Characterisation of aortic stenosis severity: a retrospective analysis of echocardiography reports in a clinical laboratory

Michael A Raddatz,1,2 Holly M Gonzales,3 Eric Farber-Eger1, Quinn S Wells,3 Brian R Lindman,3,4 W David Merryman1

ABSTRACT

Objective To evaluate how common echocardiographic metrics of aortic stenosis (AS) influence the proportion of patients who may be categorised as having severe stenosis and therefore considered for valve replacement.

Methods Retrospective analysis was performed of all echocardiograms with aortic valve area (AVA) ≤1.2 cm² and peak jet velocity (Vmax) ≥3 m/s from 1 December 2014 through 30 October 2017 at a single academic medical centre. Echocardiographic indices collected include AVA, Vmax, left ventricular ejection fraction, stroke volume and annotated aortic stenosis severity.

Results Among 807 patients with AVA ≤1.2 cm² and Vmax ≥3 m/s (44.0% female, median age 74 years (IQR: 66–81)), 45.6% had Vmax ≥4 m/s, while 75.8% had AVA ≤1 cm². 40.0% of patients had concordant indices (Vmax ≥4 m/s and AVA ≤1 cm²), and 35.8% had discordant indices (Vmax <4 m/s and AVA ≤1 cm²) of severe AS. Compared with those with concordant indices, patients with discordant indices were more commonly female (54.0% vs 44.3%, p<0.05) and less commonly characterised as severe (42.6% vs 93.8%, p<0.001). Patients with paradoxical low-flow, low-gradient severe AS by echocardiography were disproportionately female (61.5% vs 41.8%, p<0.001), and their disease was characterised as severe only 49.5% of the time.

Conclusions Patients with discordant indices, who are disproportionately female, are commonly described in clinical echocardiography reports as having less than severe AS. Given the potential benefit of AVR in patients with AVA ≤1 cm² regardless of Vmax, this could have important clinical implications.

INTRODUCTION

Aortic stenosis (AS) accounts for approximately 15 000 deaths in North America each year, and the only effective treatment is surgical or transcatheter aortic valve replacement (AVR).1 Currently, AVR is recommended in patients with severe, symptomatic AS and in some cases in those with severe, asymptomatic AS.2 Determination of AS severity relies primarily on the haemodynamic indices of peak jet velocity (Vmax) or mean transvalvular gradient across the aortic valve, and secondarily on decreased aortic valve area (AVA).3 Commonly, patients are considered to have severe AS when they meet both the AVA criteria (≤1 cm²) and haemodynamic criteria (Vmax ≥4 m/s or mean gradient ≥40 mm Hg).4 However, the guidelines also indicate that patients with Vmax 3.0–3.9 m/s and AVA ≤1 cm² (‘discordant AS’) may have severe AS if certain criteria apply.2 A number of prior studies have demonstrated that such a discordance between these indices is common and suggested that patients with discordant AS would see a survival benefit...
from AVR. Nonetheless, this discordance can yield uncertainty regarding the severity of AS, which influences clinical management.  

Herein, using echocardiographic data obtained in clinical practice, we evaluated how these indices of severe AS ($V_{\text{max}} \geq 4$ m/s and $\text{AVA} \leq 1.0$ cm$^2$, both individually and together) influence the proportion of patients who may be categorised as having severe AS. For each of these groups potentially categorised as having severe AS, we evaluated how often the AS was qualitatively described as ‘severe’ in the clinical echocardiographic report. We were particularly interested in the relationship between sex and categorisation of AS severity.

