Optimising echocardiography

to support aortic stenosis assessment and severity grading

Edwards

The ongoing challenge of distinguishing severe from less than severe aortic stenosis

- Patients are graded as having severe aortic stenosis (sAS) when they meet both the haemodynamic criteria (V_{max} ≥4 m/s or mean gradient ≥40 mm Hg) and aortic valve area (AVA) criteria (≤1 cm^2)[1]
- However, evidence suggests patients with discordant indices of V_{max} 3.0–3.9 m/s and AVA ≤1 cm^2 may have sAS if certain criteria apply[1,2]
  - For these patients, clinical echocardiography (echo) reports characterising the discordant indices as less than severe, could have adverse clinical consequences[2]

In a retrospective analysis of echocardiographic data from 807 patients with AS[2]

↓

Patients with discordant indices were found to be less commonly characterised as having sAS on an echocardiography report despite meeting echocardiographic criteria for sAS[2]

! It is vital all patients with sAS are identified to ensure they receive the treatment they need[3,4]

View subgroups of indices that could indicate sAS ›

References: 1. Baumgartner H, et al. Eur Heart J Cardiovasc Imaging. 2017;18(3):254–275. **2.** Raddatz MA, et al. Open Heart. 2020 Aug;7(2):e001331. **3.** Otto CM. Heart 2000;84(2):211–218. **4.** Thoenes M, et al. J Thorac Dis. 2018; 10(9): 5584–5594.

Echocardiography is key for assessing and grading AS

An integrated, stepwise approach that uses multiple indices* is recommended when assessing and grading AS in clinical practice[1]

Echocardiography can be used to[2]

- Confirm the presence of AS
- Assess the degree of valve calcification, left-ventricular (LV) function and wall thickness
- Detect the presence of other associated valve disease or aortic pathology and provides prognostic information

Optimal imaging is needed to determine timing of intervention for sAS, which – once symptomatic – is crucial for survival

*Transvalvular velocity/gradient, AVA, valve morphology, flow rate, LV morphology and function, blood pressure and symptoms.

References: 1. Baumgartner H, et al. Eur Heart J Cardiovasc Imaging. 2017;18(3):254–275. **2.** Baumgartner H, et al. Eur Heart J. 2017 Sep 21;38(36):2739–2791.

Optimising assessments with echocardiography

Edwards

A stepwise approach is recommended when grading AS

- Both the EACVI and ESC/EACTS recommend a stepwise approach to assessing AS severity using echocardiography[1,2]
- As high gradient generally indicates sAS,[1] this guide focusses on the low gradient track and the measurements needed to confirm true sAS:

Step 1:

Calculating mean gradient and peak velocity

Step 2:

Measuring left-ventricular outflow tract (LVOT) and LVOT velocity time integral (VTI) to calculate AVA

Step 3:

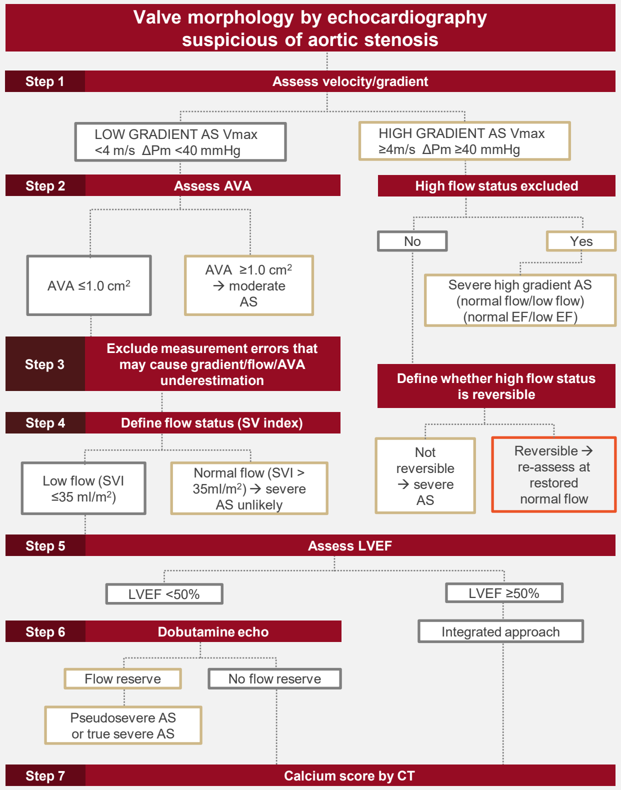
Excluding measurement errors to ensure the identified discordant indices are correct i.e., low velocity/gradient where AVA <1cm^2

