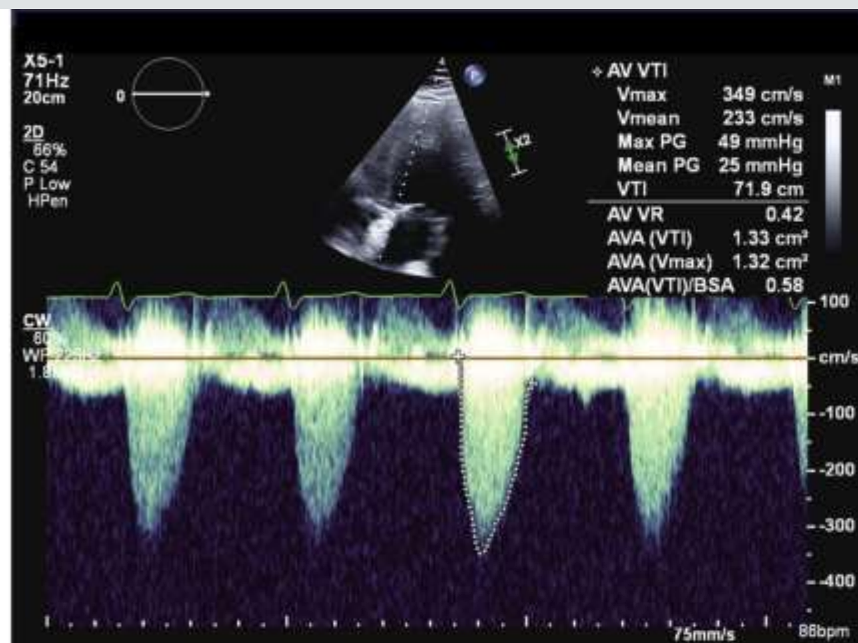
- Peak stress EOA <1.0 cm^2
- Gradient >40 mmHg
- Absolute increase in EOA <0.3 cm^2

Pseudo-severe AS

- Aortic valve area (AVA) ≥ 1.2 cm^2
- Mean transaortic gradient ≤ 30 mmHg
- Assessed at peak dobutamine infusion


Svi 32 ml/m²
Svi 31 ml/m²
Svi 39 ml/m²
Flow rate 208 ml/s
Peak LVOT
velocity 0.93 m/s
Svi 40 ml/m²
Flow rate 217 ml/
Peak LVOT
velocity 0.93 m/s
Svi 43 ml/m²
Flow rate 255 ml/
Peak LVOT
velocity 1.04 m/s
Vmax 3 m/s
MPG 22 mmHg
AVA 1.02 cm²
Vmax 3 m/s
MPG 22 mmHg
AVA 1.06 cm²
Vmax 3.4 m/s
MPG 26 mmHg
AVA 1.07 cm²
Resting
5 µ/kg/min
10 µ/kg/min
15 µ/kg/min
20 µ/kg/min
Low dose dobutamine stress echocardiography


X5-1
47Hz
22cm
2D
57%
C 52
P Low
HGen
AV VTI
Vmax 319 cm/s
Vmean 233 cm/s
Max PG 41 mmHg
Mean PG 24 mmHg
VTI 67.2 cm
AV VR 0.22
AVA (VTI) 0.98 cm²
AVA (Vmax) 0.84 cm²
AVA(VTI)/BSA 0.42
CW
100
cm/s
-100
-200
-300
-400
75mm/s
74bpm


X5-1
71Hz
20cm
2D
66%
C 54
P Low
HPen
AV VTI
Vmax 349 cm/s
Vmean 233 cm/s
Max PG 49 mmHg
Mean PG 25 mmHg
VTI 71.9 cm
AV VR 0.42
AVA (VTI) 1.33 cm²
AVA (Vmax) 1.32 cm²
AVA(VTI)/BSA 0.58
CW
100
cm/s
-100
-200
-300
-400
75mm/s
86bpm

Why Differentiating True vs Pseudo-Severe AS Matters

Management Decisions Differ Significantly

✓**True Severe AS** → AVR/TAVI **strongly indicated**

✓**Pseudo-Severe AS** → **does not benefit** from AVR/TAVI focus on **medical management of HF** .(Fougeres et al., Eur Heart J 2012)

Prognosis Differs Sharply

•**True severe AS is associated**

✓ Progressive symptoms

✓LV dysfunction

✓Increased mortality if left untreated

•**Pseudo-severe AS**

✓**Better prognosis**, especially when LVEF improves under medical therapy

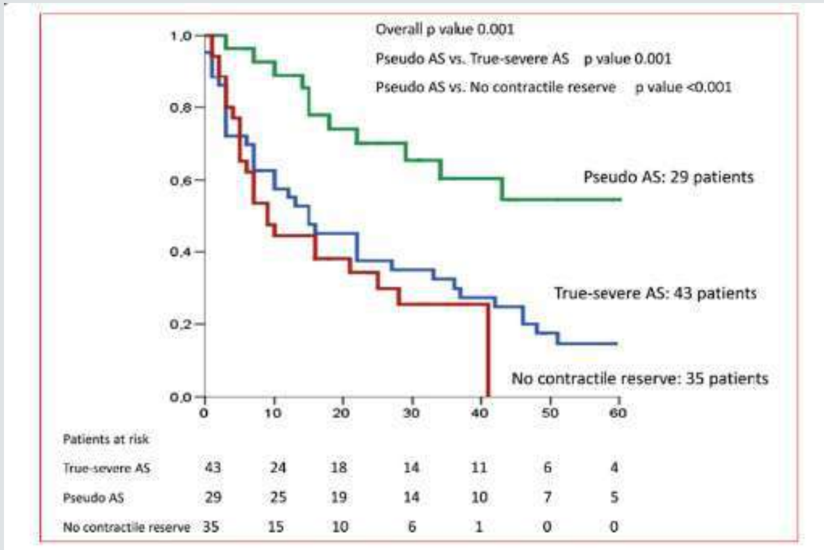
✓Valve replacement in pseudo-severe AS exposes patients to **surgical or procedural risk without clinical benefit**.
TOPAS Study (Clavel et al., JASE 2010)

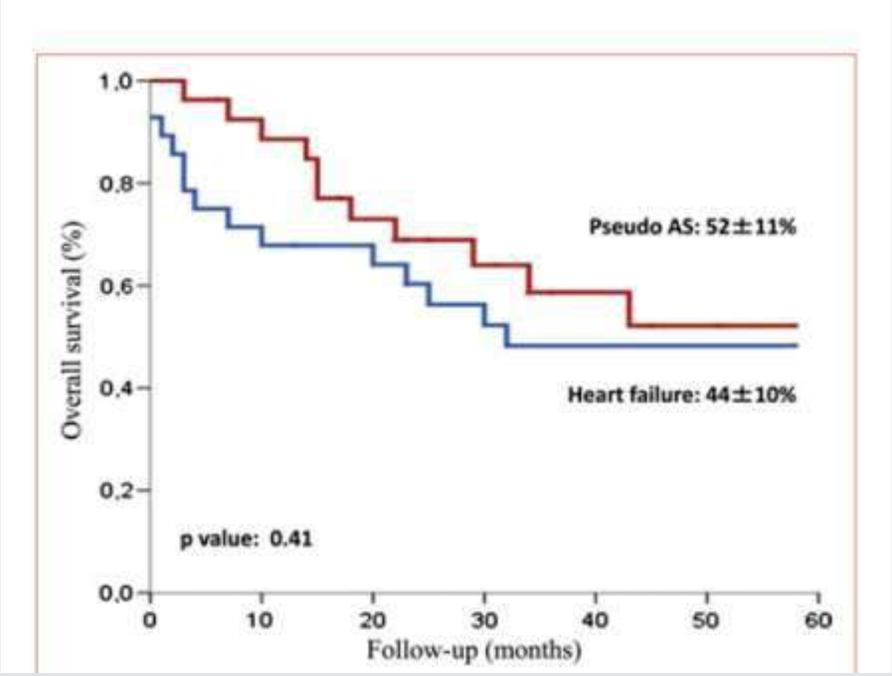
➢**True severe AS** patients had much higher **all-cause mortality** compared to pseudo-severe AS.