METHODS

Clinical transthoracic echocardiogram reports from 1 December 2014 to 30 October 2017 were retrospectively extracted from the Synthetic Derivative, a de-identified mirror of the electronic health record at Vanderbilt University Medical Center, using previously described approaches that include regular expressions and natural language processing. These echocardiographic reports were generated in the course of clinical practice in the Vanderbilt University Medical Center echocardiography laboratory, where readers are instructed to follow society guidelines for characterisation of the severity of AS. For each patient, the report with the smallest $\text{AVA}$ calculated by the velocity time integral continuity equation was identified, and all data were extracted from this report. No patient was analysed twice, and in no cases were data from two separate reports combined. Records missing data were excluded. Patients with $\text{AVA} \leq 1.2$ cm$^2$ and $V_{\text{max}} \geq 3$ m/s were analysed to include the spectrum of severe AS disease phenotypes. Patients with a severe $V_{\text{max}}$ may have $\text{AVA} > 1$ cm$^2$ in cases of aortic regurgitation, leading to our 1.2 cm$^2$ criterion, and the AHA/ACC guidelines specifically state that patients with $\text{AVA} \leq 1$ cm$^2$ but $> 0.8$ cm$^2$ should have a $V_{\text{max}} \geq 3$ m/s to be considered severe, thus forming the inclusion criteria for our study. Patient records with either a procedural code for severe AS disease phenotypes. Patients with a severe AS were particularly interested in the relationship between sex and categorisation of AS severity.

RESULTS

Among 807 patients (44.0% female) who had a recorded $\text{AVA} \leq 1.2$ cm$^2$ and $V_{\text{max}} \geq 3$ m/s, the median $\text{AVA}$ was 0.86 cm$^2$ (IQR: 0.70–1.00) and median $V_{\text{max}}$ was 3.87 m/s (IQR: 3.41–4.38) (table 1). Based on the $V_{\text{max}} \geq 4$ m/s criterion, 45.6% of the cohort was classified as having severe AS (table 2). In contrast, based on the $\text{AVA} \leq 1.0$ cm$^2$ criterion, 75.8% was classified as having severe AS. This represents a relative 66.3% increase in the proportion of patients who would be classified as having severe AS when using the $\text{AVA}$ criteria instead of the $V_{\text{max}}$ criteria, and would particularly increase the proportion of female patients considered to have severe AS (44.9% vs 96.7% relative increase in the proportion of male vs female patients) (table 2). Using an indexed $\text{AVA}$ ($\text{AVA}_i$) cut-off of $0.6$ cm$^2$/m$^2$, 94.1% of the cohort would be classified as having severe AS, including 99.0% of those with an $\text{AVA} \leq 1.0$ cm$^2$.

Patients with discordant indices of severe AS ($V_{\text{max}} < 4$ m/s and $\text{AVA} \leq 1$ cm$^2$) made up 35.8% of the study cohort, and those with concordant indices of severe AS ($V_{\text{max}} \geq 4$ m/s and $\text{AVA} \leq 1$ cm$^2$) comprised 40.0%. Compared with those with discordant indices, those with discordant indices were more likely to be female (54.0% vs 44.3%, p=0.02) and less likely to have their AS characterised as ‘severe’ on the clinical echocardiography report (42.6% vs 93.8%, p<0.001) (table 2). This difference persisted when expanding the ‘severe’ group to include those characterised as ‘moderate–severe’ (71.6% vs 98.8%, p<0.001). Replacing $V_{\text{max}}$ with mean gradient yields similar results with identical conclusions (online supplementary table 1, online supplementary figure 1). When $\text{AVA}_i \leq 0.6$ cm$^2$/m$^2$ replaced $\text{AVA} \leq 1$ cm$^2$, patients with discordant indices were again less often characterised as ‘severe’ on the echocardiography report than those with concordant indices (32.2% vs 90.3%, p<0.001). Figure 1A shows data plotted by $V_{\text{max}}$ and $\text{AVA}$, colour coded by the AS characterisation on the echocardiography report. The percentages reported as severe for each quadrant defined by an $\text{AVA}$ of 1.0 cm$^2$ and $V_{\text{max}}$ of 4 m/s are also shown. In figure 1B, data are plotted and colour coded by sex, and each quadrant shows the proportion of the population represented and the percentage female.
We further investigated these trends by comparing patients with discordant AS who were characterised as having either ‘severe’ or ‘non-severe’ disease (table 3). There were no differences between the groups with respect to body size or LVOT dimension. Although all patients had an AVA and AVAi below the threshold for severe AS, those characterised as ‘severe’ on the echocardiography report had lower AVA and AVAi and a higher transvalvular gradient than those characterised as ‘non-severe’. To identify any subgroups that may be underdiagnosed, we divided patients with discordant AS into stages as defined by AHA/ACC recommendations (table 4). Among those with AVA ≤1.0 cm², AVAi ≤0.6 cm²/m² and Vmax < 4 m/s, patients with ejection fraction (EF) < 50% (potentially stage D2 patients depending on the results of a dobutamine echocardiogram) comprised 7.3% of the total study cohort (20.8% of those with discordant indices) and were

