Prevalence and Correlates of Aortic Regurgitation in American Indians: The Strong Heart Study

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**OBJECTIVES**
We sought to determine the prevalence and correlates of aortic regurgitation (AR) in a population-based sample group.

**BACKGROUND**
Concern over induction of AR by weight loss medication highlights the importance of assessing the prevalence and correlates of AR in unselected patient groups.

**METHODS**
Aortic regurgitation was assessed by color flow Doppler echocardiography in 3,501 American Indian participants age 47 to 81 years during the second Strong Heart Study.

**RESULTS**
Mild (1+) AR was present in 7.3%, 2+ AR in 2.4% and 3+ to 4+ AR in 0.3% of participants, more frequently in those ≥60 years old than in those <60 years old (14.4% vs. 5.8%, p < 0.001); AR was unrelated to gender. Compared with participants without AR, those with mild AR had a lower body mass index (p < 0.004) and higher systolic pressure (p < 0.003). Participants with AR had larger aortic root diameters (3.6 ± 0.4 vs. 3.4 ± 0.4 cm, p < 0.001), higher creatinine levels (1.3 ± 1.3 vs. 1.0 ± 1.0 mg/dl, p < 0.001) and higher urine albumin/creatinine levels (3.6 ± 2.3 vs. 3.3 ± 2.0 log, p < 0.001), as well as higher prevalences of aortic stenosis (AS) or mitral stenosis (MS) (p < 0.001). Regression analysis showed that AR was independently related to older age and larger aortic roots (p < 0.0001), AS and absence of diabetes (p = 0.002), MS (p = 0.003) and higher log urine albumin/creatinine (p = 0.005).

**CONCLUSIONS**
Aortic regurgitation occurred in 10% of a sample group of middle-aged to older adults and was related to older age, larger aortic root diameter, aortic and mitral stenosis and albuminuria. There was no association of AR with being overweight and a negative association of AR with diabetes. (J Am Coll Cardiol 2000;36:461–7) © 2000 by the American College of Cardiology

With improving technology and increasing use of Doppler echocardiography in recent years, detection and characterization of regurgitant valvular heart disease have been facilitated. Doppler echocardiography has been used to derive estimates of the prevalence of valvular regurgitation in small, selected groups, composed primarily of normal volunteers (1–6). Other studies evaluated whether the prevalence of valvular regurgitation was related to age in small groups of apparently normal subjects (7,8). However, most of these studies predated the use of color Doppler echocardiography, which has increased the accuracy and sensitivity for the detection of valvular regurgitation. A recent study examined the prevalence of valvular regurgitation in unselected young adults (Reid JL, Gardin J, Yunis C, personal communication), and data have been provided, by the Framingham Heart Study (9) regarding the prevalence of regurgitation in adults of a wide age range.

With the recent concern over the induction of valvular heart disease by popular prescription appetite-suppressant medications, and their subsequent withdrawal from the market, there has been debate and uncertainty over the true prevalence of regurgitant valvular heart disease and its relation to obesity in the general adult population (10–14). We therefore undertook this study to assess the prevalence and correlates of aortic valve regurgitation using color Doppler echocardiography in a large, adult population that included a high proportion of overweight individuals.

**METHODS**
As previously described, the Strong Heart Study (SHS) is an epidemiologic survey of cardiovascular risk factors and prevalent and incident cardiovascular disease in 13 American Indian tribes in Arizona, Oklahoma, South Dakota and North Dakota (15–17). At enrollment, the study cohort included adult members age 45 to 74 years in three tribes in central Arizona, seven tribes in Oklahoma and three tribes...
in North and South Dakota, recruited from defined sampling frames of eligible individuals (overall participation rate 61%) and initially examined between July 1989 and January 1992. Characterization of subjects included a medical history, electrocardiogram (ECG) and measurement of brachial and ankle blood pressure; aspects of body habitus included body mass index and waist/hip ratio. Fat-free mass and adipose body mass were estimated using an RJL impedance meter (model B14101; RJL Equipment Company, Detroit, Michigan). Fasting glucose, glycosylated hemoglobin, insulin, lipid and lipoprotein levels were obtained, and a 2-h glucose tolerance test was performed as previously described (15). A total of 3,637 SHS cohort members (89% of those still alive) returned for the second SHS examination from August 1993 to December 1995, to assess changes over time in baseline measures and to perform echocardiography, pulmonary function tests and gall bladder imaging. Participants were classified as hypertensive if their rest blood pressure was $\geq 140$ mm Hg systolic or $\geq 90$ mm Hg diastolic, or if they were taking antihypertensive medications (18,19). Participants gave written, informed consent under protocols approved by tribal and Indian Health Service Institutional Review Boards.