Clavel et al., JACC 2015 – Meta-analysis (n > 800)

Fougeres et al., Eur Heart J 2012

Patients with **pseudo-severe AS** managed medically had **significantly better survival** than those with **true severe AS**, even with flow reserve present.





The role of DSE in Risk Stratification

Identifies Contractile Reserve — A Powerful Prognostic Marker

Patients **with contractile reserve**

✓ Lower operative risk

✓Greater improvement in LVEF post-AVR

✓Better long-term survival

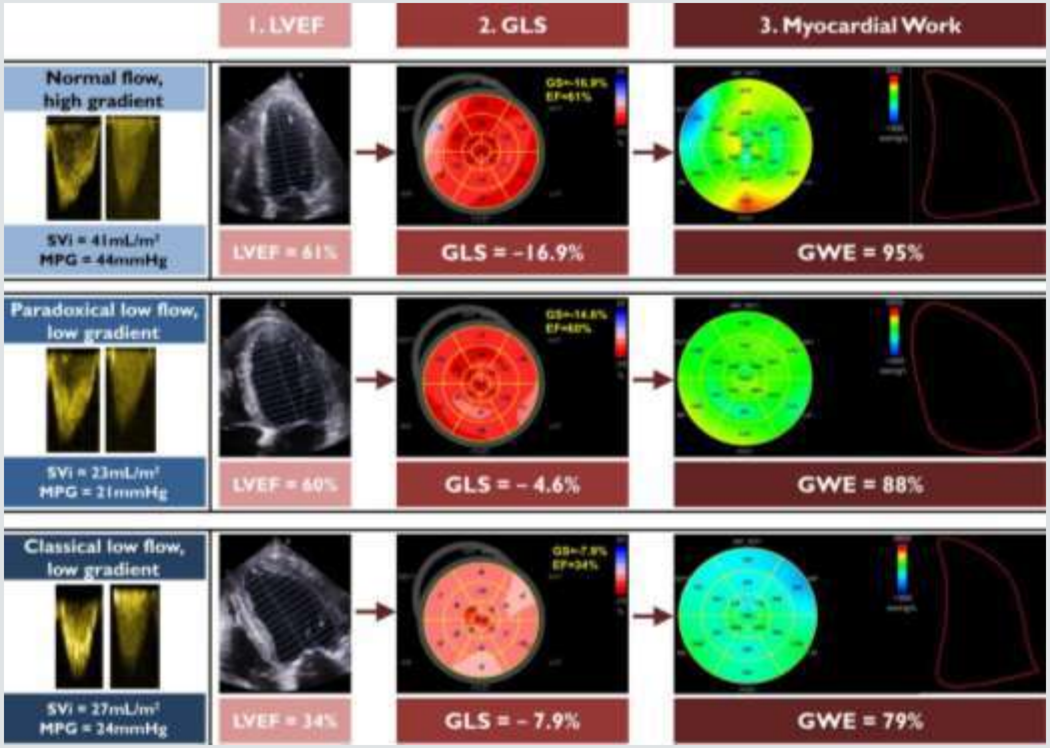
Patients without CR

✓ Higher perioperative mortality (up to 33% in earlier studies)
✓But **AVR may still be beneficial** in selected cases

CR+ associated with 5% surgical mortality vs 33% in CR− patients.

Monin et al., Circulation 2003:

Role of Strain Imaging in LF-LG Severe AS



- **Angle-independent and reproducible** assessment of myocardial function.
- Detects **subclinical LV dysfunction** even when **EF is preserved**.
- **Global longitudinal strain (GLS)** reveals:
  - Impaired deformation despite normal EF
  - Early marker of **fibrosis** and **hypertrophic remodeling**
- Critical in **paradoxical LF-LG AS** to assess **intrinsic myocardial diseas**

Lancellotti et al. (JACC, 2010)

- **GLS is significantly reduced** in LF-LG AS patients compared to normal-flow AS patients, despite similar LVEF.
- Impaired GLS correlated with **worse outcomes and symptom burden**.

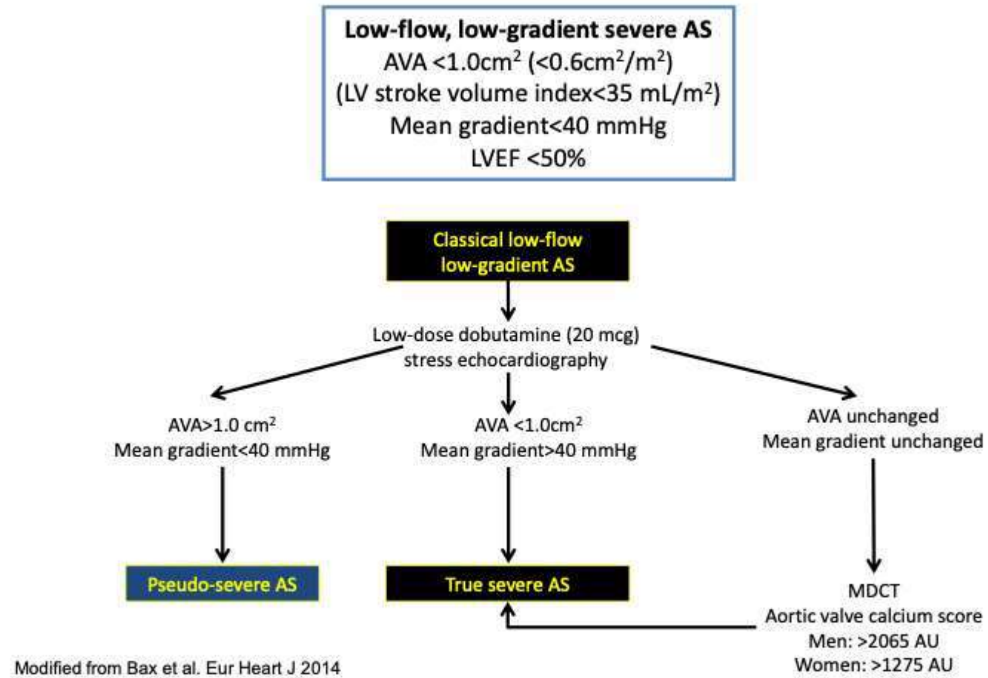
Lancellotti P et al. J Am Coll Cardiol. 2010;56(11):866–874. doi:10.1016/j.jacc.2010.02.077