**Table 1** Cohort characteristics

<table>
<thead>
<tr>
<th></th>
<th>All (807)</th>
<th>Female (355)</th>
<th>Male (452)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years</td>
<td>73.7 (65.7 to 80.9)</td>
<td>75.1 (67.0 to 82.5)</td>
<td>72.9 (64.9 to 79.9)</td>
<td>0.03</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>28.8 (25.3 to 33.8)</td>
<td>29.3 (24.8 to 35.8)</td>
<td>28.4 (25.6 to 32.6)</td>
<td>0.04</td>
</tr>
<tr>
<td>AVA, cm²</td>
<td>0.86 (0.70 to 1.00)</td>
<td>0.80 (0.65 to 0.94)</td>
<td>0.90 (0.75 to 1.03)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>AVAi, cm²/m²</td>
<td>0.43 (0.36 to 0.51)</td>
<td>0.44 (0.36 to 0.52)</td>
<td>0.43 (0.36 to 0.50)</td>
<td>0.09</td>
</tr>
<tr>
<td>Vmax, m/s</td>
<td>3.87 (3.41 to 4.38)</td>
<td>3.80 (3.37 to 4.30)</td>
<td>3.92 (3.45 to 4.41)</td>
<td>0.02</td>
</tr>
<tr>
<td>Mean gradient, mm Hg</td>
<td>35.0 (26.7 to 45.3)</td>
<td>33.0 (26.0 to 43.1)</td>
<td>36.0 (27.5 to 46.0)</td>
<td>0.01</td>
</tr>
<tr>
<td>Peak gradient, mm Hg</td>
<td>59.9 (46.7 to 76.9)</td>
<td>57.8 (45.3 to 74.0)</td>
<td>61.2 (47.7 to 78.3)</td>
<td>0.03</td>
</tr>
<tr>
<td>DI</td>
<td>0.24 (0.20 to 0.29)</td>
<td>0.26 (0.21 to 0.30)</td>
<td>0.23 (0.20 to 0.28)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Ejection fraction, %</td>
<td>55 (55 to 63)</td>
<td>58 (55 to 63)</td>
<td>55 (55 to 60)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>SV, mL</td>
<td>78.1 (64.6 to 90.4)</td>
<td>73.1 (58.9 to 84.6)</td>
<td>81.8 (70.2 to 94.1)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Indexed SV, mL/m²</td>
<td>39.7 (32.9 to 46.3)</td>
<td>39.9 (33.2 to 47.3)</td>
<td>39.4 (32.8 to 45.6)</td>
<td>0.22</td>
</tr>
<tr>
<td>LVOT diameter, cm</td>
<td>2.10 (2.00 to 2.29)</td>
<td>2.00 (1.90 to 2.00)</td>
<td>2.20 (2.10 to 2.30)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LVIDd, cm</td>
<td>4.42 (3.90 to 4.90)</td>
<td>4.10 (3.69 to 4.60)</td>
<td>4.61 (4.22 to 5.09)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LVIDs, cm</td>
<td>2.90 (2.50 to 3.46)</td>
<td>2.66 (2.31 to 3.10)</td>
<td>3.17 (2.76 to 3.62)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>BSA, m²</td>
<td>1.97 (1.77 to 2.15)</td>
<td>1.78 (1.64 to 1.96)</td>
<td>2.08 (1.93 to 2.23)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Data presented as median (25th percentile, 75th percentile). 11 female and 16 male patients did not have reliable BMIs recorded, giving n=344 and 436 for this metric, respectively. 9 female and 5 male patients did not have LVID metrics, giving n=346 and 447, respectively.

