Abstract: Aortic valve stenosis (AS) is a relatively frequent pathology in the elderly and management is mainly dependent on the degree of stenosis and the potential presence of comorbidities. Transthoracic echocardiography (TTE) is the basic initial test for aortic valve imaging, yielding valuable measurements of aortic valve area, peak velocity, mean and peak gradients and dimensionless velocity index. TTE allows to classify the type of AS, as high gradient/normal flow (HG/NF), low gradient/normal flow (LG/NF), high gradient/low flow (HG/LF) and low gradient/low flow (LG/LF); the latter is also subdivided into regular or paradoxical LG/LF according to the value of the ejection fraction (EF). Transoesophageal echocardiography (TOE) has an added value compared to TTE for detailed anatomical visualization of the aortic valve and adjacent structures, also it is particularly useful as a perprocedural test during transcatheter aortic valve implantation (TAVI). Moreover, stress echocardiography (SE) is useful in cases where accurate assessment of the degree of stenosis is challenging, especially in LF/LG AS. In summary, appropriate assessment of AS is essential in order to guide decision making and echocardiography is the gold standard test for this purpose.

Keywords: Aortic valve stenosis (AS), Transthoracic echocardiography (TTE), echocardiography
interventional management which may consist of surgical AV replacement (SAVR), transcatheter AV implantation (TAVI) or balloon valvuloplasty as stand-alone approach when more advanced techniques are not feasible or contraindicated [2].

**TRANSTHORACIC ECHOCARDIOGRAPHY**

TTE is the basic exam initially performed for AS assessment, it allows a qualitative estimate (visual assessment) of AV shape and morphology, also it allows to visualize cusps mobility, the potential presence of calcifications, and associated regurgitation. Moreover, TTE allows to measure systolic and diastolic function, LV shape and dimensions, also it allows to document the presence of associated valvular lesions (eg, mitral regurgitation, etc...). Besides the qualitative estimate, TTE allows a quantitative analysis of AV, including AV area (AVA) using planimetry and continuity equation, peak aortic velocity, mean and peak gradients, velocity time integral (VTI) and dimensionless index.

AS is graded as mild, moderate or severe, and such classification is based on one or more criteria according to the American Society of Echocardiography [2]- (table 1).

| Table 1: Criteria for grading the severity of AS, according to European Association of Echocardiography/American Society of Echocardiography guidelines (2) |
|---------------------------------|----------------|----------------|----------------|
| Peak aortic jet velocity (m/s) | Mild 2.0–2.9   | Moderate 3.0–3.9 | Severe ≥4.0 |
| Mean pressure gradient (mmHg)  | <20            | 20–39          | ≥40           |
| Aortic valve area (cm²)        | >1.5           | 1.0–1.5        | ≤1.0         |
| Indexed aortic valve area (cm²/m²) | >0.85       | 0.60–0.85      | ≤0.60        |
| Dimensionless index            | >0.50          | 0.25–0.50      | ≤0.25        |

There is a complex interplay between gradients and flow, also gradients are mainly dependent on AS severity along with systolic function, whereas flow is dependent on both systolic and diastolic function; moreover, gradient is correlated to flow while the reverse is not true. Of note, low gradient (LG) is considered as such when it is <40 mm Hg and low flow (LF) is considered as such when indexed stroke volume <35 mL/m² as assessed by TTE (3).

Severe AS is defined as a peak aortic jet velocity >4.0 m/s, a mean gradient >40 mmHg, and/or an aortic valve area (AVA) <1.0 cm² (4). The interplay between gradient and flow is complex and it makes the diagnosis of severity of AS difficult sometimes, and therefore management decisions become a challenging clinical scenario. In practice, AS is divided by echocardiography as HG/NF, LG/NF, HG/LF and LG/LF; the latter subtype usually needs to be extensively explored to rule out true severe AS from pseudosevere AS [3, 4].

The paradoxical form of LF/LG AS is associated with an ejection fraction >50%. The pathophysiology is related to a restrictive pattern in some patients with severe AS (i.e., <1.0 cm² and/or indexed AVA of <0.6 cm²/m²), resulting in lower transvalvular flow rates (i.e., stroke volume index <35 ml/m²) and lower than expected...
transvalvular gradients (i.e., <40 mm Hg) despite a preserved LVEF [5].

