Transesophageal echocardiography in corroborating aortic stenosis severity in patients with low-gradient aortic stenosis with preserved ejection fraction

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DOI: 10.33963/v.phj.104047

Received:
November 1, 2024

Accepted:
December 13, 2024

Early publication date:
December 17, 2024

INTRODUCTION

In approximately 50% of cases, severe aortic stenosis (AS) is classified as low-gradient (LGAS), and in 35% of patients, it is low-flow (LF) LGAS [1].

The aim of this study was to determine the usefulness of two-dimensional transoesophageal echocardiography (2D-TOE) in assessing aortic valve area by planimetry (AVAPlaniTOE) in patients with severe LGAS with preserved ejection fraction (LGAS pEF) diagnosed by 2D transthoracic echocardiography (2D-TTE).

METHODS

Patient population

From a database of patients treated at the National Institute of Cardiology in Warsaw between 2013 and 2022, a group of 102 patients with symptomatic severe LGAS with pEF were selected, who also had 2D-TOE. Clinical data were retrieved from patient records. The study group included patients with normal sinus rhythm and permanent atrial fibrillation (AFib) (n = 26), as well as with normal-flow and LF (n = 35).

Echocardiography

2D-TTE examinations were performed according to current guidelines [1–3] using the Vivid E95™ device with an M5SC-D probe (GE HealthCare; Vingmed Ultrasound, Horten, Norway). Right ventricular systolic pressure, stroke volume (SV), aortic valve area (AVA) and doppler velocity index were calculated using standard methods [1]. AVA and SV were indexed to body surface area. Energy loss coefficient (ELCo) was calculated using the formula:

$$ELCo = \frac{AVA \times AoA}{AVA - AoA}$$

where AoA = cross-sectional area of the ascending aorta at the sinotubular (STJ) level.

Energy loss index (ELI) was calculated by the following formula (indexed for body surface area):

$$ELI = \frac{(AVA \times AoA)/AoA - AVA}{BSA}$$

2D-TOE examinations were performed according to current guidelines [4] also using the same device. A 6VT-D probe was used. AVAPlaniTOE was measured in the transverse short-axis plane of aortic valve, in the mid-systole, in zoom mode, by manually tracing the anatomical orifice area at the blood-cusp interface (Supplementary material, *Figure S1*). At least 5 measurements were made (for cases with permanent AFib and significant calcifications, up to 10 measurements were performed).

Echocardiographic measurements were made using EchoPAC software (v. 204; GE HealthCare; Vingmed Ultrasound, Horten, Norway). In 2D-TTE severe LGAS was diagnosed based on AVA ≤1.0 cm^2 and mean aortic gradient (mAG) <40 mm Hg. LF was diagnosed when indexed stroke volume (SVi) was <35 ml/m^2. In 2D-TOE true-severe LGAS was diagnosed based on AVAPlaniTOE ≤1.0 cm^2.

The comparison between pseudo-severe and true-severe AS subgroups based on AVAPlaniTOE, as well as between four groups categorized by 2D-TOE and SVi values, was performed. A sub-analysis of the normal-flow and LF groups, as well as those with permanent AFib and normal sinus rhythm, was also conducted.

The study protocol was approved by the Regional Bioethics Committee at the National Institute of Cardiology in Warsaw.

Statistical analysis

Normality of numerical variables was tested using the Shapiro–Wilk test. Data were presented as mean (SD) for normally distributed variables or as median and quartiles for non-normal data. Where relevant, the standard error of the mean (SE) was also reported to provide an estimate of the variability of the sample mean. Differences between groups were tested using Student's t-test, Mann–Whitney test, or analysis of variance with Tukey–Kramer or Dwass–Steel–Critchlow–Fligner tests for multiple comparisons. Categorical variables were analyzed using the χ^2 or Fisher exact test. Pearson's correlation coefficient was used to assess linear correlations. A two-sided *P*-value <0.05 was considered significant. All analyses were conducted using SAS software, version 9.4 (SAS Institute, Cary, NC, US).

Intra- and inter-observer variability and method agreement

Intra- and inter-observer variability for AVAPlaniTOE assessment were evaluated in 20 randomly selected patients using the Intraclass Correlation Coefficient (ICC [2,1]) with a two-way random effects model. Variability was assessed with 95% confidence intervals (CI). The agreement between AVA by continuity equation and AVAPlaniTOE was analyzed using Bland–Altman plots. All analyses were conducted using MedCalc software (version 19.4.1, MedCalc Software Ltd, Ostend, Belgium).

