Table 3 Recommendations for classification of AS severity

	Aortic sclerosis	Mild	Moderate	Severe
Aortic jet velocity (m/s)	$\leq$2.5 m/s	2.6–2.9	3.0–4.0	>4.0
Mean gradient (mmHg)	–	<20 (<30[a])	20–40[b] (30–50[a])	>40[b] (>50[a])
AVA (cm^2)	–	>1.5	1.0–1.5	<1.0
Indexed AVA (cm^2/m^2)		>0.85	0.60–0.85	<0.6
Velocity ratio		>0.50	0.25–0.50	<0.25

[a]ESC Guidelines.
[b]AHA/ACC Guidelines.

reduced. Aortic stenosis with its abrupt widening from the small orifice to the larger aorta has an unfavourable geometry for pressure recovery. In AS, PR (in mmHg) can indeed be calculated from the Doppler gradient that corresponds to the initial pressure drop across the valve (i.e. $4v^2$), the effective orifice area as given by the continuity equation (EOA) and the cross-sectional area (CSA) of the ascending aorta (AoA) by the following equation: PR = $4v^2 \times 2\text{EOA/AoA} \times (1-\text{EOA/AoA})$.[11] Thus, PR is basically related to the ratio of EOA/AoA. As a relatively small EOA is required to create a relevant gradient, AoA must also be relatively small to end up with a ratio favouring PR. For clinical purposes, aortic sizes, therefore, appear to be the key player and PR must be taken into account primarily in patients with a diameter of the ascending aorta <30 mm.[11] It may be clinically relevant particularly in congenital AS. However, in most adults with native AS, the magnitude of PR is small and can be ignored as long as the diameter of the aorta is >30 mm. When the aorta is <30 mm, however, one should be aware that the initial pressure drop from LV to the vena contracta as reflected by Doppler measurement may be significantly higher than the actual net pressure drop across the stenosis, which represents the pathophysiologically relevant measurement.[11]

Current guidelines for decision-making in patients with valvular heart disease recommend non-invasive evaluation with Doppler echocardiography.[1,2,12,13] Cardiac catheterization is not recommended except in cases where echocardiography is non-diagnostic or is discrepant with clinical data. The prediction of clinical outcomes has been primarily studied using Doppler velocity data.

B.1.3. Valve area. Doppler velocity and pressure gradients are flow dependent; for a given orifice area, velocity and gradient increase with an increase in transaortic flow rate, and decrease with a decrease in flow rate. Calculation of the stenotic orifice area or aortic valve area (AVA) is helpful when flow rates are very low or very high, although even the degree of valve opening varies to some degree with flow rate (see below).

Aortic valve area is calculated based on the continuity-equation (Figure 4) concept that the stroke volume (SV) ejected through the

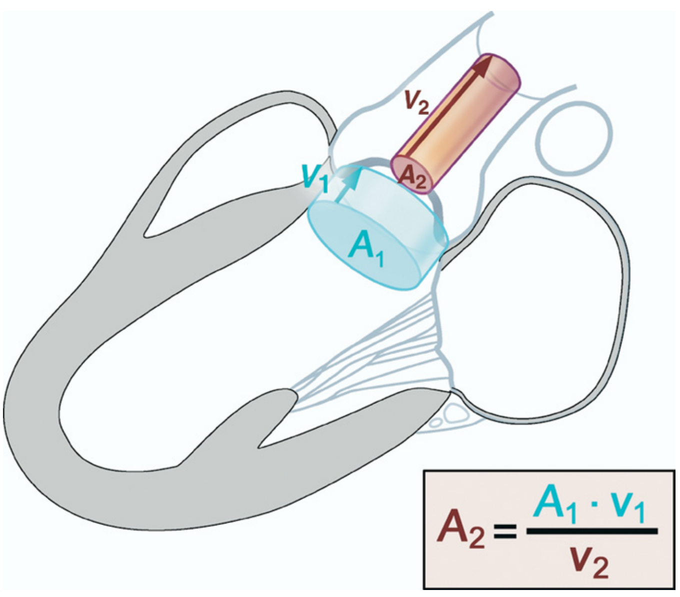

Figure 4 Schematic diagram of continuity equation.

LV outflow tract (LVOT) all passes through the stenotic orifice (AVA) and thus SV is equal at both sites:

$$SV_{AV} = SV_{LVOT}$$

Because volume flow rate through any CSA is equal to the CSA times flow velocity over the ejection period (the VTI of the systolic velocity curve), this equation can be rewritten as:

$$AVA \times VTI_{AV} = CSA_{LVOT} \times VTI_{LVOT}$$

Solving for AVA yields the continuity equation[14,15]