**Echocardiographic methods.** Studies were performed using Acuson 128 (Acuson, Inc., Mountain View, California) phased-array echocardiography with M-mode, two-dimensional and pulsed, continuous wave and color flow Doppler modalities (20,21). Examination tables with apical cut-outs were used with the head of the table elevated $30^\circ$C in a partial decubitus position. The parasternal acoustic window was used to record $\approx 10$ consecutive beats of two-dimensional and M-mode recording of the left ventricular (LV) internal diameter and wall thickness at or just below the tips of the mitral valve leaflets in long- and short-axis LV views and long-axis views of the mitral valve. M-mode and two-dimensional short- and long-axis views of the aortic root and left atrium were also obtained. The apical acoustic window was employed to record $\approx 10$ cycles of two- and four-chamber recordings to assess LV wall motion.

Color flow Doppler recordings from the parasternal and apical windows were used to search for aortic and mitral regurgitation (22). Aortic regurgitation (AR) was identified according to the extent of diastolic turbulent flow in the LV, indicated by a variance signal, with mild (1+) AR identified by a jet occupying $<20\%$ of the aortic annular diameter at its origin and extending less than half way to the tip of the anterior mitral leaflet; moderate (2+) AR by jets filling 20% to 40% of the annular diameter extending up to the tip of the anterior mitral leaflet; moderately severe (3+) AR by jets occupying 40% to 60% of the annular diameter extending to or slightly beyond the tip of the anterior mitral leaflet; and severe (4+) AR by jets occupying $>60\%$ of the annular diameter extending to the posterior wall of the LV or more than half way to the LV apex. For jets oriented perpendicular to the aortic annular plane, rather than crossing the valve’s LV surface, priority was given to jet length criteria. Recordings were made entirely on videotape. Concomitant mitral regurgitation was assessed by color Doppler criteria according to regurgitant jet area and depth (22).

**Echocardiographic measurements.** Preliminary measurements were made at the Reading Center in New York by an experienced sonography reader (M.P.) and verified, with corrections when necessary, by a physician investigator (R.B.D. or M.J.R.). Correct orientation of planes for imaging and Doppler recording was verified as previously described (23). Measurements were made using a computerized review station equipped with digitizing tablet and monitor screen overlay. Left ventricular internal dimension and interventricular septal and posterior wall thickness were made at end diastole and end systole on up to three cycles, according to American Society of Echocardiography (ASE) recommendations (24). When optimal LV orientation could not be obtained, as is common in subjects who are overweight or $>60$ years old, correctly oriented two-dimensional linear dimensions were made by the ASE leading-edge convention (25). Aortic annular dimension was measured between the hinging points of the aortic valve leaflets in the parasternal or apical long-axis view that revealed the largest aortic annular diameter. Diameters of the aortic annulus and aortic root at the sinuses of Valsalva were measured in the long-axis view that maximized these dimensions (26). Aortic annular diameter was measured from the trailing edge to the leading edge at the hinging points of the aortic cusps to the annulus, using color flow mapping to help delineate tissue–blood interfaces, when necessary; aortic root dimensions were measured using the leading-edge convention (26). The presence of bicuspid aortic valves was determined by visualization of the valve in short-axis views. Aortic stenosis (AS) was identified by detection of moderately or severely reduced aortic cusp motion and graded as moderate if the valve area by the continuity equation (using additional continuous wave recordings) was $0.45$ to $0.8 \text{cm}^2/\text{m}^2$, and severe if it was smaller.

**Data handling and statistical analyses.** Data are reported as the mean value ± SD for continuous variables and proportions for categorical variables. Data management and analysis were performed using a microcomputer equipped...
with SPSS 7.5 software (SPSS, Chicago, Illinois). The prevalence of AR between groups delineated by gender, decade of age, presence of diabetes and hypertension was assessed by the chi-square test. Differences in clinical variables among participants with and without AR were assessed by one-way analysis of variance, followed by the REGWF post-hoc test (27). Independence of an association of other variables with AR was assessed by logistic and linear regression analyses. Two-tailed p < 0.05 was considered statistically significant.