Step 4:

Defining flow status by calculating the stroke volume index (SVi)

Step 5:

Assessing LV ejection fraction (LVEF) to identify patients with true sAS (including the use of dobutamine echocardiography [**Step 6**] and calcium score [**Step 7**])



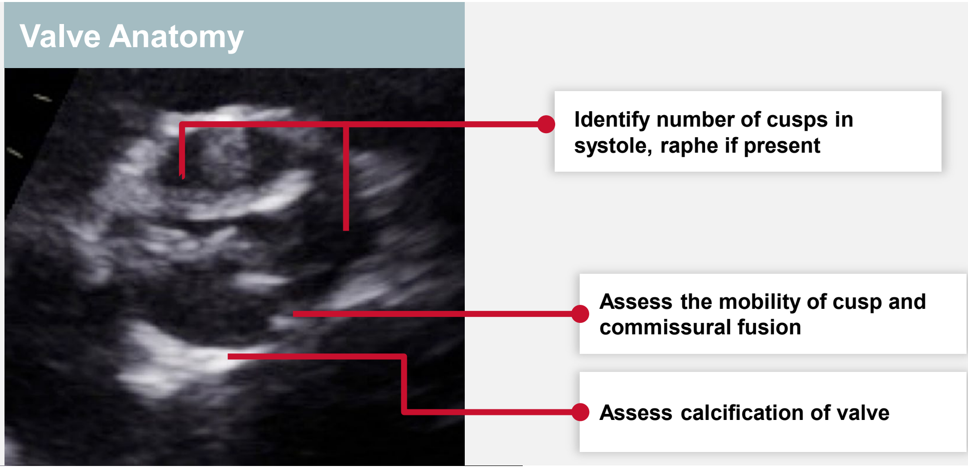
Adapted from Baumgartner H. et al. 2017.[2]

EACTS, European Association for Cardio-Thoracic Surgery; EACVI, European Association of Cardiovascular Imaging; ESC, European Cardiology Society.

References: 1. Baumgartner H, et al. Eur Heart J Cardiovasc Imaging. 2017;18(3):254–275. **2.** Baumgartner H, et al. Eur Heart J. 2017 Sep 21;38(36):2739–2791.

Before taking measurements: Confirming visual signs of AS

Check if the valve has visual signs of AS (i.e. signs of calcification and little exertion of the leaflets) to identify who has sAS and requires further assessment[1]



Adapted from Ring L, et al. 2021.[2]

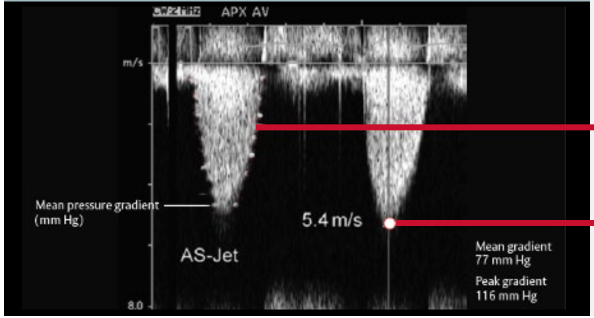
View the visual signs of AS on aortic valve anatomy at different AS severities

References: 1. Baumgartner H, et al. Eur Heart J Cardiovasc Imaging. 2017;18(3):254–275. **2.** Ring L, et al. Echo Res Pract. 2021; 8(1); G19–G59.