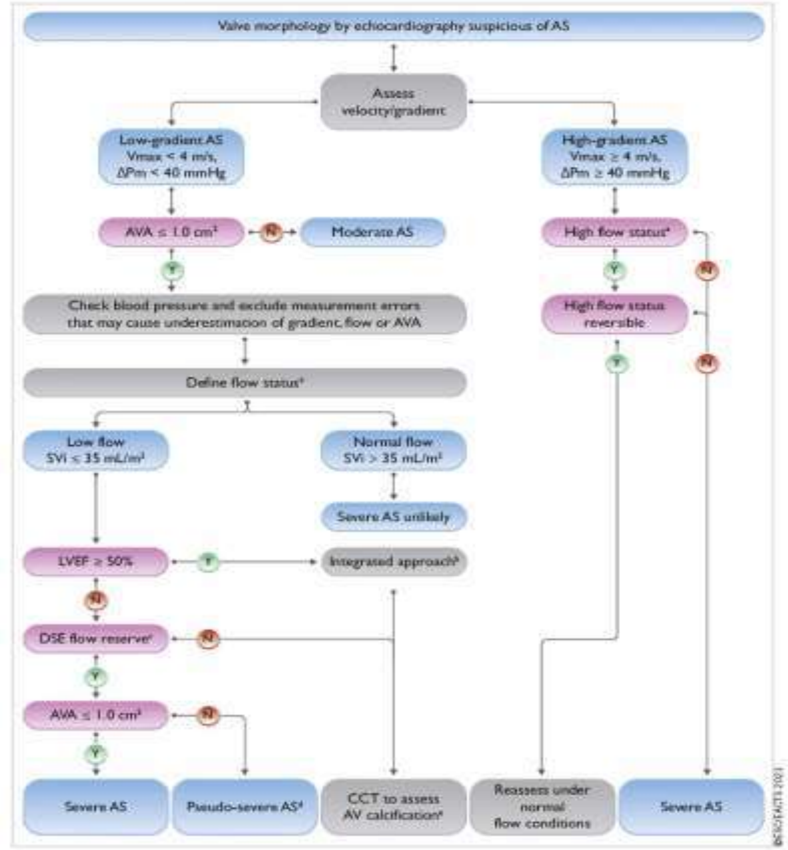
Bohbot et al. (JACC Cardiovasc Imaging, 2020)

- Studied LV mechanics using STE in patients with paradoxical LF-LG AS
- Found that **GLS <15%** was associated with **increased mortality** and **symptom progression**.

Bohbot Y et al. JACC Cardiovasc Imaging. 2020;13(1):101–113. doi:10.1016/j.jcmg.2019.01.036

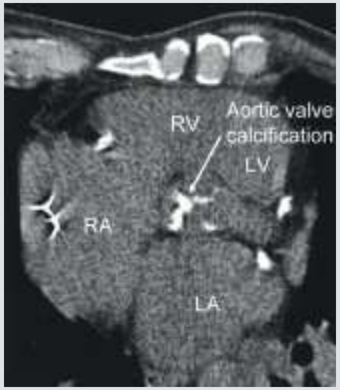
Algorithm for severe AS diagnosis in HF





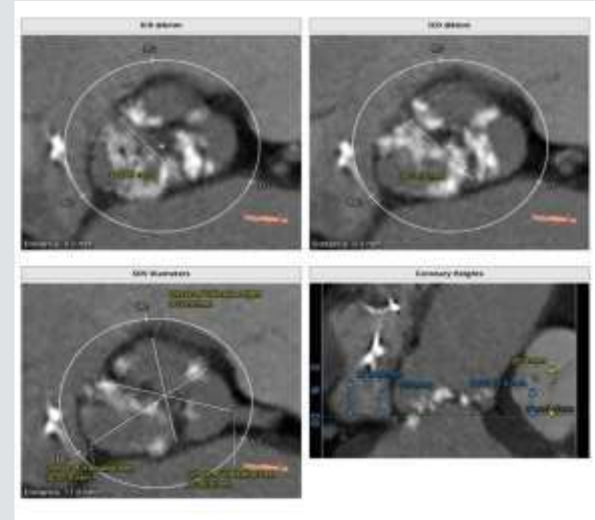
- If dobutamine stress echo is **inconclusive**, or there's **no change in valve area or gradient** ➡ we move to **MDCT** for further clarification

- Using **aortic valve calcium scoring**, MDCT helps confirm the diagnosis:



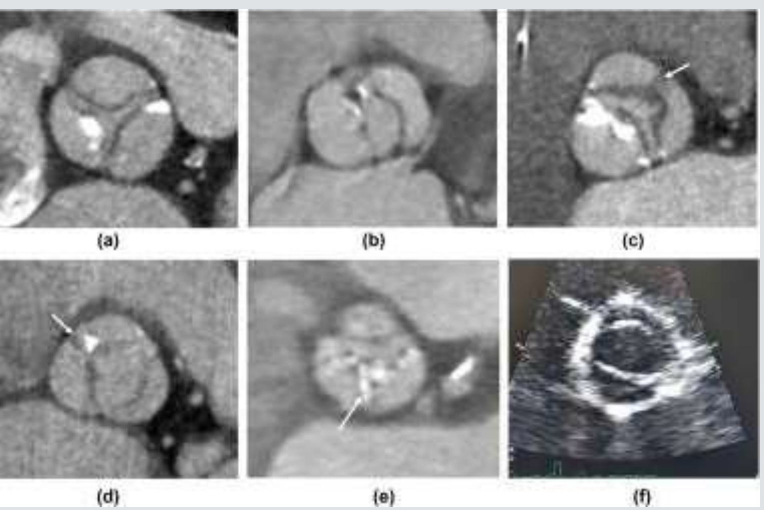
- Scores **above 2,065 AU in men** or **1,275 AU in women** support **true severe AS**.
- Scores below these suggest **pseudo-severe AS**.

CT ROLE IN AS



Structural Planning:

- **Gold standard** for TAVI preparation
- Accurately measures:
    - Aortic annulus diameter, area, and perimeter
    - Coronary ostia height
    - Aortic root dimensions
    - Access route suitability



Aortic Valve Calcium Score (Agatston Units):

- Used when AS severity is unclear (LFLG AS)
- Severe AS is **likely** if:
    - 2065 AU (men)
    - 1275 AU (women)

Additional Uses:

- Detection of valve and root calcification
- Prediction of complications (aortic rupture, annular dissection, paravalvular leak)

Limitations

- **Rheumatic AS**: Less accurate (due to fibrosis > calcification)

Study/Guideline	Women (AU)	Men (AU)	Notes
ESC Guidelines (2021)			Widely adopted clinical thresholds
Clavel et al., JACC 2013	≥1,274	≥2,065	Multicenter validation study
Pawade et al., JACC Imaging 2019	≥1,377	≥2,062	High diagnostic accuracy
Boulif et al., 2021	≥1,569	≥2,238	AUC: 0.94 for both sexes
Wang et al., Radiology 2021 (Meta-analysis)	Mean AVCS: 3,219 (Severe AS)	–	Pooled data from 12 studies
Nature Sci Rep 2023 (Degenerative AS)			Population-specific thresholds

Study	Population	Sensitivity (%)	Specificity (%)	AUC
Clavel et al.	Mixed (646)	83–84	88	~0.89
Pawade et al.	Prospective	84–85	87–88	~0.90
Boulif et al.	Diagnostic	—	—	0.94
Wang et al.	Meta (n > 4,000)	86	87	—

Clinical Implications of AVCS

- **Risk Stratification**:

Helps identify patients at **higher risk of adverse outcomes** after TAVI

- **Procedure Planning**:

High AVCS may guide **valve choice** and the need for **protective strategies** (to reduce paravalvular leak or annular rupture risk)

- **Patient Counseling**:

Supports informed discussions about **prognosis**, **TAVI risks**, and **expected outcomes**.