**STRESS ECHOCARDIOGRAPHY**

Severe symptomatic AS is an indication for AV replacement and exercise testing is usually contraindicated. In patients with classical LF/LG AS, dobutamine stress echocardiography (DSE) should be used to distinguish patients with true severe AS from those with pseudo-severe AS [6]. DSE in AS aims to increase cardiac output without precipitating significant myocardial ischemia; accordingly, a low dose dobutamine (up to 20 μg/kg/min) protocol is implemented. Dobutamine infusion is started at a low dose (2.5 μg/kg/min), then the dose is increased every 3-5 min to a maximum of 10 to 20 mg/kg/min. The infusion should be stopped when heart rate rises more than 20 bpm over baseline or exceeds 100 bpm, also infusion should be stopped if blood pressure drops, if significant arrhythmias occur or if the patient exhibits significant symptoms [7].

The classical view where data are acquired is A3C or A5C view, however the same window should be used throughout the test to allow comparison of data across the different stages. Stroke volume is measured by subtracting LV end-systolic volume from LV end-diastolic volume. At every stage of the test, AV/VTI, LVOT/VTI, transvalvular mean and peak gradients, stroke volume and LVEF are acquired and stored. The LVOT diameter is measured at baseline at mid-systole and the same diameter is used to calculate by continuity-equation the valve area at each stage; whether LVOT diameter should be remeasured during the test and AVA recalculated accordingly is debated, given that LVOT diameter is a dynamic parameter and it may vary (increase or decrease) according to changes in LV end diastolic volume and pressure [8, 9].

Table 2: Changes in Echo parameters during stress; (+), minor increase; (+++), significant increase; (=), similar; (-), decrease

<table>
<thead>
<tr>
<th></th>
<th>True severe AS</th>
<th>Pseudo-severe AS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stroke volume and LVOT velocity</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Transvalvular gradients</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td>Aortic valve area</td>
<td>= or (-)</td>
<td>+</td>
</tr>
</tbody>
</table>

**TRANSOESOPHAGEAL ECHOCARDIOGRAPHY**

TOE provides definitely a better anatomical view of the AV and related structures, also it allows a more precise measurement of the LVOT and annulus diameter, these parameters are important when there is a management perspective for TAVI. Moreover, TOE is useful to monitor per-procedural TAVI process and to diagnose potential complications related to the procedure, like cardiac tamponade, left ventricular dysfunction, severe aortic regurgitation [12]. Aortic valve anatomy and morphology should be assessed in detail: bicuspid aortic valve is generally considered a relative contraindication to TAVI; moreover, extensive or asymmetric calcification, especially of the commissures and of the edge of the leaflets may result in unfavorable deployment of the valve and complications like paraprosthetic regurgitation [13].

In fact, several steps of the TAVI procedure may be guided by TOE, especially aortic valve crossing, balloon dilatation, and positioning and deployment of the prosthesis. Of note, there are two types of prostheses commonly implanted: the shorter,
balloon-expanded Edwards Sapien prosthesis (Edwards Life Science), which is anchored at the annulus and extends to a level below the sino-tubular junction, and the longer self-expandable Core Valve (Medtronic), which extends from the annulus into the proximal ascending aorta; the positioning of the latter should aim a ventricular edge placed 5–10 mm below the aortic annular plane. In addition, it is important to confirm that all the prosthetic cusps are moving well, that the valve stent is well deployed (using 2D or 3D views), and that there is no significant transprosthetic or paraprosthetic regurgitation [14, 15].

Severe hypotension, cardiac arrhythmias, and acute ECG changes may occur during all phases of the TAVI procedure and TOE can immediately identify potential complications. Occlusion of the coronary ostia may occur by fragment embolization or by an obstructive portion of the valve frame, sealing cuff, or native cusp. 3D TOE may directly visualize the distance of the left main coronary ostium to the implanted valve showing whether the prosthesis reaches or overlaps the coronary ostium. Rarely, a tear or rupture of the aortic root may be observed during balloon valvuloplasty or prosthesis deployment [14]. Major complications of TOE include laryngospasm, arrhythmias, oesophageal perforation, and haemorrhage from oesophageal varices [15].

The following diagram (figure 3) shows the main views acquired via TOE relevant to Aorta and Aortic valve.

Fig-3: Main views relevant to Aortic valve and Aorta via TOE. Ao, Aorta; SAX, short axis; CV; chamber view; ME, mid esophageal; Asc, ascending; LAX, long axis; AV, aortic valve; Dsc, descending; TG, transgastric

**CONCLUSION**

TTE provide basic data for diagnosis and management of AS, however, other advanced echo techniques like SE may be needed in special cases like LF/LG AS, also TOE is often required in cases where TTE signal quality is not optimal, also for per-procedural guiding and for monitoring potential complications during TAVI procedure. TOE and SE are advanced echocardiographic techniques described more than 15 years ago, however they may be poorly implemented even in institutions where equipment is not the issue; the reluctance to the use of these valuable echo techniques may be related to impediments stemming either from the operator awareness and skills, or from the institutional capability and policy.

**REFERENCES**


