Aortic Valve: What Parameters? How Severe?

Objectives

1. To identify the echo indices used to evaluate the severity of aortic stenosis and aortic regurgitation and to understand the limitations of these indices.
2. To identify the role of echocardiography in the management of patients with aortic valve disease.

Discussion

Aortic Stenosis (AS)

Quantitation of the hemodynamic severity is a critical component of the management of AS patients. Clinically, maximum AS jet velocity (V_{max}), mean pressure gradient (ΔP_{mean}) and effective orifice area (EOA) are recommended to be measured in all AS patients. V_{max} provides the simplest measure of AS severity and is measured using CW Doppler. The valve should be interrogated from multiple windows to make sure that the highest velocity is identified and that the stenosis severity is not underestimated. V_{max} is the strongest predictor of clinical outcome in most studies and severe AS has been defined as a $V_{max} \geq 4$m/s because of the poor prognosis of these patients. ΔP_{mean} is measured using the simplified Bernoulli equation ($\Delta P = 4V^2$). However, the modified Bernoulli equation ($\Delta P = 4[V_{max}^2 - V_{LVOT}^2]$) should be used when the LVOT velocity exceeds 1.5m/s or V_{max} is <3m/s to avoid overestimating ΔP_{mean} and the AS severity. Pressure recovery can account for discrepancies between catheterization and echocardiography pressure gradients, but the discrepancy is not usually clinically relevant unless the ascending aorta diameter is <30mm. $\Delta P_{mean} \geq 40$ mmHg equates to a $V_{max} \geq 4$m/s and is associated with a poor prognosis. V_{max} and ΔP_{mean} are affected by the stroke volume and can underestimate AS severity when stroke volume is reduced. EOA derived by continuity equation ($EOA = [AREA_{LVOT} \times VTI_{LVOT}]VTI_{AS}$) provides a two-dimensional depiction of the aortic valve orifice and provides a more hemodynamically stable index of AS severity. An $EOA \leq 1.0cm^2$ is associated with a worse prognosis, although in general, V_{max} has a stronger association with clinical outcome. An $EOA \leq 1.0cm^2$ suggests the presence of severe AS.

Conflicting hemodynamic data in which EOA is $\leq 1.0cm^2$, but V_{max} is <4m/s or ΔP_{mean} is <40mmHg, is a common clinical occurrence. This phenomenon can occur because of technical reasons (underestimation of the V_{LVOT} or LVOT diameter/area) or physiologic reasons (small body size, inherent inconsistencies in the criteria for severe AS in the valve guidelines, low flow state). Measurement error can be ruled out by confirming the stroke volume measurement using 3D-TTE, or confirming the EOA measurement using 2D/3D-TEE. Indexing EOA for body surface area ($EOAi > 0.6cm^2/m^2$ = non-severe AS) and calculating the indexed stroke volume ($<35ml/m^2$ = low flow state) may provide a physiologic explanation for the discrepancy.

The 2014 AHA/ACC Valve Guidelines provide a new classification for AS with 4 progressive stages (A to D). Stage A consists of patients at risk for developing AS (bicuspid aortic valve, aortic sclerosis, etc), Stage B consists of patients with asymptomatic mild (V_{max} 2.0-2.9m/s, ΔP_{mean}<20mmHg) or moderate AS (V_{max} 3.0-3.9m/s, ΔP_{mean}<40mmHg). Stage C consists of asymptomatic patients with criteria for severe AS ($V_{max} \geq 4$m/s, $\Delta P_{mean} \geq 40$mmHg [Typically $EOA \leq 1.0cm^2$]) with either a compensated LV (LVEF≥50%) (C1) or decompensated LV (LVEF<50%) (C2). Stage D consists of patients with symptomatic severe AS. These patients can be divided into Stage D1 (High gradient AS: $V_{max} \geq 4$m/s, $\Delta P_{mean} \geq 40$mmHG [Typically $EOA \leq 1.0cm^2$], Stage D2 (low flow low gradient AS with reduced LVEF: $EOA \leq 1.0cm^2$, V_{max}<4m/s, ΔP_{mean}<40mmHg and ↓LVEF, with an $EOA \leq 1.0cm^2$ and V_{max}>4m/s during dobutamine echo) and Stage D3 (low gradient AS with preserved LVEF: $EOA \leq 1.0cm^2$, Vmax<4m/s, ΔP_{mean}<40mmHgG, $EOAi \leq 0.6cm^2/m^2$, $SVi < 35ml/m^2$). Surgery is recommended in Stage C2 and Stage D patients. Patients

with asymptomatic mild, moderate and severe AS need regular echo follow-up at q3-5, q1-2 and q0.5-1 years, respectively.

Aortic Regurgitation (AR)

The evaluation of AR severity requires the integration of multiple Doppler echo indices. The size of the turbulent flow jet within the left ventricle (colour jet length/area) can be used to diagnose AR, but is not recommended to quantify AR severity because of a strong dependence on the aorto-LV diastolic gradient and LV compliance. AR severity is often overestimated using the jet size in the apical views. Measures related to the size of the effective regurgitant orifice area (EROA) (ratio of jet area to LVOT area or jet height to LVOT height; vena contracta width; AR pressure half-time) can be used to semiquantitate AR severity, but are limited when the jet is eccentric, the EROA is asymmetrical or when multiple jets are present. The AR pressure half-time is affected by LV compliance, AR acuteness and the aorta-LV pressure gradient, and should only be used as a complementary finding of AR severity. Quantitative measurements of the EROA, regurgitant volume and regurgitant fraction are recommended whenever possible and can be calculated using the PISA method ($ERO=2\pi r^2 x V_{alias}/V_{AR}$, $RV=EROxVTI_{AR}$) or Doppler volumetric method ($RV= SV_{AV}-SV_{MV}$, $ERO=RV/VTI_{AR}$, $RF=RV/SV_{AV}x100\%$).

Severe AR is suggested by a jet width >65% of the LVOT height, jet area >60% of the LVOT area, vena contracta width >0.6cm, holodiastolic flow reversal in the descending thoracic aorta (>20cm/s) or proximal abdominal aorta, RVol>60 mL/beat, RF>50% and ERO>0.3cm^2, along with evidence of LV dilation. Mild AR is suggested by a jet width <25% of the LVOT height, jet area <5% of the LVOT area, vena contracta width <0.3cm, RVol<30mL/beat, RF<30% and ERO<0.10cm^2.

The 2014 AHA/ACC Valve Guidelines provide a classification for the stages of chronic AR. Stage A consists of patients at risk for the development of AR (bicuspid aortic valve, dilated aorta, etc), Stage B consists of patients with asymptomatic mild or moderate AR, Stage C consists of asymptomatic patients with criteria for severe AR with a compensated LV (LVEF≥50% and LVESD <50mm) (C1) or decompensated LV (LVEF<50% or LVESD>50mm or indexed LVESD>25mm/m^2) (C2). Stage D are patients with symptomatic severe AR. Surgery is recommended for Stage C2 and Stage D patients. Patients with asymptomatic mild, moderate and severe AR need regular echo follow-up at q3-5, q1-2 and q0.5-1 years, respectively.

Importantly, the evaluation of the AR patient should also include a description of the mechanism of the valve regurgitation (Type 1 - aortic root enlargement with normal cusps or cusp perforation; Type II - cusp prolapse, Type III – cusp restriction), which provides important information about the suitability for aortic valve repair.

Conclusion

Echocardiography plays a critical role in the diagnosis and management of patients with aortic valve disease. The examination should include a comprehensive evaluation of the valve pathology, disease severity and left ventricular size and function.

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