Step 1: Measuring mean gradient and peak velocity

To measure mean gradient, obtain the highest velocity using continuous wave (CW) doppler and use multiple acoustic windows *(e.g. apical, suprasternal, right-parasternal)*

AV jet velocity and VTI-CW Doppler sample



Trace around the outer edge of dense signal to obtain VTI

Take maximum velocity measurement from the peak of dense velocity curve

Adapted from Baumgartner H, et al. 2017[1]

To improve data acquisition

- Optimise the signal by decreasing gain, increasing wall filter and adjusting baseline curve and scale
- Use grey scale spectral display with expanded time scale
- Adjust the velocity range and baseline so that the velocity signal fits but fills the vertical scale

To optimise measurement

- Measure the maximum velocity at the peak of dense velocity curve. Be careful to avoid noise and fine linear signals
- Trace around the outer edge of the dense signal to obtain VTI
- Calculate mean gradient from the traced velocity curve
- Report window where maximum velocity is obtained

View jet velocity at different AS severities

Reference: 1. Baumgartner H, et al. Eur Heart J Cardiovasc Imaging. 2017;18(3):254–275

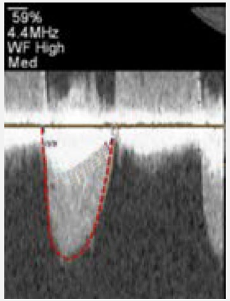
Pitfalls to avoid when measuring velocity and mean gradient

Avoiding the following pitfalls during CW doppler acquisition and utilising multiple windows will help to optimise assessments

Pitfall to avoid & incorrect example

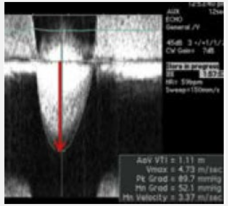
AS severity can be underestimated if imaging of the vena contracta (the narrowest and highest velocity portion of the jet) is off-axis[1]

- The presence of a faint transaortic flow (red trace) may indicate that the insonation beam is angled away from the vena contracta[1]



The direction of the transaortic jet may often be anterior and to the right[1]

- The severity of AS in up to 50% of patients could be underestimated if the peak velocity is measured from a single apical window[1]



Measurement limitations[2]

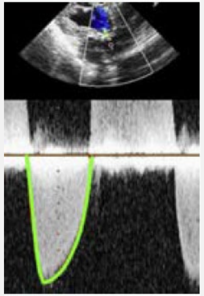
VELOCITY/GRADIENT

- Parallel alignment of the ultrasound beam is required for correct measurement
- Flow dependent
- The accuracy of the pressure gradients is dependent on accurate velocity

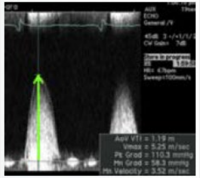
Correct measurement & example

Adjust the imaging window to find the most dense and uniform continuous-wave spectral profile[1]

Use multiple acoustic windows (e.g. apical, suprasternal and right parasternal) during the CW doppler assessment to minimise errors[2]



For example, in the example here the right parasternal window showed peak velocities that were 0.5 m/sec higher. Demonstrating why the use of multiple acoustic windows is recommended[1]



All images Hahn RT, et al. 2018.[1]

References: 1. Hahn RT, et al. J Am Soc Echocardiogr. 2018;31(4):405–433. **2.** Baumgartner H, et al. Eur Heart J Cardiovasc Imaging. 2017;18(3):254–275.

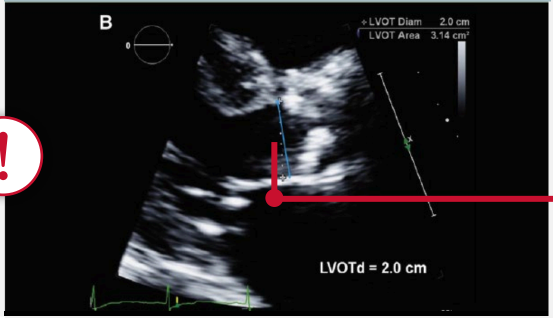
Step 2a: Measuring LVOT and LVOT VTI

To calculate AVA and other indices

Take LVOT diameter measurements in the parasternal long axis (PLAX) view[1]

!