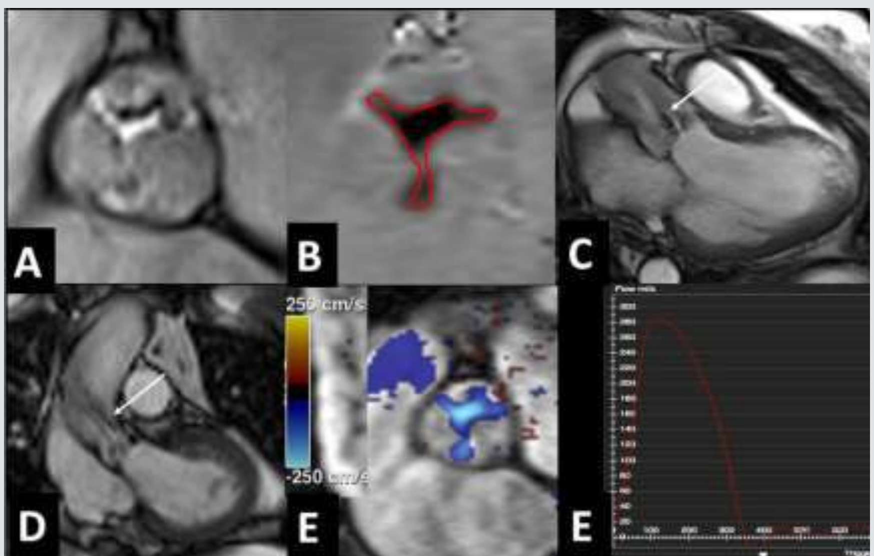
Cardiac MRI

➢ **LV Volumes and Function (Gold Standard)**

- Most accurate for LV mass, volumes, EF, and remodeling
- Useful when echo is limited or underestimates values

Myocardial Fibrosis Assessment

- **LGE** → detects replacement fibrosis (linked to poor outcomes)
- **T1 mapping / ECV** → quantifies early diffuse fibrosis
- Guides timing of AVR before irreversible damage



➢ **Valve Assessment and Flow Quantification**

- Measures AV velocity, stroke volume, and gradients
- Helpful in bicuspid valves or inconclusive Doppler studies

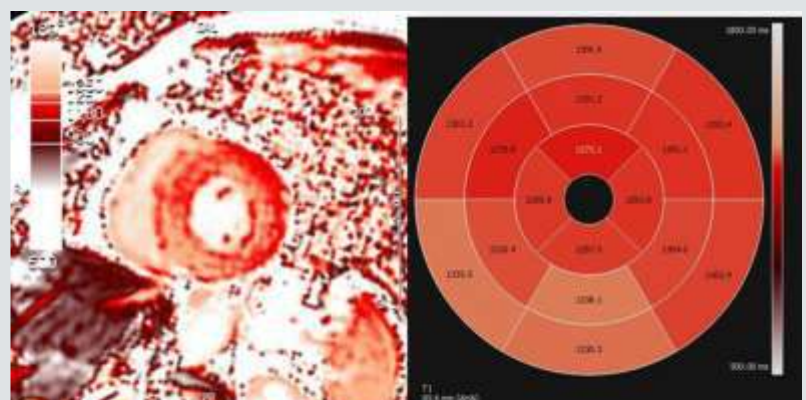
➢ **Differentiating AS Etiologies**

- Detects infiltrative cardiomyopathies (e.g., amyloidosis, HCM)
- **T1 mapping** can reveal ATTR amyloidosis in elderly LF-L AS

➢ **TAVR planning**

➢ **Post-TAVR assessment:**

Paravalvular leak (PVL)
Myocardial recovery



CMR Weaknesses

- Jet visualization is less clear on MRI compared to echo
- Lower spatial and temporal resolution
- Underestimates peak velocities
- Flow quantification may have errors

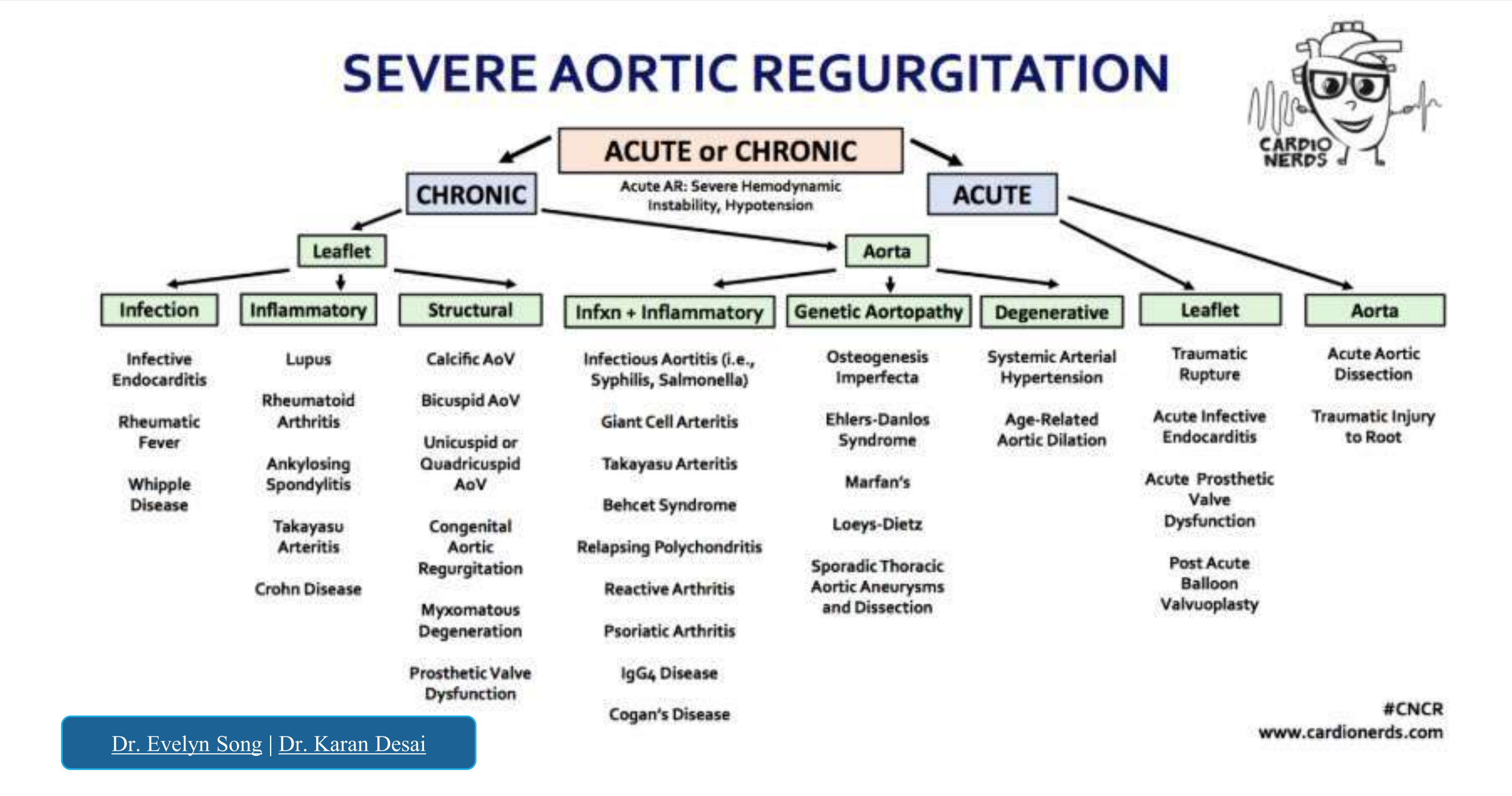
CMR Strengths

- Unlimited acoustic windows
- Excellent image quality (3D anatomy, SSFP, GRE)
- Accurate **flow quantification** with low observer variability
- **Gold standard** for LV/RV size and function
- Multiparametric approach (LGE, ischemia, T1 mapping)