RESULTS AND DISCUSSION

The baseline demographic and clinical characteristics of the patients and echocardiographic characteristics of the group are shown in Supplementary material, *Table S1* and *S2*.

In 57 (55.9%) patients, AVA by continuity equation in 2D-TTE was lower than AVAPlaniTOE; in 22 (21.6%) it was larger, and in 23 (22.5%) it was equal (data not shown), with 2D-TTE generally overestimating AVA by a mean of –0.07 (0.02) (SE) cm^2 compared to AVAPlaniTOE (Supplementary material *Figure S2A* and *S2B*). Based on these findings, 16 (15.7%) patients were reclassified as having pseudo-severe AS (AVAPlaniTOE >1.0 cm^2).

Baseline demographic and clinical characteristics (Supplementary material, *Table S3*) did not show differences across the groups. However, several echocardiographic variables exhibited significant variation among them (Supplementary material, *Table S4*).

In patients with LF and permanent AFib, there was no difference in mean AVAPlaniTOE (*P* = 0.18 and *P* = 0.70, respectively).

The ICC for inter-observer reliability was 0.934 (95% CI, 0.844–0.973) for AVAPlaniTOE, indicating substantial agreement between observers. The mean intra-observer reliability was also substantial at 0.942 (95% CI, 0.889–0.976).

To the best of our knowledge, no study has specifically addressed the evaluation of AVA by planimetry in 2D-TOE in patients with severe LGAS pEF based on 2D-TTE.

We believe that the planimetric assessment of AVA in 2D-TOE can complement the integrated staging algorithm for determining AS severity proposed by Baumgartner et al. [1], and it can be implemented in the so-called LG AS "difficult track". Stoddard et al. [5] demonstrated that planimetric measurement of AVA in 2D-TOE is an effective method for determining the severity of AS, similar to the findings of Kim et al. [6].

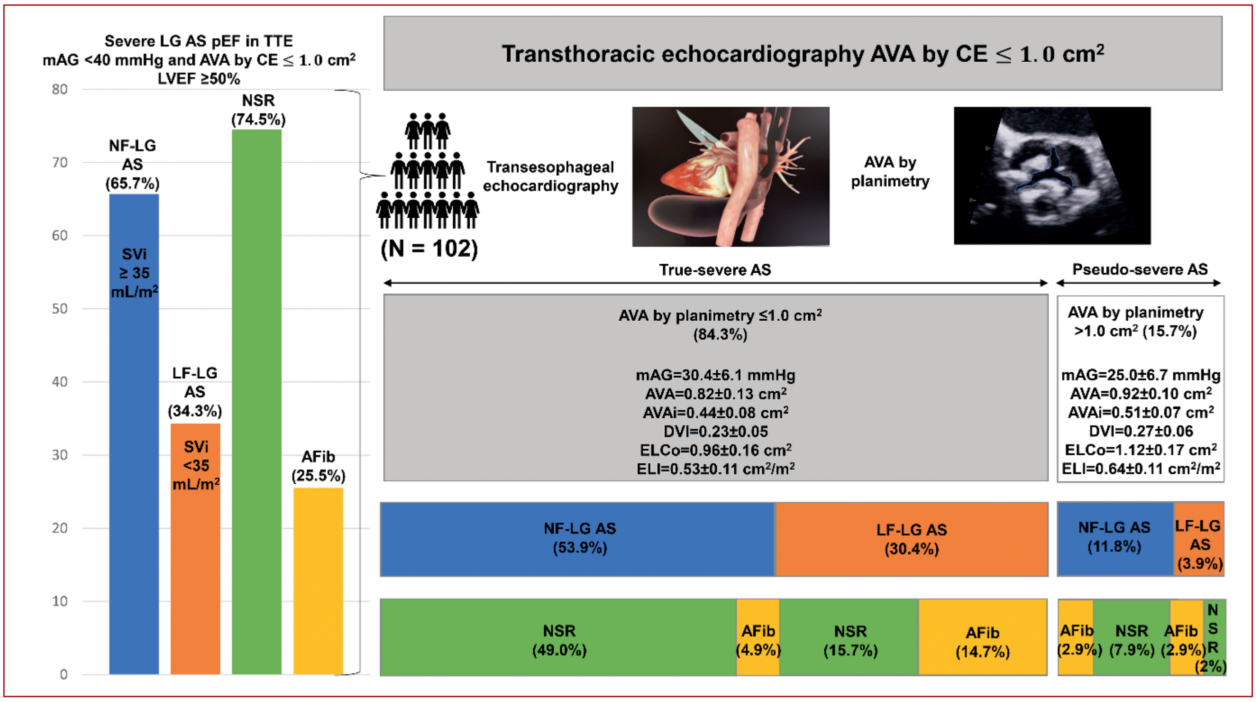
Although our study demonstrated 100% feasibility of 2D-TOE for determining AVA by planimetry, this may be an overestimation. However, LGAS patients typically have lower aortic valve calcium score [1], which facilitates AVAplaniTOE measurements. Due to the fact that only 52.9% of the study patients underwent cardiac computed tomography, including just 3 patients reclassified into the pseudo-severe AS group, a comparative analysis between the groups was not performed.