AVA, aortic valve area; AVAi, indexed AVA; BMI, body mass index; BSA, body surface area; DI, dimensionless index; LVID, left ventricular internal dimension; LVIDd, LVID in diastole; LVIDs, LVID in systole; LVOT, left ventricle outflow tract; SV, stroke volume; Vmax, peak jet velocity.

**Table 2** Aortic valve area and peak jet velocity as indices of severe aortic stenosis

<table>
<thead>
<tr>
<th></th>
<th>Total (807)</th>
<th>Vmax ≥4</th>
<th>AVA≤1 All</th>
<th>Vmax ≥4</th>
<th>Vmax &lt;4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total (% of cohort)</td>
<td>807</td>
<td>364 (45.6%)</td>
<td>612 (75.8%)</td>
<td>323 (40.0%)</td>
<td>289 (35.8%)</td>
</tr>
<tr>
<td>Male (% of male patients)</td>
<td>452</td>
<td>214 (47.3%)</td>
<td>313 (69.2%)</td>
<td>180 (39.8%)</td>
<td>133 (29.4%)</td>
</tr>
<tr>
<td>Female (% of female patients)</td>
<td>355</td>
<td>150 (42.3%)</td>
<td>299 (84.2%)</td>
<td>143 (40.3%)</td>
<td>156 (43.9%)</td>
</tr>
<tr>
<td>% Female</td>
<td>44.0%</td>
<td>41.2%</td>
<td>48.9%</td>
<td>44.3%</td>
<td>54.0%</td>
</tr>
<tr>
<td>Severity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None noted</td>
<td>4 (0.5%)</td>
<td>0 (0.0%)</td>
<td>2 (0.3%)</td>
<td>0 (0.0%)</td>
<td>2 (0.7%)</td>
</tr>
<tr>
<td>Mild</td>
<td>10 (1.2%)</td>
<td>0 (0.0%)</td>
<td>5 (0.8%)</td>
<td>0 (0.0%)</td>
<td>5 (1.7%)</td>
</tr>
<tr>
<td>Mild–moderate</td>
<td>17 (2.1%)</td>
<td>0 (0.0%)</td>
<td>8 (1.3%)</td>
<td>0 (0.0%)</td>
<td>8 (2.8%)</td>
</tr>
<tr>
<td>Moderate</td>
<td>181 (22.4%)</td>
<td>10 (2.7%)</td>
<td>71 (11.6%)</td>
<td>4 (1.2%)</td>
<td>67 (23.2%)</td>
</tr>
<tr>
<td>Moderate–severe</td>
<td>140 (17.3%)</td>
<td>28 (7.7%)</td>
<td>100 (16.3%)</td>
<td>16 (5.0%)</td>
<td>84 (29.1%)</td>
</tr>
<tr>
<td>Severe</td>
<td>455 (56.4%)</td>
<td>326 (89.6%)</td>
<td>426 (89.6%)</td>
<td>303 (93.8%)</td>
<td>123 (42.6%)</td>
</tr>
</tbody>
</table>

Severity data presented as number (%), AVA, aortic valve area; Vmax, peak jet velocity.
infrequently female (27.1%), and patients with EF ≥50% comprised 27.8% of the study cohort (79.2% of those with discordant indices). Among this latter group, those with paradoxical low-flow, low-gradient AS (stroke volume index <35 mL/m², stage D3 by echocardiography) represented 11.3% of the study cohort (32.2% of those with discordant indices), were disproportionately female (61.5% vs 41.8%, p<0.001), and were characterised as having ‘severe’ AS only 49.5% of the time. Online supplementary figure 2 shows data plotted by V_max and AVA, colour coded with ‘low-flow’ status by stroke volume index (≥35 mL/m² vs <35 mL/m²) in all patients. Left ventricular internal diameter was also assessed for characterisation of those with discordant AS, and within each sex there were no significant differences between those with non-severe, severe and discordant severe AS (online supplementary table 2).