RESULTS

A total of 3,501 SHS participants (97% of those attending the second examination) had echocardiograms (1,316 men and 2,185 women, age range 46 to 82 years [mean 60 ± 8]). Arterial blood pressure was 130 ± 21/75 ± 10 mm Hg; 1,671 (46%) had hypertension according to the fifth report of the Joint National Committee on detection, evaluation and treatment of high blood pressure (JNC-V) criteria (21). Body mass index was 31.2 ± 6.5 kg/m²; 29% had normal body weight, 17% were overweight and 53% were obese by National Institutes of Health Consensus Conference criteria (28). Diabetes mellitus was present, according to World Health Organization criteria (29), in 1,811 participants (52%).

Prevalence of AR. Mild (1+) AR was found in 257 participants (7.3%)—97 1,316 (7.4%) of 1,316 men and 160 (7.3%) of 2,185 women (p = NS). Moderate to severe (≥2+) AR was found in 93 subjects (2.7%), including 38 men (3.0%) and 55 women (2.5%; p = NS). As Figure 1 demonstrates, the prevalence of mild AR increased stepwise from 4.5% in subjects <50 years old to 16.4% in those 70 to 79 years old; the corresponding increase in the prevalence of moderate to severe AR was from 1.6% to 4.5% (p < 0.002). The overall prevalence of AR was slightly lower in participants with diabetes (8.7%) than in those with normal glucose tolerance (10.6%) or impaired glucose tolerance (glucose levels of 140 to 200 mg/dl 2 h after a 75-g glucose load) (11.3%; overall p < 0.05). There was no difference in the prevalence of AR between obese and nonobese participants (9.2% vs. 11.1%, p = 0.15). Participants in the three SHS regions had similar prevalences of mild AR (6.7% to 8.1%) and ≥2+ AR (1.9% to 2.7%) (p = NS).

Clinical variables. Table 1 shows clinical and demographic variables in SHS participants stratified by severity of AR. The presence of AR was associated with a lower body mass index, by ~1 kg/m², in both subgroups with AR. This was because of lower adipose body mass in participants with AR, with no intergroup difference in fat-free mass or height. There was no difference in the change in weight from the first to the second SHS examination between participants with no AR (mean −0.3 ± 7.5 kg) and those with mild (1+) AR (mean −0.9 ± 6.9 kg) or ≥2+ AR (mean −0.9 ± 5.5 kg) (overall p = 0.28). The intergroup difference in body mass index, but not in weight change, was confirmed in an additional analysis (data not shown) that excluded individuals with specific causes of AR.

Systolic blood pressure was higher in participants with AR than in those with no AR. Diastolic blood pressure was lower in those with ≥2+ AR than in those without AR, but did not differ between individuals with no AR and those with 1+ AR. Pulse pressure increased stepwise from participants with no AR to those with ≥2+ AR (p = 0.01 after adjusting for age). No difference existed among groups

| Table 1. Characteristics of Strong Heart Study Participants Classified by the Presence and Degree of AR |
|---|---|---|---|---|
| | No AR | 1+ AR | ≥2+ AR | p Value* |
| Age (yrs) | 64 ± 8 | 63 ± 8 | 41.7% | 0.001 |
| Male | 37.6% | 38.3% | 41.7% | 0.795 |
| Weight (kg) | 84.6 ± 18.7 | 80.3 ± 16.0 | 81.6 ± 16.6 | 0.001 |
| Height (cm) | 164.3 ± 8.9 | 163.2 ± 8.7 | 163.3 ± 8.9 | 0.123 |
| Systolic BP (mm Hg) | 129.7 ± 20.4 | 133.2 ± 20.8 | 134.5 ± 22.0 | 0.003 |
| Diastolic BP (mm Hg) | 75.0 ± 10.2 | 75.4 ± 11.8 | 72.1 ± 9.5 | 0.021 |
| Pulse pressure (mm Hg) | 54.7 ± 17.2 | 57.7 ± 17.2 | 62.4 ± 20.0 | <0.001 |
| BMI (kg/m²) | 31.3 ± 6.5 | 30.1 ± 5.8 | 30.6 ± 5.9 | 0.012 |
| Fat-free mass (kg) | 52.9 ± 11.5 | 51.4 ± 10.2 | 53.6 ± 11.1 | 0.119 |
| Adipose mass (kg) | 31.7 ± 12.5 | 29.1 ± 11.1 | 28.7 ± 11.3 | 0.001 |
| Ankle/arm index | 1.14 ± 0.16 | 1.14 ± 0.14 | 1.13 ± 0.14 | 0.399 |
| Stroke index/pulse pressure (ml/mm Hg per m²) | 0.39 ± 0.10 | 0.41 ± 0.15 | 0.44 ± 0.11 | <0.001 |

*By analysis of variance. Data are presented as the mean value ± SD, except for male gender.