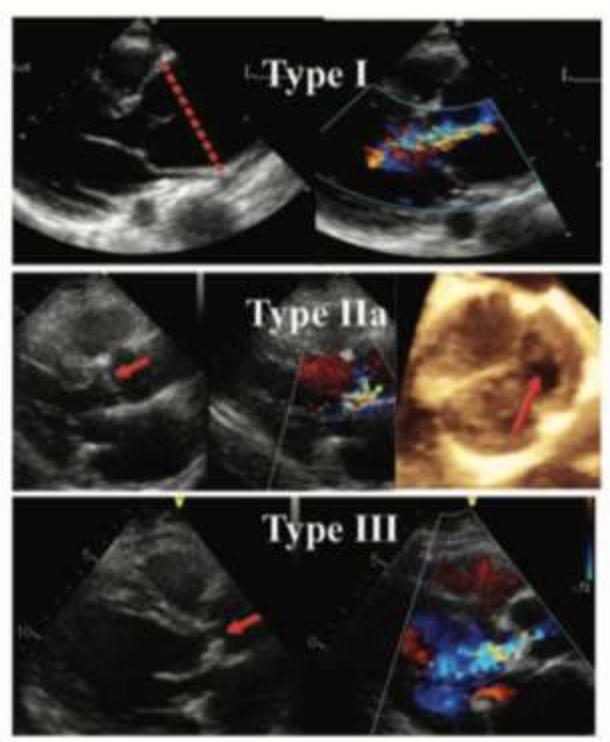
Take-Home Messages: Aortic Stenosis Imaging

- Use **multiple imaging tools** to assess and manage AS accurately
- **Echo** is first-line, but has limits in low-flow or poor windows
- **CT** confirms AS severity when echo is unclear; key for **TAVI planning**
- **DSE** helps distinguish **true vs. pseudo-severe AS** in low-flow states
- **CMR** offers precise LV data and detects **fibrosis or amyloidosis**
- Combined imaging improves diagnosis, guides therapy, and supports better outcomes

Aortic Regurgitation



Dr. Evelyn Song | Dr. Karan Desai



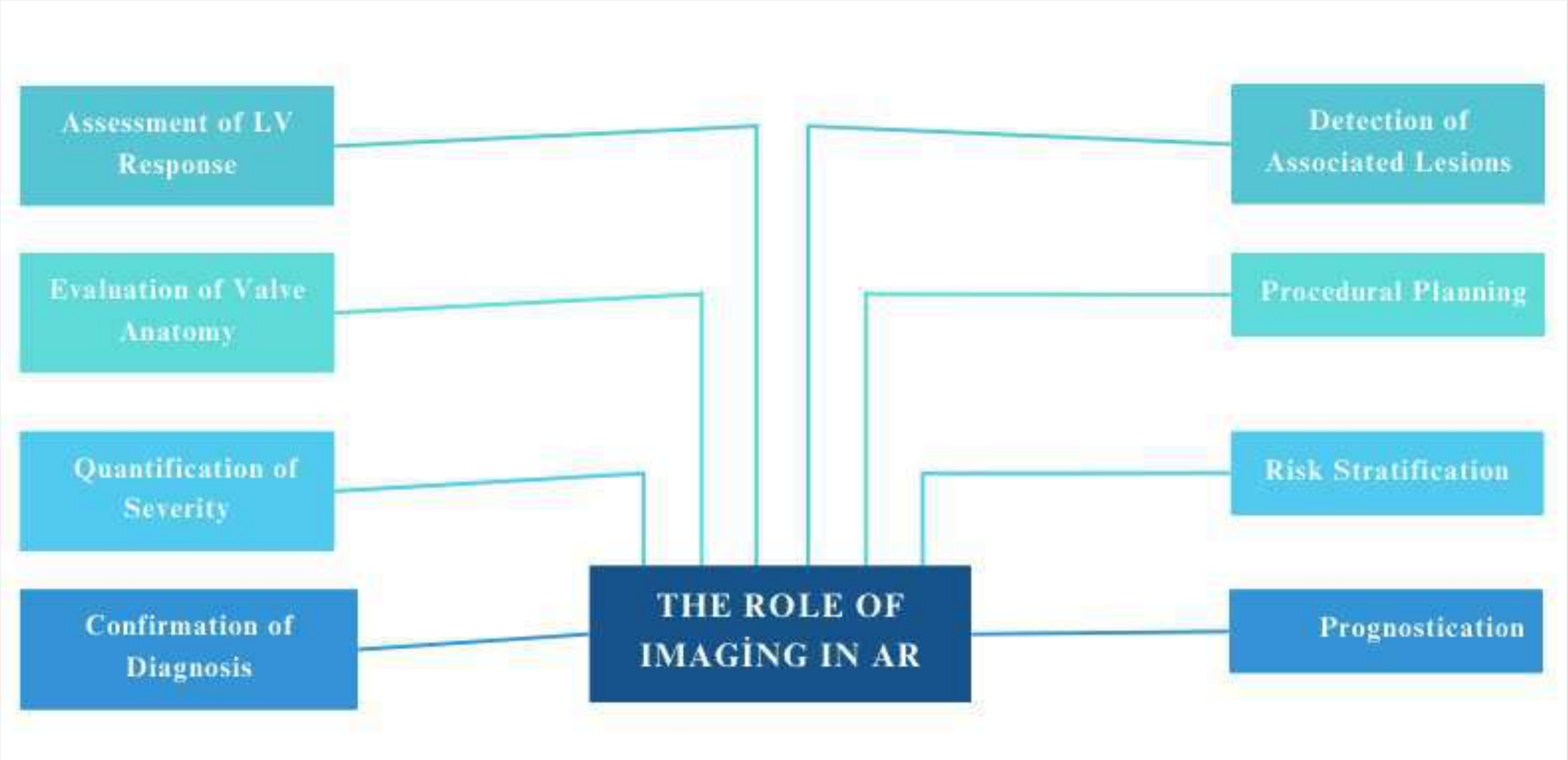
Qualitative	
Valve morphology	Abnormal/flail/large coaptation defect
Colour flow regurgitant jet area[a]	Large in central jets, variable in eccentric jets
CW signal of regurgitant jet	Dense
Other	Holodiastolic flow reversal in descending aorta (EDV >20 cm/s)
Semiquantitative	
Vena contracta width (mm)	>6
Pressure half-time[b] (ms)	<200
Quantitative	
EROA (mm^2)	≥30
Regurgitant volume (mL/beat)	≥60
Enlargement of cardiac chambers	LV dilatation

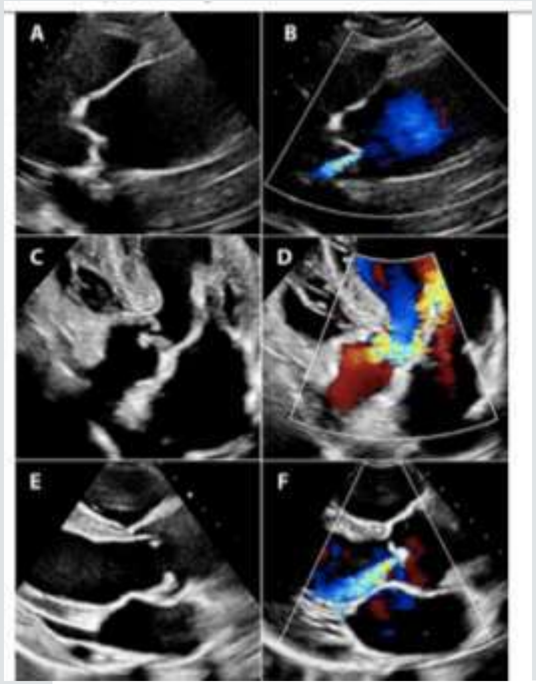
Table 3 **Functional classification of AR lesions**