LVOT diameter CSA



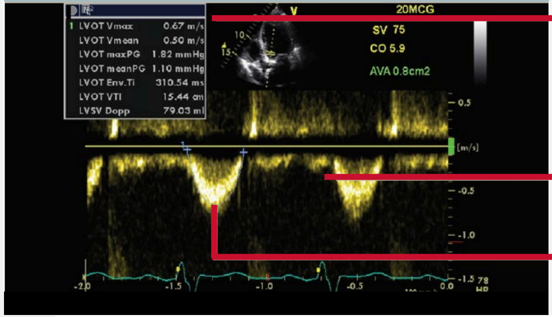
Adapted from Baumgartner H. et al. 2017.[1]

Take LVOT diameter measurements at the same anatomic level as the velocity recording

- Diameter is used to calculate a circular cross-sectional area (CSA)
- Measure from the inner edge of the septal endocardium and the anterior mitral leaflet in the mid-systole (blue arrow)
- Take the measurement parallel and adjacent to the aortic valve or at the site of the velocity measurement

Measure LVOT VTI using pulsed wave (PW) doppler and apical long-axis or 5-chamber view

LVOT VTI – PW – Doppler sample



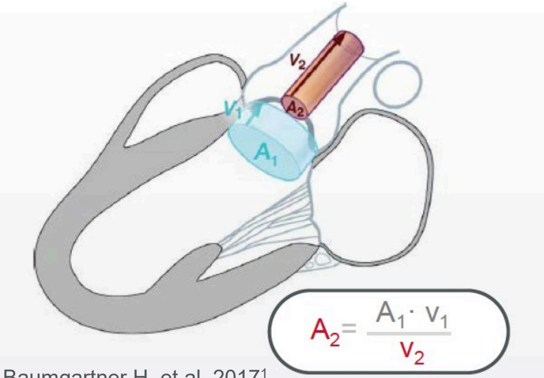
- Report window where maximum velocity and mean gradient are obtained
- Trace around the outer edge of dense signal to obtain VTI
- Measure the maximum velocity at the peak of dense velocity curve. Be careful to avoid noise and fine linear signals

Pitfalls to avoid when measuring LVOT

Reference: 1. Baumgartner H, et al. Eur Heart J Cardiovasc Imaging. 2017;18(3):254–275.

Step 2b: Calculating AVA

To assess if a patient with low gradient AS is at risk of sAS, calculate the AVA using the continuity equation.



Baumgartner H, et al. 2017[1]

- **The continuity equation is based on conservation of mass and assumes that the stroke volume ejected through the LVOT all passes through the AVA[1]**
- **The equation requires the following measurements:[1]**
  - **A_1 = LVOT diameter** for calculation of circular cross sectional area
  - **V_1 = LVOT (peak V & VTI)** recorded with PW doppler
  - **V_2 = AV (peak V & VTI)** recorded with CW doppler

Step 3: Excluding measurement errors

To identify who has moderate AS and might have sAS with discordant indices

A major limitation of the standard continuity equation is the assumption of a circular outflow tract shape, despite LVOT becoming progressively more elliptical (rather than circular) in many patients[1]

Consequently, when LVOT diameter is squared for the calculation of cross-sectional area, it has the potential to be the greatest source of measurement error in the continuity equation[1]

LVOT VTI

Can give you cardiac output

Stroke volume = LVOT area x LVOT VTI.
Cardiac output is = Heart rate x stroke volume

Reference: 1. Baumgartner H, et al. Eur Heart J Cardiovasc Imaging. 2017;18(3):254–275.