AR = aortic regurgitation; BMI = body mass index; BP = blood pressure.
defined by the presence and severity of AR in the ankle/arm blood pressure index. The stroke index/pulse pressure ratio, a measure of systemic arterial capacitance, was higher in individuals with ≥2+ AR.

**Laboratory variables (Table 2).** In analyses that considered markers of extracardiac vascular disease, the presence of AR was associated with higher serum creatinine levels as well as a higher log of the urine albumin/creatinine ratio. Lipid values, including total cholesterol, triglycerides and high and low density lipoproteins did not differ between groups. Insulin levels were not significantly different between participants with and those without AR, but fasting glucose levels were lower in individuals with ≥2+ AR, and glucose values 2 h after a 75-g glucose load were marginally lower in those with AR. In addition, glycylated hemoglobin levels were marginally lower in those with AR than in those without AR. Fibrinogen levels did not differ between groups with and without AR.

**Potential causes of AR.** Aortic root diameter at the level of the sinuses of Valsalva, as measured on two-dimensional echocardiography, was larger in both groups with AR (3.6 ± 0.4 cm in each) than in those without AR (mean 3.4 ± 0.4 cm, p < 0.001 after adjustment for age). Aortic stenosis, which was detected in 0.7% of the population, was more prevalent in the group with AR than in the group without AR. In fact, as demonstrated in Figure 2, the prevalence of AR rose from 7.4% among individuals without AS to 45% in those with mild AS and to 100% in those with moderate or severe AS. The SHS participants with aortic valve thickening or with a bicuspid aortic valve (overall prevalence 0.3%) were also more likely to have AR (Fig. 3, 4). There was also a higher prevalence of AR in participants with mitral stenosis (MS) (8 [53%] of 15) than in those without this marker of rheumatic heart disease (342 [10%] of 3,486, p < 0.001). Compared with participants with no mitral regurgitation, there were higher prevalences of mild AR and ≥2+ AR in those with mild and ≥2+ mitral regurgitation (5.8% vs. 13.2% and 13.2% and 1.7% vs. 4.5% and 19.7%, respectively; overall p < 0.001). The prevalence of AR of any degree was slightly higher in SHS participants with hypertension by JNC-V criteria (11.4%) than in normotensive individuals (8.8%, p = 0.02).

**Effects of AR on the LV.** Analyses of LV status excluded participants with ≥2+ mitral regurgitation as a potentially confounding cause of LV volume overload. Left ventricular internal dimension in diastole increased stepwise with increasing AR (Table 3). Posterior wall and interventricular septal thicknesses were also greater in subjects with AR than in those without AR, but did not differ between the group with mild and the group with moderate to severe AR. Echocardiographic LV mass and LV mass indexed for different measures of body size were greater in participants

**Table 2.** Laboratory Findings in Strong Heart Study Participants Classified by the Presence and Degree of AR

<table>
<thead>
<tr>
<th></th>
<th>No AR</th>
<th>1+ AR</th>
<th>2+ AR</th>
<th>p Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creatinine (mg/dl)</td>
<td>1.0 ± 0.9</td>
<td>1.2 ± 1.2</td>
<td>1.3 ± 1.3</td>
<td>0.001</td>
</tr>
<tr>
<td>Urine albumin/creatinine (log)</td>
<td>3.3 ± 2.0</td>
<td>3.7 ± 2.0</td>
<td>3.6 ± 2.3</td>
<td>0.008</td>
</tr>
<tr>
<td>Total cholesterol (mg/dl)</td>
<td>190.4 ± 40.1</td>
<td>185.1 ± 38.3</td>
<td>185.8 ± 47.5</td>
<td>0.077</td>
</tr>
<tr>
<td>HDL cholesterol (mg/dl)</td>
<td>41.3 ± 13.4</td>
<td>41.1 ± 13.6</td>
<td>39.7 ± 13.3</td>
<td>0.501</td>
</tr>
<tr>
<td>LDL cholesterol (mg/dl)</td>
<td>118.5 ± 34.3</td>
<td>115.5 ± 31.0</td>
<td>116.8 ± 39.0</td>
<td>0.385</td>
</tr>
<tr>
<td>Triglycerides (mg/dl)</td>
<td>188 ± 3.7</td>
<td>184 ± 100.8</td>
<td>149 ± 108.5</td>
<td>0.287</td>
</tr>
<tr>
<td>Insulin (IU)</td>
<td>22.7 ± 27.1</td>
<td>19.4 ± 15.5</td>
<td>21.1 ± 28.7</td>
<td>0.106</td>
</tr>
<tr>
<td>Fasting glucose (mg/dl)</td>
<td>155 ± 80</td>
<td>146 ± 72</td>
<td>135 ± 60</td>
<td>0.007</td>
</tr>
<tr>
<td>2-h Glucose (mg/dl)</td>
<td>169 ± 94</td>
<td>154 ± 80</td>
<td>151 ± 74</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>Glycosylated hemoglobin (%)</td>
<td>6.9 ± 2.4</td>
<td>6.7 ± 2.3</td>
<td>6.4 ± 2.1</td>
<td>0.017</td>
</tr>
<tr>
<td>Fibrinogen (mg/dl)</td>
<td>364 ± 83</td>
<td>366 ± 79</td>
<td>365 ± 88</td>
<td>0.966</td>
</tr>
</tbody>
</table>