### Table 3

Characteristics of patients with discordant aortic stenosis characterised as either severe or non-severe

<table>
<thead>
<tr>
<th></th>
<th>Severe (123)</th>
<th>Non-severe (160)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years</td>
<td>76.4 (70.4 to 83.7)</td>
<td>73.1 (63.5 to 80.1)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Sex, % male (n)</td>
<td>49.6% (61)</td>
<td>45.0% (72)</td>
<td>0.44</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>27.8 (24.2 to 32.9)</td>
<td>28.4 (24.9 to 33.8)</td>
<td>0.66</td>
</tr>
<tr>
<td>AVA, cm²</td>
<td>0.77 (0.63 to 0.86)</td>
<td>0.90 (0.77 to 0.96)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>AVAi, cm²/m²</td>
<td>0.40 (0.33 to 0.45)</td>
<td>0.45 (0.40 to 0.51)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>V_max, m/s</td>
<td>3.58 (3.28 to 3.79)</td>
<td>3.44 (3.24 to 3.63)</td>
<td>0.004</td>
</tr>
<tr>
<td>Mean gradient, mm Hg</td>
<td>29.7 (25.5 to 33.1)</td>
<td>27.0 (23.8 to 31.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Peak gradient, mm Hg</td>
<td>51.8 (43.0 to 57.2)</td>
<td>47.3 (42.0 to 52.8)</td>
<td>0.003</td>
</tr>
<tr>
<td>DI</td>
<td>0.22 (0.19 to 0.26)</td>
<td>0.26 (0.23 to 0.30)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Ejection fraction, %</td>
<td>55 (38 to 60)</td>
<td>55 (55 to 61)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>SV, mL</td>
<td>61.1 (50.6 to 73.7)</td>
<td>71.2 (60.2 to 80.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Indexed SV, mL/m²</td>
<td>32.5 (26.1 to 38.2)</td>
<td>37.5 (30.7 to 42.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LVOT diameter, cm</td>
<td>2.02 (2.00 to 2.27)</td>
<td>2.00 (2.00 to 2.20)</td>
<td>0.20</td>
</tr>
<tr>
<td>LVIDd, cm</td>
<td>4.59 (3.98 to 5.03)</td>
<td>4.32 (3.93 to 4.80)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LVIDs, cm</td>
<td>3.17 (2.60 to 3.84)</td>
<td>2.90 (2.50 to 3.30)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>BSA, m²</td>
<td>1.93 (1.72 to 2.10)</td>
<td>1.90 (1.73 to 2.06)</td>
<td>0.72</td>
</tr>
</tbody>
</table>

Data presented as median (25th percentile, 75th percentile) except where otherwise noted. 7 severe and 4 non-severe patients did not have reliable BMIs recorded, giving n=116 and 156 for this metric, respectively. 3 severe and 2 non-severe patients did not have LVID metrics, giving n=120 and 158, respectively.

AVA, aortic valve area; AVAi, indexed AVA; BMI, body mass index; BSA, body surface area; DI, dimensionless index; LVID, left ventricular internal dimension; LVIDd, LVID in diastole; LVIDs, LVID in systole; LVOT, left ventricle outflow tract; SV, stroke volume; V_max, peak jet velocity.
DISCUSSION

Using data from clinical echocardiography reports of patients with AVA ≤1.2 cm² and Vmax ≥3 m/s, we found that shifting from a specific definition of severe AS (Vmax ≥4 m/s) to a sensitive definition (AVA ≤1 cm²) resulted in a 66% relative increase in the number of patients with potentially severe AS, with a 97% relative increase in female patients. This observed increase is similar to previously reported data, but it also provides quantitative insight into how this move would affect female patients in particular. Furthermore, while patients with concordant indices of AS severity by echocardiography are usually characterised as having severe AS (94% of the time in our study), discordant indices are common (observed almost as commonly as concordant indices among those with AVA ≤1 cm²), disproportionately observed in female patients, and yield a characterisation of ‘severe’ AS as a minority of the time (43%).