The correctness of our AVAPlaniTOE measurements and the exact diagnosis are supported by the higher mAG in the group with true-severe AS (30.4 [6.1] vs. 25.0 [6.7] mm Hg; *P* = 0.002), as well as the lower AVA (0.82 [0.13] vs. 0.92 [0.10] cm^2; *P* = 0.006). According to Baumgartner et al. [1], mAG ≥30 mm Hg and AVA by continuity equation ≤0.8 cm^2 increase the likelihood of severe AS in patients with LGAS pEF. Additionally, the significantly reduced doppler velocity index value, supports the accuracy of our AVAPlaniTOE assessment.

As 68.6% of patients in the study group had an STJ diameter of less than 3.0 cm, we calculated the ELI [1, 7], and a value of 0.53 (0.11) cm^2/m^2 [8, 9] confirmed the accuracy of AS severity assessment by planimetry in 2D-TOE. Additionally, we calculated the ELCo [10], with a value of 0.96 (0.18) (*P* <0.001), which further supports our findings.

No significant difference was observed in AVAPlaniTOE assessment for patients with LF (34.3%; Supplementary material, *Table S5* and *S6*) or for those with permanent AFib (25.5%; Supplementary material, *Table S7* and *S8*), further supporting the usefulness of 2D-TOE.

Finally, the comparison of the four groups with different AVAPlaniTOE and SVi values suggests that patients with smaller AVA and reduced SVi, particularly those in the group with AVAPlaniTOE ≤1.0 cm^2 and SVi <35 ml/m^2, exhibit worse ventricular function, smaller LVOT and aor-



Graphical abstract.

Abbreviations: AFib, atrial fibrillation; AS, aortic stenosis; AVA, aortic valve area; AVAi, aortic valve area index; DVI, doppler velocity index; ELCo, energy loss coefficient; ELI, energy loss index; LG, low-gradient; mAG, mean aortic gradient; NSR, normal sinus rhythm; pEF, preserved ejection fraction; TTE, transthoracic echocardiography

tic annulus diameters, and greater energy loss across the aortic valve. In interpreting the results, it is important to note that group 2 (n = 9; with AVAPlaniTOE >1.0 cm² and SVi <35 ml/m²) had a smaller sample size, which may affect the robustness of the comparisons.

Limitations

This was a retrospective, single-center study conducted on a small, heterogeneous patient population. Only 52.9% of patients underwent cardiac computed tomography, limiting our ability to correlate aortic valve calcium scores with AVAPlaniTOE, preventing the establishment of a clear relationship between valvular calcification and planimetric measurements.

Conclusions and clinical implications

Patients with LGAS pEF and a planimetric AVA ≤1.0 cm², as assessed by 2D-TOE, exhibit stenosis severity parameters in 2D-TTE that meet the criteria for severe AS. 2D-TOE offers a reliable approach for AVA assessment by planimetry, even in patients with LF, permanent AFib, or reduced STJ diameter.

Supplementary material

Supplementary material is available at https://journals.viamedica.pl/polish_heart_journal.

Article information

Conflict of interest: None declared.

Funding: None.

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