Step 4: Defining flow status

An AVA ≤1.0 cm^2 suggests but does not confirm sAS, therefore it is important to exclude measurement errors and define flow status using SVi[1]

- SVi is calculated as: SVi = Stroke volume in mL / Body surface area in m^2
- If SVi is normal (>35 mL/m^2) sAS is unlikely even if AVA is calculated as ≤1.0 cm^2
- As many as 35% of sAS patients may be in a low-flow state (SVi ≤35 mL/m^2) and require careful haemodynamic evaluation to determine if they have sAS[2]

Step 5: Assessing LV ejection fraction

To identify patients with true sAS

For patients with low SVi, LVEF should be assessed to identify those with preserved ejection fraction versus those with reduced ejection fraction

- Patients with lower than expected gradients despite preserved LVEF can lead to an underestimation of severity, which may delay aortic valve replacement[3]
- Use LVEF to determine the cause of the low-flow state:[2]
  - In patients with a reduced LVEF (<40%) dobutamine stress echocardiography (**Step 6**) can be used to differentiate between true sAS and pseudo-sAS (where uncertainty remains, assessing the calcium score by MSCT (**Step 7**) can help identify true sAS)[1]
  - In patients with preserved LVEF an integrated approach, including the use of MSCT (**Step 7**), should be used to determine true sAS

! A high calcium score can confirm sAS while a low score makes sAS highly unlikely

References: 1. Baumgartner H, et al. Eur Heart J Cardiovasc Imaging. 2017;18(3):254–275. **2.** Clavel MA, et al. Eur Heart J. 2016; 37(34):2645–2657. **3.** Dumesnil JG, et al. Eur Heart J. 2010;31(3):281–289.

Help avoid misdiagnosis of AS severity in your patients by optimising echocardiogram assessment

- sAS can pose unique challenges that require special considerations during work-up and imaging

- Evidence has shown some patients with sAS and discordant indices are being characterised as having less severe AS in clinical echocardiography (echo) reports, which could have adverse clinical consequences[1]

- Both the EACVI and ESC/EACTS recommend an integrated, stepwise approach that uses echocardiography to assess multiple indices* when grading AS severity in clinical practice[2,3]

*Transvalvular velocity/gradient, AVA, valve morphology, flow rate, left ventricular (LV) morphology and function, blood pressure and symptoms.

References: 1. Raddatz MA, et al. Open Heart. 2020 Aug;7(2):e001331. **2.** Baumgartner H, et al. Eur Heart J Cardiovasc Imaging. 2017;18(3):254–275. **3.** Baumgartner H, et al. Eur Heart J. 2017 Sep 21;38(36):2739–2791. **4.** Holmes DR Jr, et al. Ann Thorac Surg. 2012;93(4):1340–1395.

Thank you

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Subgroups of indices that could indicate sAS[1,2]

X

Subgroup	AVA	Mean pressure gradient	SVi	Ejection fraction	Haemodynamic consequences
High gradient AS	<1 cm^2	>40 mmHg	-	-	sAS assumed irrespective of whether LVEF and flow are normal or reduced
Low-flow, low-gradient AS with reduced ejection fraction	<1 cm^2	<40 mmHg	≤35 mL/m^2	<50%	Low-dose dobutamine echocardiography is recommended in this setting to distinguish true from pseudo sAS: ▪ This is defined by an increase to an AVA of >1.0 cm^2 with flow normalisation
Low-flow, low-gradient AS with preserved ejection fraction	<1 cm^2	<40 mmHg	≤35 mL/m^2	≥50%	Exclude measurement errors and other reasons for such echocardiographic findings. The degree of valve calcification by MSCT can help identify true sAS: ▪ A high calcium score can confirm sAS while a low score makes severe AS highly unlikely
Normal-flow, low gradient AS with preserved ejection fraction	<1 cm^2	<40 mmHg	>35 mL/m^2	≥50%	Generally indicates moderate AS.

AS, aortic stenosis; AVA, aortic valve area; LVEF, left-ventricular ejection fraction; LVOT, left-ventricular outflow tract; MSCT, multislice computer topography; sAS, severe aortic stenosis; SVi, stroke volume index.