To our knowledge, this is the first study to demonstrate how echocardiographic data are integrated by an echocardiographer when reporting the overall AS severity in a clinical report. This has important implications, as those who receive and read an echocardiography report (particularly if they do not have expertise in valve disease or reading raw echocardiography images) may not be inclined to refer a patient with anything less than ‘severe AS’ for AVR consideration. In this sense, the summary statement of AS severity on the clinical echocardiography report is consequential. Multiple recent studies, although retrospective and non-randomised, report a survival advantage from AVR for those with AVA ≤1 cm² regardless of Vmax, with improved survival with AVR over medical therapy for those with Vmax ≥3 m/s, transvalvular mean gradient 25–40 mm Hg and AVA≤1 cm², and Dayan et al reported improved survival with AVR for the same group, even when assessing specifically the subgroup with preserved stroke volume index (normal-flow, low-gradient AS). Notably, these studies did not include, for example, valve calcium scoring to clarify the severity of AS when indices were discordant, and they included the resting echocardiographic indices alone (as in our study).

Thus, regardless of additional testing or measures of ventricular performance, patients with these discordant indices of AS severity seem to benefit from AVR. Since the guidelines recommend AVR only for patients with ‘severe AS’ and patients with discordant indices of AS severity are commonly characterised as having less than severe AS on echocardiography reports, this undoubtedly influences clinical management decisions and leads to less and later referrals for AVR as prior studies have shown.

This particularly affects female patients who were disproportionately represented among those with discordant AS in our analysis. Indeed, female patients seem to suffer from disproportionate delay of referral for AVR. The prevalence of discordant AS in female patients could be due to several factors including differences in valve calcification and flow. Previous studies have shown that while AS is driven primarily by calcification in male patients, there is a more dominant fibrotic component in female patients. Between these, calcification was seen to

Table 4: Left ventricle metrics and characterisation of echocardiography in patients with discordant aortic stenosis

<table>
<thead>
<tr>
<th>Severity grading</th>
<th>AVA ≤1, AVAi ≤0.6, Vmax &lt;4</th>
<th>EF ≥50%</th>
<th>AVA ≤1, AVAi ≤0.6, Vmax &lt;4</th>
<th>EF ≥50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total (% of cohort)</td>
<td>283 (35.1%)</td>
<td>59 (7.3%)</td>
<td>224 (27.8%)</td>
<td>91 (11.3%)</td>
</tr>
<tr>
<td>Male (% of male patients)</td>
<td>133 (29.4%)</td>
<td>43 (9.5%)</td>
<td>90 (19.9%)</td>
<td>35 (7.7%)</td>
</tr>
<tr>
<td>Female (% of female patients)</td>
<td>150 (42.2%)</td>
<td>16 (4.5%)</td>
<td>134 (37.7%)</td>
<td>56 (15.8%)</td>
</tr>
<tr>
<td>% Female</td>
<td>53.0%</td>
<td>27.1%</td>
<td>59.8%</td>
<td>61.5%</td>
</tr>
<tr>
<td>Severity grading</td>
<td>None</td>
<td>Mild</td>
<td>Mild–moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>All</td>
<td>1 (0.4%)</td>
<td>5 (1.8%)</td>
<td>8 (2.6%)</td>
<td>65 (23.0%)</td>
</tr>
<tr>
<td>All</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>10 (16.9%)</td>
</tr>
<tr>
<td>All</td>
<td>1 (0.4%)</td>
<td>5 (2.2%)</td>
<td>8 (3.6%)</td>
<td>55 (24.6%)</td>
</tr>
<tr>
<td>All</td>
<td>1 (1.1%)</td>
<td>3 (3.2%)</td>
<td>4 (4.4%)</td>
<td>21 (23.1%)</td>
</tr>
<tr>
<td>All</td>
<td>0 (0.0%)</td>
<td>2 (1.5%)</td>
<td>4 (3.0%)</td>
<td>34 (25.6%)</td>
</tr>
</tbody>
</table>

Severity data reported as number (%). AVA, aortic valve area; AVAi, indexed AVA; EF, ejection fraction; SVi, indexed stroke volume; Vmax, peak jet velocity.
be associated with higher gradients. Female patients also
tend to have a lower stroke volume than male patients,
which is associated with lower transvalvular gradients.