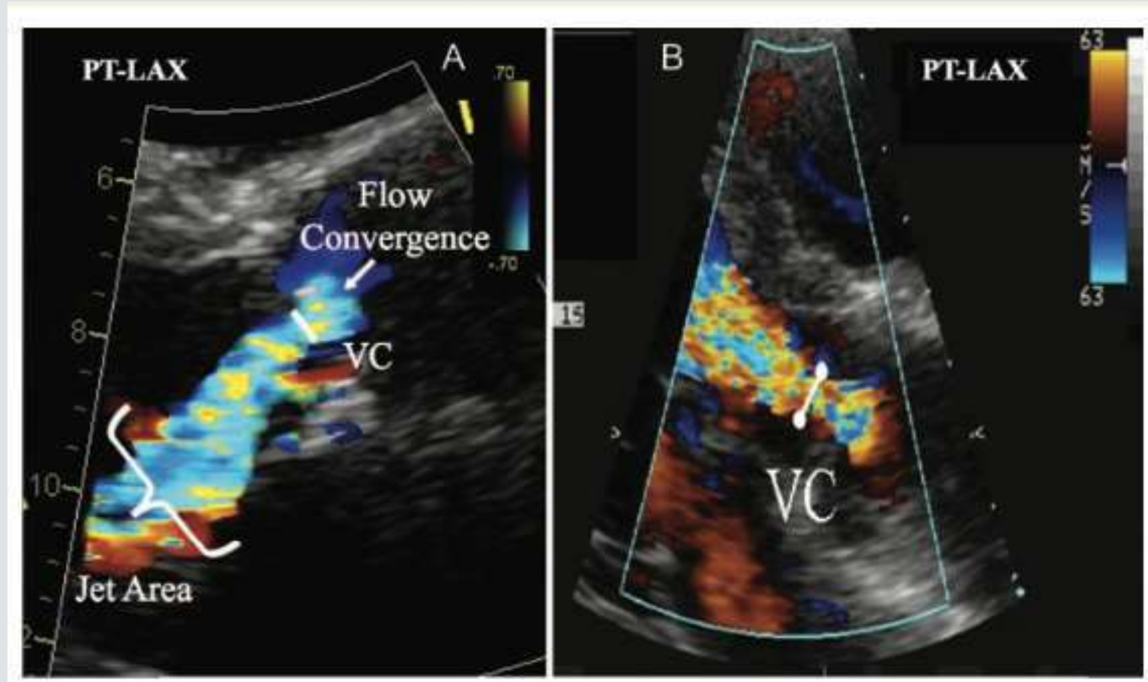
Dysfunction	Echo findings
Type I: enlargement of the aortic root with normal cusps	Dilatation of any components of the aortic root (aortic annulus, sinuses of valsalva, sinotubular junction)
Type IIa: cusp prolapse with eccentric AR jet	
Cusp flail	Complete eversion of a cusp into the LVOT in long-axis views
Partial cusp prolapse	Distal part of a cusp prolapsing into the LVOT (clear bending of the cusp body on long-axis views and the presence of a small circular structure near the cusp free edge on short-axis views)
Whole cusp prolapse	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 AR jet without definite evidence of cusp prolapse
Type III: poor cusps quality or quantity	Thickened and rigid valves with reduced motion Tissue destruction (endocarditis) Large calcification spots/extensive calcifications of all cusps interfering with cusp motion

The degree of calcification of the aortic valve is scored 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.

IMAGING IN AR







Parameters	Mild	Moderate	Severe
Qualitative			
Aortic valve morphology	Normal/Abnormal	Normal/Abnormal	Abnormal/flail/large coaptation defect
Colour flow AR jet width[a]	Small in central jets	Intermediate	Large in central jet, variable in eccentric jets
CW signal of AR jet	Incomplete/faint	Dense	Dense
Diastolic flow reversal in descending aorta	Brief, protodiastolic flow reversal	Intermediate	Holodiastolic flow reversal (end-diastolic velocity >20 cm/s)
Semi-quantitative			
VC width (mm)	<3	Intermediate	>6
Pressure half-time (ms)[b]	>500	Intermediate	<200
Quantitative			
EROA (mm^2)	<10	10–19; 20–29[c]	≥30
R Vol (mL)	<30	30–44; 45–59[c]	≥60
+LV size[d]			

Table 2 Echocardiographic parameters used to quantify regurgitation severity: advantages and limitations

Parameters	Usefulness/advantages	Limitations
Valve morphology	Flail valve is specific for severe regurgitation (i.e. ruptured PMs in MR)	Other abnormalities are non-specific for severe valvular regurgitation
Tricuspid annulus diameter in TR	Dilatation sensitive for severe TR	Dilatation seen in other conditions Need to be confirmed in further studies
Colour flow regurgitant jet	Ease of use Evaluates the spatial orientation of regurgitant jet Good screening test for mild vs. severe regurgitation	Can be inaccurate for estimation of regurgitation severity Influenced by technical and haemodynamic factors Expands unpredictably below the orifice in AR or PR Underestimates eccentric jet adhering the atrial wall (Coanda effect) in MR or TR
VC width	Relatively quick and easy Relatively independent of haemodynamic and instrumentation factors Not affected by other valve leak Good for extremes regurgitation: mild vs. severe Can be used in eccentric jet	Not valid for multiple jets Small values; small measurement errors leads to large % error Intermediate values need confirmation Affected by systolic changes in regurgitant flow Lacks published data in PR
PISA method	Can be used in eccentric jets Not affected by the aetiology of regurgitation or other valve leak Quantitative: estimates lesion severity (EROA) and volume overload (R Vol) Flow convergence at 50 cm/s alerts to significant MR Large flow convergence at 28 cm/s alerts to significant TR	PISA shape affected by the aliasing velocity in case of non-circular orifice by systolic changes in regurgitant flow by adjacent structures (flow constraints) PISA radius is more a hemi-ellipse Errors in PISA measurement are squared Inter-observer variability Not valid for multiple jets Feasibility limited by aortic valve calcifications in AR Validated in only few studies in TR Lacks published data in PR
CW regurgitant jet profile	Simple, easily available	Qualitative, complementary finding Complete signal difficult to obtain in eccentric jet
Pressure half-time in AR or PR	Simple	Affected by LV compliance, blood pressure, acuity
Diastolic flow reversal in the descending aorta in AR	Simple	Affected by sample volume location and acuteness of AR Affected by aortic compliance. Brief velocity reversal is normal Cut-off validated for distal aortic arch
Pulmonary vein flow in MR	Simple Systolic flow reversal is specific for severe MR	Affected by LA pressure, atrial fibrillation Not accurate if MR jet is directed into the sampled vein
Hepatic vein flow in TR	Simple Systolic flow reversal is specific for severe TR	Affected by RA pressure, atrial fibrillation
Peak E velocity in MR or TR	Simple, easily available Usually increased in severe regurgitation	Affected by atrial pressure, atrial fibrillation, ventricular relaxation Complementary finding
Atrial and ventricular size	Dilatation is sensitive for chronic severe regurgitation Normal size almost excludes severe chronic regurgitation	Dilatation observed in other conditions (non-specific) May be normal in acute severe regurgitation

TOE

- **Suboptimal TTE images**
- **Unclear mechanism** of AR
- **Suspected infective endocarditis**
- **Pre-surgical or pre-TAVI planning**
- **Prosthetic valve regurgitation assessment**
- When **AR severity is discordant** with clinical findings