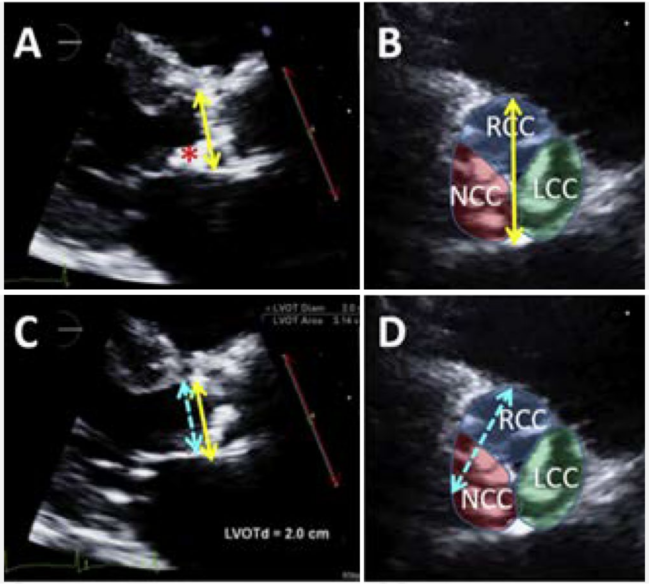
References: **1.** Baumgartner H, et al. Eur Heart J Cardiovasc Imaging. 2017;18(3):254–275. **2.** Baumgartner H, et al. Eur Heart J. 2017 Sep 21;38(36):2739–2791.

Pitfalls to avoid when measuring LVOT[1]

X

A

Yellow arrow is measurement of largest diameter by excluding ectopic calcium (red asterisk)



Representation of measurement from short axis view

B

C

The yellow arrow is larger suggested measurement (dashed blue arrow)

Representation of where incorrect measurement would be taken from short axis view

D

Adapted from Hahn RT & Pibarot P. 2017.[1]

LCC, left coronary cusp; LVOT, left-ventricular outflow tract; LVOTd, LVOT diameter; NCC, noncoronary cusp; RCC, right coronary cusp.

Reference: 1. Hahn RT & Pibarot P.JASE 2017;*correspondence to the editor*;30(10):1038–1041.

Visual signs of AS in AVA[1]

Normal

Aortic Stenosis

Mild-to-moderate aortic stenosis

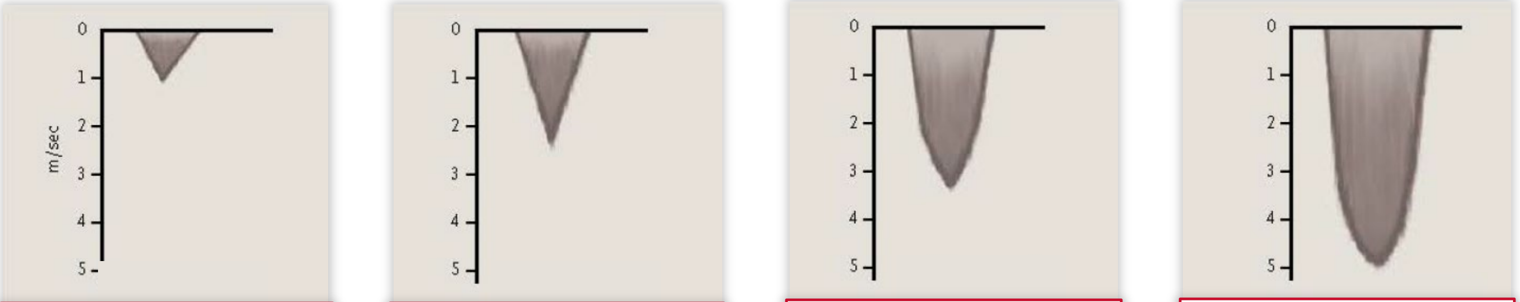
Severe aortic stenosis

Adapted from Otto CM. 2008.[1]

If the data does not support the visual signs of AS, check for measurement errors

Reference: 1. Otto CM. N Engl J Med. 2008;359(13):1395–1398.

Visual signs of AS in AVA[1]



Normal | **Aortic Stenosis <2.5 m/sec** | **Mild-to-moderate aortic stenosis 2.5-4 m/sec** | **Severe aortic stenosis >4 m/sec**

Adapted from Otto CM. 2008.[1]

! If the data does not support the visual signs of AS, check for measurement errors

Reference: 1. Otto CM. N Engl J Med. 2008;359(13):1395–1398.