The frequent characterisation of patients with discord-
ant AS indices as having less than severe AS is likely
due to two primary reasons. First, it is likely influenced
by the explicit prioritisation in the guidelines of Vmax
and transvalvular mean gradient over AVA in the assess-
ment of AS severity. While updates in the guidelines
have increasingly allowed for subgroups of patients to
be classified as having severe AS despite a Vmax <4 m/s,
the long-standing paradigm of prioritising Vmax over AVA
leads to clinicians reluctant to classify a patient as having
severe AS with Vmax <4 m/s. However, the rationale for
prioritising Vmax over AVA in the diagnosis of severe AS is
based on small studies that neither examine hard clinical
events nor compare prompt AVR versus clinical surveil-
lance at various Vmax or AVA thresholds. Second, in
cases of discordant measurements, additional testing with
nitroprusside, dobutamine, or aortic valve calcium
scoring is increasingly performed to clarify whether AS
is severe. Previous work has highlighted the need for
such additional testing in discordant AS. Knowing this,
echocardiographers may be reluctant to over-call ‘severe
AS’ when they know these additional tests may help clarify
the diagnosis. However, to readers of echocardiography
reports who do not commonly care for patients with AS,
the diagnosis of anything other than ‘severe AS’ on the
echocardiography report may simply be interpreted as a
signal to ‘continue watching’ that patient rather than to
perform an adjunctive test to clarify the true severity of
stenosis.

System-level changes may be warranted to address
these challenges, which likely have adverse clinical conse-
quences. So as not to potentially delay referral for valve
replacement in patients with discordant indices of AS
severity, if the echocardiographer is not going to char-
acterise discordant AS indices (AVA <1 cm² and Vmax
<4 m/s) as ‘severe’ on the clinical report, then it may
be appropriate to include the following on the report:
‘possibly severe AS, but additional evaluation or testing
is needed.’ This would enable the echocardiographer to
not ‘over-call’ severe AS when they believe further testing
is needed, but also help ensure that these patients with
discordant indices are not passively watched but instead
further evaluated and, as appropriate, referred for AVR
in a timely manner. In addition, quality improvement
efforts in echocardiography laboratories could reinforce
that a Vmax ≥4 m/s is not required for the diagnosis of
severe AS.

Limitations
In this cross-sectional study based solely on echocar-
diography data, we do not have information on clinical
presentation, symptoms, referral to AVR or long-
term outcomes. Furthermore, we do not have data
from dobutamine echocardiograms or valve calcium
scores from CT studies. Our focus was on relating the
haemodynamic indices of AS obtained on an echocardi-
gram to how echocardiographers assimilate that infor-
mation and report a summative characterisation of AS
severity. Using the resting echocardiographic indices
alone is consistent with the fact that most of the studies
on the relationship between AS severity and outcomes
simply rely on these resting echocardiographic haemody-
namic indices (AVA, Vmax) and not on adjunctive informa-
tion from stress testing or valve calcium scores. Addition-
ally, we did not assess for measurement error or attempt
to validate sonographer measurements. Importantly, we
are not commenting here on the underlying biology or
pathology. Instead, we have evaluated the cardiologist’s
qualitative read given these values. Finally, these data
were collected from a single academic medical centre,
which may not be representative of other echocardiog-
raphy laboratories.

Conclusions
The proportion of patients and relative percentage of
female patients potentially categorised as having severe AS
is markedly influenced by the echocardiographic indices
of severe AS used. Clinical echocardiography reports
usually characterise discordant indices of AS severity,
which are common and disproportionately observed in
female patients, as less than severe, which could have
adverse clinical consequences. When discordant indices
of AS severity are encountered and characterisation of AS
severity is uncertain, notation in the clinical echocardi-
graphy report of the need for additional evaluation or
testing may minimise the number of patients who experi-
ence a delay in referral for AVR.
REFERENCES