Advantages of TOE in AR

- **High-resolution imaging** of:
  - Aortic valve anatomy and leaflet motion
  - Commissures, fenestrations, prolapse or flail
- **Superior visualization of:**
  - **Eccentric jets**
  - **Vegetations**, leaflet perforation, and abscesses
  - **Aortic root and ascending aorta dimensions**

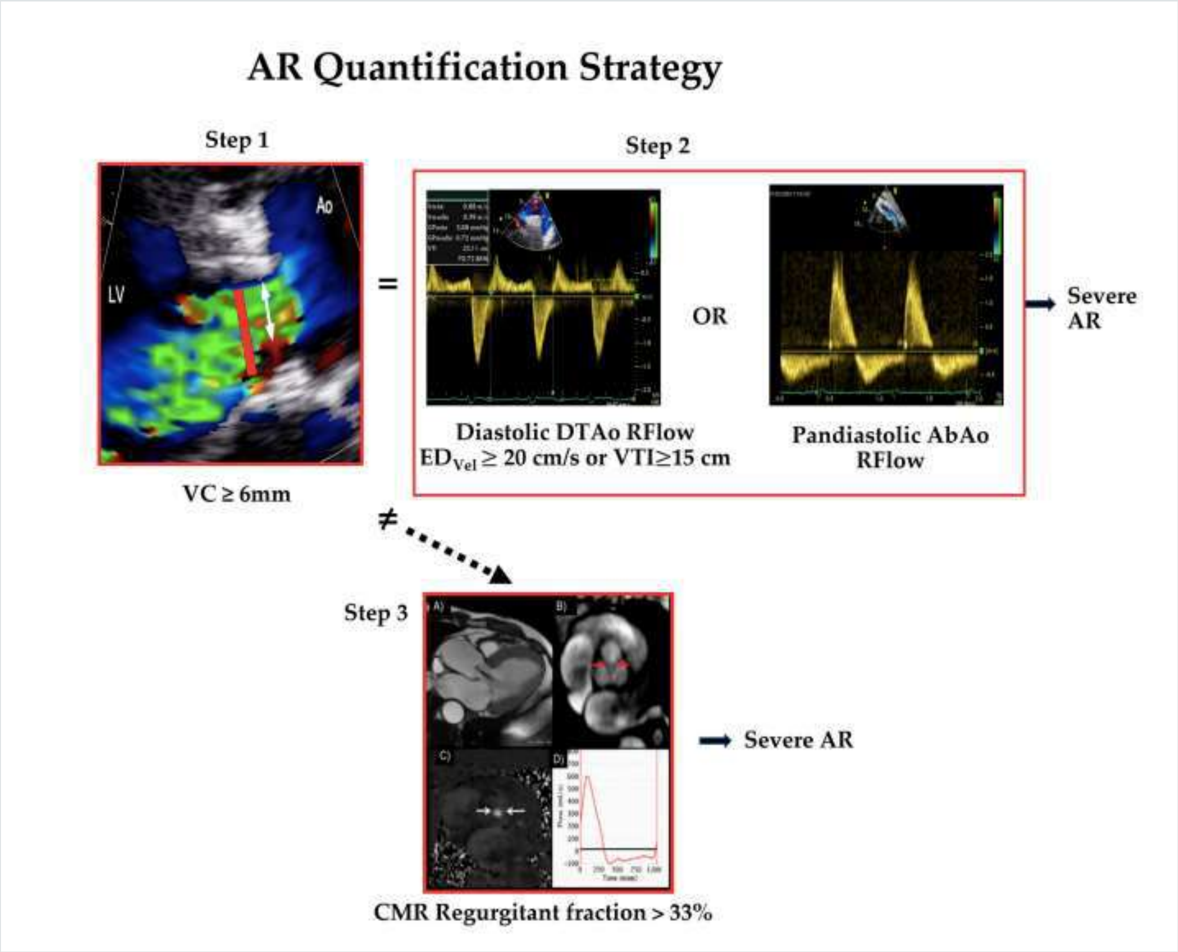
Better alignment of Doppler beam for pressure half-time and CW Doppler if apical TTE views are inadequate

What TOE Adds to AR Quantification

- Confirms jet origin and direction
- Assesses **coaptation defects, cusp prolapse**
- Evaluates **valve repair feasibility** (especially in isolated AR)
- May improve assessment of **Vena Contracta width**
- Complements 3D imaging when available

Limitations of TOE

- Semi-invasive; requires sedation
- Not ideal for continuous monitoring or serial follow-up
- May have limited field of view for distal aorta unless complemented with other modalities



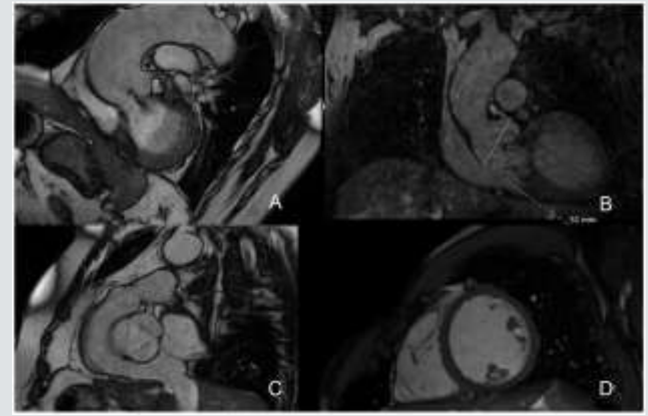
When is CMR Recommended?
ACC/AHA and ESC/EACTS when:

- **TTE or TOE is inconclusive**
- Additional quantification or anatomic detail is needed
- **Preoperative planning** for chronic AR with LV remodeling

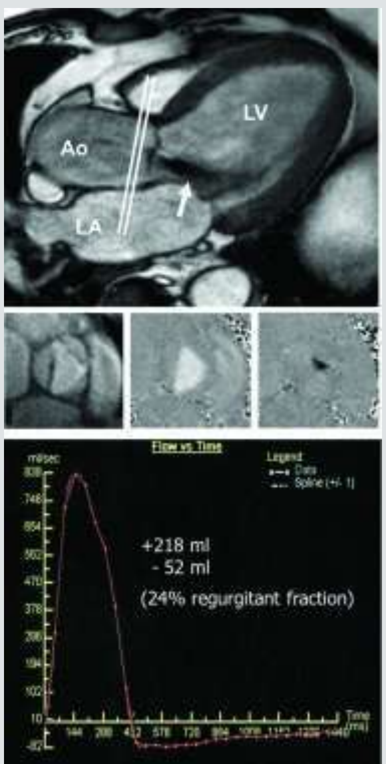
What Can CMR Do in AR?

Accurately assesses:

- ➢Regurgitant Volume and Regurgitant Fraction
- ➢Mechanism of AR
- ➢LV and aortic root morphology
- ➢Thoracic aorta dimensions



Quantification done using **2D phase contrast imaging** at the sinotubular junction



Key Parameters and Thresholds

CMR Regurgitant Fraction :

- ➢**RF >33–35%** → indicates **significant/severe AR**
- ➢RF values correlate better with **3D echo** than with 2D echo

Holodiastolic flow reversal in proximal descending aorta:

- ➢Strong prognostic marker
- ➢Associated with **2.8× increased risk** of death or HF hospitalization

Technical Considerations and Limitations

- Ensure **perpendicular imaging plane** at the aorta to avoid underestimation
- **AS + AR** → requires additional obtainings at LVOT/aortic annulus
- **Patient positioning** (at isocenter) and **background correction** are essential to reduce measurement error
- **Atrial fibrillation** → requires multiple cycle averaging for accuracy

Myerson et al.

Finding: A CMR-derived regurgitant fraction (**CMR-RF**) >33% strongly predicts need for surgery.