*By analysis of variance. Data are presented as the mean value ± SD.

AR = aortic regurgitation; HDL = high density lipoprotein; LDL = low density lipoprotein.

**Figure 2.** The prevalences of both mild (1+) AR (solid bars) and more severe (≥2+) AR (open bars) show progressive increases from individuals with no AS to those with mild AS to those with moderate or severe AS (p < 0.001).

**Figure 3.** The prevalences of both mild (1+) AR (solid bars) and more severe (≥2+) AR (open bars) were substantially higher (p < 0.001) in individuals with bicuspid as opposed to trileaflet aortic valves.
FIGURE 4. The prevalences of both mild (1+ AR (solid bars) and more severe (≥2+ AR (open bars)) were higher (p < 0.01) in individuals with thickened aortic valve cusps versus cusps of normal thickness.

with versus without AR. Further, LV mass increased stepwise with increasing severity of AR. Relative wall thickness did not differ between subjects with and without AR. As a result, the prevalence of eccentric LV hypertrophy was elevated (37%) in participants with mild AR, especially in those with at least 2+ AR (48%; p < 0.001).

Left ventricular ejection fraction endocardial and mid-wall fractional shortening were slightly lower in participants with versus without AR, although there was no difference between the groups with mild versus moderate to severe AR (Table 4). Mid-wall fractional shortening was slightly reduced in participants with mild AR, but not in individuals with more severe regurgitation. Circumferential end-systolic stress showed a stepwise increase with increasing severity of AR, and as a result, stress-corrected LV mid-wall shortening—a measure of LV myocardial contractility—did not differ between the groups. In contrast, the end-systolic stress/volume index ratio—a measure of LV chamber contractility—showed stepwise decreases with increasing severity of AR.

Regression analyses. A logistic regression model was developed in which the presence or absence of AR was related to the participants’ characteristics (age, body mass index, presence of hypertension or diabetes) and potential etiologies (aortic root diameter, AS and MS) as independent variables (with the addition of gender and height because of their known relations to other independent variables). Older age was the strongest correlate of AR, followed by aortic root diameter (both p < 0.0001), presence of AS and absence of diabetes (both p = 0.002), presence of MS (p = 0.003) and higher log albumin/creatinine ratio (p = 0.005). Gender, body mass index, height and hypertension by JNC-V criteria were not independently related to the presence of AR. These results were confirmed in a linear regression analysis in which the grades (0 to 4+) of severity of AR were used as the dependent variable.

DISCUSSION

The present study provides population-based data showing that AR occurs in ~10% of middle-aged to elderly individuals, in accordance with the only previous epidemiologic study in this age range (9). In addition, AR increased in prevalence with advancing age and with the presence of hypertension, as expected from the limited data previously available (9,30). Both of these findings are compatible with damage to the aortic valve occurring gradually over time due to hemodynamic stress. Regression analyses showed that AR was independently associated with older age but not with hypertension when other variables were considered.