$$AVA = \frac{CSA_{LVOT} \times VTI_{LVOT}}{VTI_{AV}}$$

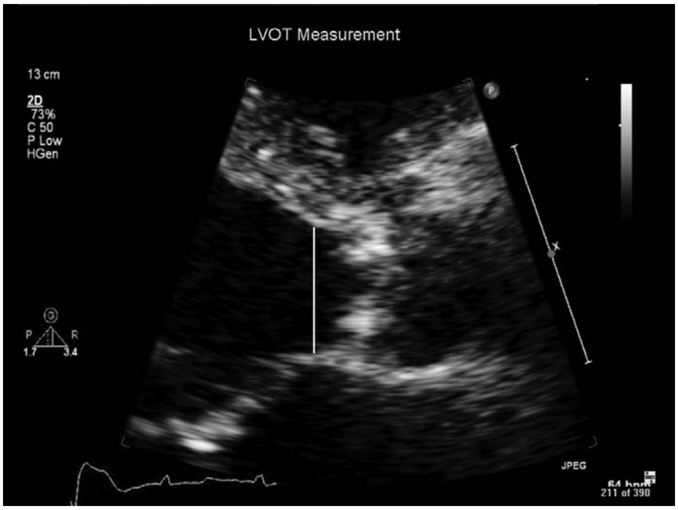

Figure 5 Left ventricular outflow tract diameter is measured in the parasternal long-axis view in mid-systole from the white–black interface of the septal endocardium to the anterior mitral leaflet, parallel to the aortic valve plane and within 0.5–1.0 cm of the valve orifice.

Calculation of continuity-equation valve area requires three measurements:

- AS jet velocity by CWD
- LVOT diameter for calculation of a circular CSA
- LVOT velocity recorded with pulsed Doppler.

AS jet velocity is recorded with CWD and the VTI is measured as described above.

Left ventricular outflow tract stroke volume

Accurate SV calculations depend on precisely recording the LVOT diameter and velocity. It is essential that both measurements are made at the same distance from the aortic valve. When a smooth velocity curve can be obtained at the annulus, this site is preferred (i.e. particularly in congenital AS with doming valve). However, flow acceleration at the annulus level and even more proximally occurs in many patients, particularly those with calcific AS, so that the sample volume needs to be moved apically from 0.5 to 1.0 cm to obtain a laminar flow curve without spectral dispersion. In this case, the diameter measurement should be made at this distance from the valve (Figure 5). However, it should be remembered that LVOT becomes progressively more elliptical (rather than circular) in many patients, which may result in underestimation of LVOT CSA and in consequence underestimation of SV and eventually AVA.[16] Diameter is measured from the inner edge to inner edge of the septal endocardium, and the anterior mitral leaflet in mid-systole. Diameter measurements are most accurate using the zoom mode with careful angulation of the transducer and with gain and processing adjusted to optimize the images. Usually three or more beats are averaged in sinus rhythm, averaging of more beats is appropriate with irregular rhythms (at least 5 consecutive beats). With careful attention to the technical details, diameter can be measured in nearly all patients. Then, the CSA of the LVOT is calculated as the area of a circle with the limitations mentioned above:

$$CSA_{LVOT} = \pi\left(\frac{D}{2}\right)^2$$

where D is diameter. LVOT velocity is recorded with pulsed Doppler from an apical approach, in either the anteriorly angulated four-chamber view (or 'five-chamber view') or in the apical long-axis view. The pulsed-Doppler sample volume is positioned just proximal to the aortic valve so that the location of the velocity recording matches the LVOT diameter measurement. When the sample volume is optimally positioned, the recording (Figure 6) shows a smooth velocity curve with a well-defined peak, narrow band of velocities throughout systole. As mentioned above, this may not be the case in many patients at the annulus due to flow convergence resulting in spectral dispersion. In this case, the sample volume is then slowly moved towards the apex until a smooth velocity curve is obtained. The VTI is measured by tracing the dense modal velocity throughout systole.[17]

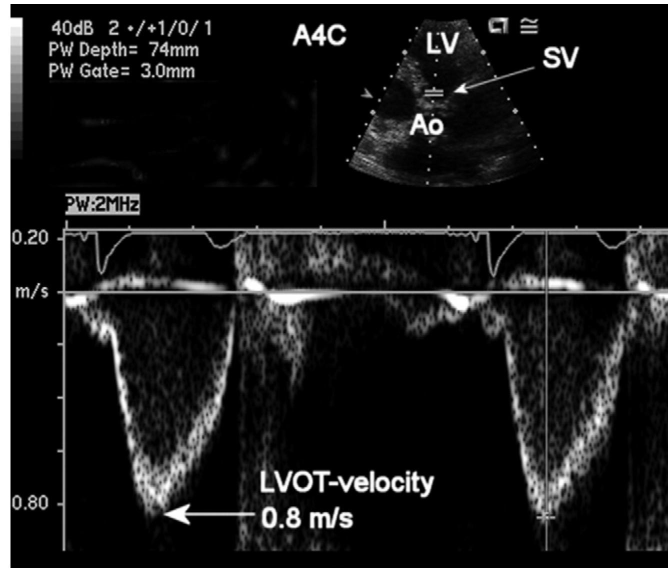

Figure 6 Left ventricular outflow tract (LVOT) velocity is measured from the apical approach either in an apical long-axis view or an anteriorly angulated four-chamber view (as shown here). Using pulsed-Doppler, the sample volume (SV), with a length (or gate) of 3–5 mm, is positioned on the LV side of the aortic valve, just proximal to the region of flow acceleration into the jet. An optimal signal shows a smooth velocity curve with a narrow velocity range at each time point. Maximum velocity is measured as shown. The VTI is measured by tracing the modal velocity (middle of the dense signal) for use in the continuity equation or calculation of stroke volume.