Preserved ejection fraction can accompany low gradient severe aortic stenosis: impact of pathophysiology on diagnostic imaging

Thomas Bartel* and Silvana Müller

Division of Cardiology, Department of Internal Medicine III, Medical University Innsbruck, A-6020 Innsbruck, Austria

Online publish-ahead-of-print 2 May 2013

This editorial refers to ‘Differential left ventricular remodelling and longitudinal function distinguishes low flow from normal-flow preserved ejection fraction low-gradient severe aortic stenosis’, by P. Mehrotra et al., on page 1906

Grading the severity of aortic stenosis (AS) on the basis of aortic valve area (AVA), mean pressure gradient, and left ventricular (LV) ejection fraction (EF) at rest and under stress was believed to be straightforward matter, an approach also permitting discrimination between ‘classic’ low gradient/lower output AS and pseudo-severe AS. If we are still accustomed to equate LVEF with systolic function, we need to ask if that is really permissible. In some patients with low gradient, findings remain incongruous, i.e. the LVEF is normal although significant AS is very likely.

Aortic stenosis always begets LV remodelling mainly characterized by myocardial hypertrophy. In some individuals, however, the natural course of AS is accompanied by a degree of hypertrophy which exceeds a ‘certain’ level characterized by a relative wall thickness (RWT) of > 50%, a phenomenon also known as ‘increased concentric remodelling’ (ICR). For a variety of reasons, including straightening of the cavity and decreased filling due to impaired diastolic LV function, ICR brings about a decrease in the end-diastolic volume (EDV). Therefore, a normal EF suggesting normal systolic LV function may be associated with a low LV stroke volume index (SVI) if the contractility cannot increase to the extent needed to compensate for the low EDV. This means that an LVEF still within normal limits may actually conceal a low flow condition defined as an SVI < 35 mL/m² from our ‘diagnostic eyes’ if the EDV is small. Another reason why reliance on EF can be deceptive is the fact that absolute wall thickening may be preserved, while relative wall thickening is reduced. ICR decreases not only the EDV, but also the longitudinal shortening force (Figure 1). Thus, the haemodynamic performance of low flow and low gradient (LFLG) ventricles with preserved EF but ICR is comparable with the performance in ‘classic’ low output states. Ultimately, it does not make any difference whether LFLG is the result of low EDV and reduced longitudinal shortening force or the result of low EF: the clinical end-result is low flow, which carries a poor prognosis if treated medically rather than surgically.

Consequently, echocardiographic indices beyond EF are required if we do not want to miss LFLG AS. Impaired longitudinal function is a diagnostically usable attribute of ICR. When considering different echocardiographic modalities in that respect, the distinction between motion and deformation imaging is important. Displacement and velocity represent motion. Strain and strain rate represent movement due to the effects of neighbouring segments, and are therefore parameters of deformation to be measured by speckle tracking. In patients with valvular heart disease, strain and strain rate of longitudinal myocardial contraction tend to reflect systolic LV performance better than EF, particularly in cases of significant AS.

Algorithms for measurement remain to be standardized and to take into account that deformation is load dependent just like all volume-based parameters of ventricular function. In contrast, motion parameters, i.e. longitudinal ventricular shortening and shortening velocity, are less load dependent, and this includes the M-mode measurement of septal mitral annular displacement and the tissue Doppler-derived septal mitral annular peak velocity. For depicting reduced LV function in ICR, these parameters may be even more useful than deformation imaging, since they are related to acceleration, a direct measure of force and thus of contractility. The proposed automated analysis from three-dimensional data sets may further expedite diagnostics.

In contrast, calculating SVI with the continuity equation remains challenging and must be considered deficient for several reasons, e.g. the assumptions that this kind of flow measurement based on a small sample volume is representative for the flow velocity over the whole LV outflow tract and the assumption that the latter has a circular cross-section. Such calculated parameters may therefore overestimate SVI and may consecutively hide LFLG AS.

In individuals presenting with normal flow and a low gradient (NFLG), the EDV may be large enough for the actually normal systolic LV function to provide normal flow (Figure 1). In borderline cases, increased LV contractility might compensate for small EDV to a
AVA and additionally on the energy loss index,\textsuperscript{11} which has been repeatedly shown to improve assessment of stenosis severity? (iii) To what extent will the continuity equation underestimate AVA when it overestimates SVI? (iv) Can theoretical considerations depict the real world where AS is frequently combined with some degree of aortic regurgitation, which causes a certain underestimation of AVA calculated by the Gorlin formula or the continuity equation. Patients with NFLG with a calculated AVA below 1.0 cm\textsuperscript{2} tend to have moderate concentric remodelling (i.e., RWT <50\%) and a more benign prognosis. This makes us believe that this kind of AS is not comparable with high gradient AS. In summary, NFLG AS is possibly something like a transitional stage between moderate and severe AS and needs to be discriminated from any kind of LFLG AS, including the ‘classic’ variant or the one caused by ICR. Consequently, further interrogation with current echocardiographic tools in addition to traditional measurements is needed to estimate longitudinal LV function in all patients with low gradient AS. This approach represents nothing less than a paradigm shift.

**Conflict of interest:** T.B. has disclosed industry relationships with Edwards Lifescience, Biosense Webster, and Abbott Laboratories. S.M. has no conflict to declare.

### References


---

**Figure 1**

Significant aortic stenosis with preserved ejection fraction and low gradient may be associated with normal flow (upper panels) or with low flow (lower panels). Left upper panel: moderate concentric remodelling leaving sufficient end-diastolic volume. Right upper panel: normal longitudinal left ventricular function expressed by mitral annular displacement provides normal flow. Left lower panel: reduced end-diastolic volume is the first result of increased concentric remodelling. Right lower panel: impaired longitudinal function expressed by decreased mitral annular displacement, a secondary effect of increased concentric remodelling, leading to low flow. AS, aortic stenosis; F, flow; ↓, mitral annular displacement; *, ≥1.1 cm; †, ≥1.1 cm; ‡, <1.1 cm.