Clinical Outcome:

- 85% of patients with **CMR-RF >33%** required surgery
- Only 8% with **CMR-RF ≤33%** progressed to surgery

Relevance: Suggested **33% as a clinically meaningful CMR-RF threshold** for significant AR.

Vejpongsa et al.

Finding: Showed that a **CMR-RF threshold of 35%** is a more **sensitive indicator** of severe AR than the echo threshold (RF >50%).

Relevance: Emphasized that the **CMR cut-off for severity may be lower than echo**, and better reflects early LV remodeling.

Cardiac CT

- **Not a first-line tool** for AR severity grading due to lack of **Doppler** and **flow assessment**

- **Best used for anatomical evaluation**, especially when echo or CMR is limited

It has some strengths like:

High-resolution imaging of:

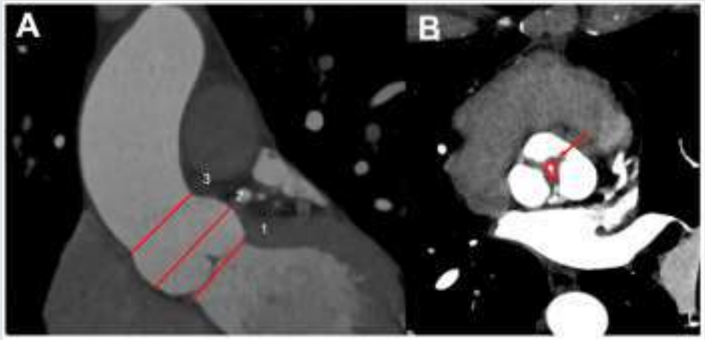
- Aortic valve morphology (e.g., cusp prolapse, calcification)
- Aortic root and ascending aorta dimensions
- Aortic root structure in connective tissue disease or aortopathy

Geometric measurement of regurgitant orifice area (ROA)

- Helpful when echo windows are poor or jets are eccentric

Multiplanar reconstruction provides accurate and reproducible sizing

- **Useful in preoperative planning**, especially in patients with LV remodeling or aortic dilation



It has some limitations:

ROA by CT is often overestimated, particularly in:

- **Eccentric jets**
- **Heavy calcification**
- **Cusp prolapse**

Cannot assess regurgitant volume or pressure gradients
Should be interpreted **with echo and CMR** findings whenever possible

Diagnostic Evaluation of LV Response and Remodeling in AR

Why It Matters

- **LV response to AR** is central to risk stratification and surgical timing
- **Chronic AR** → progressive **volume overload** → LV dilation → **systolic dysfunction** → heart failure.
- The goal is **early detection of subclinical dysfunction** before irreversible remodeling.

Echocardiographic Assessment

Linear Dimensions

➢**LVEDD and LVESD**: Historically used, reproducible, and guideline-supported.

➢**LVESD is a stronger predictor of outcomes** than LVEDD.

➢**LVESDi ≥25 mm/m²** is the current surgical cut-off per ACC/AHA & ESC/EACTS guidelines.

Evidence for Lower Cutoffs

➢**Mentias et al.**: LVESDi >20 mm/m² → higher mortality

➢**Yang et al.**: Mortality significantly increases between LVESDi 20–25 mm/m² (HR 1.53) and >25 mm/m² (HR 2.23).

Limitations

➢2D measurements may underestimate LV size in **asymmetric dilation**

➢May be unreliable in poor acoustic windows or with **septal hypertrophy**

Volumetric Echocardiography (2D & 3D)

- **LV volumes (LVEDV, LVESV)** are **more reflective of AR burden** than linear dimensions

- **Contrast-enhanced echo** improves volumetric accuracy

- **3D Echo** approaches CMR accuracy but depends on image quality.

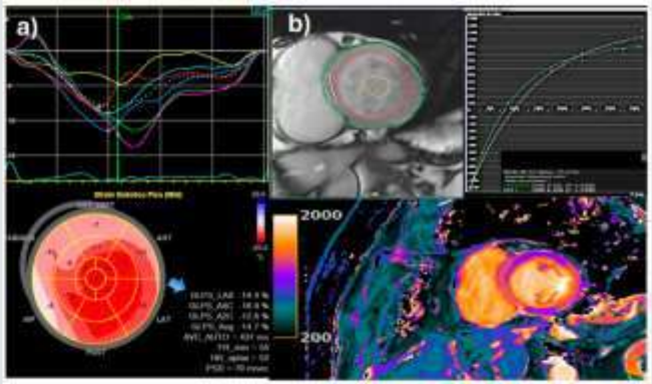
Strain Imaging: Speckle Tracking (GLS)

➢**GLS is an early marker of dysfunction** even with preserved EF

➢**Worsening GLS (−15% to −19%)** is linked to:

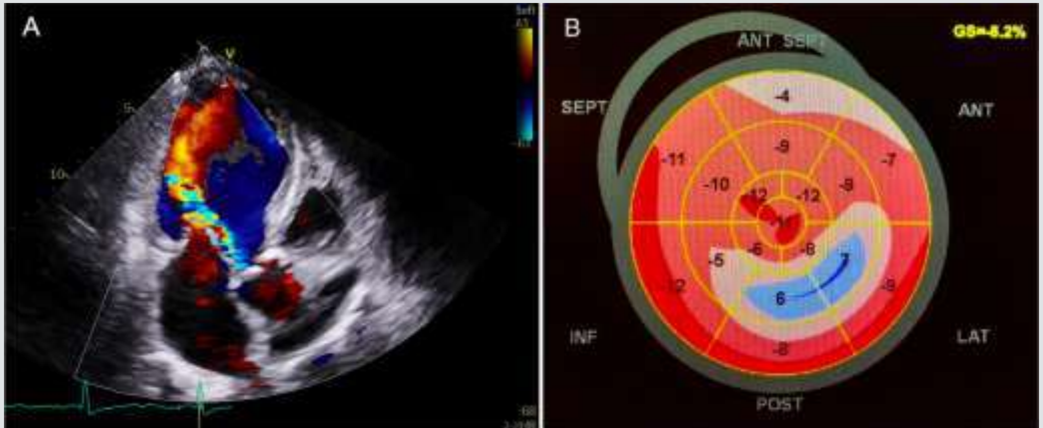
- Disease progression
- Poor surgical outcomes
- Higher mortality (2.6–4× increased risk).

➢**ΔGLS >5% post-AVR** → have worse long-term survival.



LV Myocardial Work Index (MWI) and **Constructive Work**:

- Independent of preload/afterload
- Correlate with AR severity
- Predict postoperative remodeling.



CMR: The Gold Standard for LV Remodeling

- **CMR > Echo** for volume reproducibility and accuracy
- **LVESVi >45 mL/m²** and **LVEDVi >129–155 mL/m²** indicate poor prognosis and reverse remodeling
- **CMR-derived volumes outperform Echo** in identifying symptomatic progression
- **Late Gadolinium Enhancement (LGE)** identifies **replacement fibrosis**
- **ECV >30 mL/m²** → associated with adverse outcomes.

Age and Sex-Specific Remodeling

- **Women and older adults** often show **blunted LV dilation**, which may delay referral
- Thresholds for intervention may need **sex-specific adjustment**

Take-Home Points: Imaging in Aortic Regurgitation

- Start with TTE
- Always integrate multiple parameters
- Assess LV remodeling early
- Use GLS even EF is preserved
- CMR is gold standard for volumes and regurgitant fraction
- TOE adds value when TTE is inconclusive
- CT is best for aortic anatomy, not severity
- Use a multimodal approach

Meet Our Structural Heart Team

Thank You for Your Attention