Obesity and AR. In contrast to the aforementioned positive associations, univariate analyses showed a highly significant and previously unreported negative association between AR and obesity. The mechanism of this association is uncertain. Although we did not find an association between AR and weight loss over the several years before the echocardiographic study, it is possible that individuals with AR may have lost weight over a longer period, owing to either the presence of subtle symptoms or medical advice after earlier clinical recognition of heart murmur. The fact that body mass index was not independently associated with AR in regression analyses raises the possibility that some of the etiologies of AR that we found to be independently associated with AR (aortic root enlargement, AS or MS) could be associated with lower body weight, as previously observed for mitral valve prolapse, another common valvular abnormality (31). However, the negative relation between body mass index and AR persisted in analyses excluding individuals with specific causes of AR. Whatever the pathophysiologic mechanism, the present findings conclusively exclude a positive association between being overweight and AR. As a result, the apparent excess of AR in some (10–14)

Table 3. Left Ventricular Geometry in Relation to Presence and Degree of AR

<table>
<thead>
<tr>
<th></th>
<th>No AR</th>
<th>1+ AR</th>
<th>≥2+ AR</th>
<th>p Value†</th>
</tr>
</thead>
<tbody>
<tr>
<td>LVID (cm)</td>
<td>5.0 ± 0.5</td>
<td>5.1 ± 0.6</td>
<td>5.3 ± 0.6</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>PWT (cm)</td>
<td>0.86 ± 0.10</td>
<td>0.88 ± 0.11</td>
<td>0.89 ± 0.10</td>
<td>0.003</td>
</tr>
<tr>
<td>IVS (cm)</td>
<td>0.93 ± 0.13</td>
<td>0.95 ± 0.13</td>
<td>0.96 ± 0.12</td>
<td>0.002</td>
</tr>
<tr>
<td>RWT</td>
<td>0.35 ± 0.05</td>
<td>0.35 ± 0.06</td>
<td>0.34 ± 0.05</td>
<td>0.237</td>
</tr>
<tr>
<td>LV mass (g)</td>
<td>157.4 ± 19.7</td>
<td>169.0 ± 43.5</td>
<td>182.1 ± 47.5</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>LV mass index (g/m²)</td>
<td>82.9 ± 18.9</td>
<td>91.7 ± 23.2</td>
<td>98.0 ± 23.3</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>LVM/fat-free mass (g/kg)</td>
<td>3.0 ± 0.7</td>
<td>3.4 ± 0.9</td>
<td>3.6 ± 0.9</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>LV mass/height² (g/m²)</td>
<td>41.4 ± 10.4</td>
<td>45.5 ± 12.9</td>
<td>49.3 ± 13.0</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

*Excluding participants with ≥2+ mitral regurgitation as a confounding cause of volume overload. †By analysis of variance. Data are presented as the mean value ± SD.

AR = aortic regurgitation; IVS = interventricular septal thickness; LV = left ventricular; LVID = left ventricular end-diastolic diameter; PWT = posterior wall thickness; RWT = relative wall thickness.
studies in groups of overweight patients who had taken appetite-suppressant medications cannot be attributed to an underlying association between being overweight and AR. Of note, we also observed a negative association between being overweight and mitral regurgitation in the SHS study group (32).

Causes of AR. The present study provides the first population-based information on the association between several potential mechanisms of AR and the actual presence of valvular regurgitation. In accordance with previous studies, a positive association was observed between aortic root diameter and the presence and severity of AR (33–35). This association may reflect the essential role of the aortic root in supporting the aortic valve cusps, such that dilation of the root may pull apart the moorings of the leaflets, especially at the commissures, reduce the overlap between leaflets and thereby promote regurgitation. Larger aortic size and the presence of AS and MS, a marker of rheumatic valvular disease, were all independently associated with AR in regression analyses. In addition, we observed positive associations between AR and aortic cusp calcification, a potential cause of suboptimal leaflet apposition, and between AR and the bicuspid aortic valve. In addition to the potential disadvantage, in terms of efficient valve function, with having two rather than the usual three cusps, we have previously identified an association between regurgitant bicuspid aortic valves and aortic dilation (36).

Left ventricular effects of AR. Finally, the present study provides the first population-based data on the impact of AR of differing severity, demonstrated by standard Doppler echocardiographic methods, on LV structure and function. In accordance with standard concepts of the impact of volume overloading on the LV, increasing degrees of AR were associated with stepwise increases in LV chamber dimension and wall thickness without a change in relative wall thickness, resulting in rise of prevalences of eccentric LV hypertrophy. Left ventricular chamber function, as measured by endocardial fractional shortening and the end-systolic stress/volume index ratio, was slightly reduced in the presence of AR, but myocardial function, as assessed by LV mid-wall shortening and stress-corrected mid-wall shortening, was not systematically affected by AR. This suggests that the decline in LV chamber function was related to increased arterial pressure and, consequently, end-systolic stress, which was not offset by a compensatory increase in LV wall thickness.

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