PATHOPHYSIOLOGY AND NATURAL HISTORY
VALVULAR HEART DISEASE

Age-related valvular regurgitation: a study by pulsed Doppler echocardiography

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ABSTRACT To assess the prevalence of valvular regurgitation in the aged, we studied 176 apparently healthy volunteers with no history or physical evidence of cardiac abnormality. Their ages ranged from 40 to 90 (66 ± 14, mean ± SD) years. We examined these subjects by pulsed Doppler echocardiography combined with two-dimensional echocardiography to determine the prevalence of valvular regurgitation. Regurgitation began to appear in subjects in their fifties, increasing in prevalence with advancing age (r = .81, p < .001), and was documented in all over age 80. Similarly, regurgitation involving more than one valve appeared in those 60 years and older, and was very common (89%) in subjects in their eighties. With each type of valvular regurgitation, the prevalence of each type of regurgitation increased with aging, but this tendency was most prominent for aortic regurgitation. We conclude that (1) single or multivalvular regurgitation as detected by pulsed Doppler echocardiography is very common in the aged and may be considered a normal finding in the absence of other evidence of heart disease, and (2) the high prevalence of regurgitation in the aged must be taken into account when Doppler examinations are being performed.


PULSED DOPPLER echocardiography is a noninvasive technique that has proved useful in the detection of valvular regurgitation. The high degree of specificity and sensitivity of this technique has been reported.1-11

The atrioventricular valves are known to become thicker and more opaque with advancing age,12-15 and similar changes may occur in the semilunar valves. The grade of these changes is in part genetically determined and in part age related.12,16 Therefore, multivalvular regurgitation of little or no clinical significance can be expected to occur in older subjects. The purpose of this study was to investigate the prevalence of valvular regurgitation in the aged by pulsed Doppler echocardiography.

Subjects and methods

Apparently healthy volunteers without cardiac symptoms were studied. All were outpatients or inpatients of the Department of Ophthalmology of Kobe General Hospital who were undergoing routine vision testing or were being considered for cataract surgery. None had received a prior diagnosis of cardiac disease or had valvular regurgitation of a known cause such as rheumatic fever, myocardial infarction, hypertension, or mitral valve prolapse. Before the pulsed Doppler echocardiographic study, a physical examination was performed and a 12-lead electrocardiogram as well as a two-dimensional echocardiogram were recorded to exclude known causes of valvular regurgitation. Patients were excluded if they had a significant murmur, atrial fibrillation, left ventricular hypertrophy, evidence of previous myocardial infarction, asynergy of the left ventricle, mitral annular calcification, or a perceptible aortic valve abnormality. Finally, 176 of 227 apparently healthy volunteers were studied by pulsed Doppler echocardiography. Their ages ranged from 40 to 90 (mean ± SD, 66 ± 14) years. These subjects were divided into five groups according to age.

Pulsed Doppler echocardiography was performed with a commercially available bidirectional ultrasonic pulsed Doppler flowmeter (Toshiba SDS-21A) combined with a real-time, phased-array two-dimensional echocardiograph (Toshiba SSS-40A). The frequency of the pulsed Doppler flowmeter was 2.4 MHz and the pulse repetition rate was 4 KHz. The sample volume had a teardrop shape and was 2 mm deep and 4 mm wide. The site of sampling volume could be set at any depth from 0 to 16 cm from the transducer and was displayed on the two-dimensional and M mode echocardiograms. The Doppler signal was passed through a high-pass filter (400 Hz) to eliminate the influence of movements of the intracardiac structures. Frequency analysis of the Doppler signals was carried out in real time by fast-Fourier transform. Doppler signals were recorded by a strip-chart recorder at a paper speed of 50 mm/sec along with M mode echocardiograms, electrocardiograms, and phonocardiograms.
TABLE 1

Prevalence of valvular regurgitation in each age group

<table>
<thead>
<tr>
<th>Age (yr)</th>
<th>40–49 (n = 33)</th>
<th>50–59 (n = 35)</th>
<th>60–69 (n = 36)</th>
<th>70–79 (n = 37)</th>
<th>80+ (n = 35)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No regurg</td>
<td>32 (97%)</td>
<td>30 (86%)</td>
<td>11 (31%)</td>
<td>2 (5%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Single valve regurg</td>
<td>1 (3%)</td>
<td>4 (11%)</td>
<td>12 (33%)</td>
<td>7 (19%)</td>
<td>4 (11%)</td>
</tr>
<tr>
<td>Multi valve regurg</td>
<td>0 (0%)</td>
<td>1 (3%)</td>
<td>13 (36%)</td>
<td>28 (76%)</td>
<td>31 (89%)</td>
</tr>
</tbody>
</table>

Two-dimensional echocardiograms were obtained with the use of standard imaging planes to demonstrate each valve clearly. In each imaging plane, a Doppler examination was performed. For the detection of atrioventricular valve regurgitation, the sample volume was placed behind the atrioventricular valves in the atrium and moved in each direction to map the whole atrium. For the detection of semilunar valve regurgitation, the sample volume was placed in the ventricular outflow tract beneath the semilunar valves and swept in each direction.

Regurgitation was judged to be present when disturbed or turbulent flows were detected during the entirety of systole or diastole.

Semiquantification of each type of regurgitation was estimated on the basis of the location and area of distribution of the regurgitant signals detected.

Atrioventricular valve regurgitation was defined as trivial or mild when the regurgitant spectral signal was recorded just below the atrioventricular valve or in the proximal third of the atrium. Significant atrioventricular valve regurgitation was considered to be present when the regurgitant jet was recorded in the mid (moderate) or distal (severe) atrial cavity.

In patients with aortic regurgitation, regurgitant signals obtained just below the aortic valve in the left ventricular outflow tract were considered to be trivial. Signals localized to the outflow tract region and not extending to the tip of the mitral valve were mild. Regurgitation detected at the tip of the valve and extending to the papillary muscle was moderate, whereas that extending farther was severe. Moderate and severe degrees of regurgitation were considered to be clinically significant.

Pulmonary regurgitation was also established as trivial or mild when the disturbed diastolic flow signals could be obtained just below the pulmonary valve or less than 1.5 cm from the pulmonary valve into the right ventricular outflow tract. Significant pulmonary regurgitation (moderate or severe) was defined by regurgitant signals recorded more than 1.5 cm from the pulmonary valve into the right ventricular outflow tract.

Statistical analysis was performed by nonparametric techniques with respect to the prevalence of valvular regurgitation in each age group.

The Kruskall-Wallis test and subsequently Spearman’s rank correlation test were applied to assess the correlation between the number of regurgitant valves and age groups (tables 1 and 2). The number of regurgitant valves was ranked as a numerical variable.

A probability value of less than .01 was considered to indicate a significant difference.

Results

Prevalence of valvular regurgitation. Valvular regurgitation began to appear in subjects 50 or more years, and was documented in the all over 80 (table 1). The prevalence of regurgitation increased with advancing age (r = .81, p < .001).

Multivalvar regurgitation appeared in subjects 60 or more years old, and was very common (88%) in those 80 or more (table 1 and 2). The prevalence of involvement of two, three, and four valves increased progressively in proportion to aging (r = .81, p < .001).

Figure 1 indicates Doppler flow signals in a subject with regurgitation of all four valves. Involvement of all four valves was documented in nine of 37 subjects (24%) in their seventies and 11 of 35 subjects (31%) in their eighties (table 2).

In each valve — mitral, aortic, and tricuspid — the prevalence of regurgitation increased with increasing age (table 3). This tendency was most prominent in those with aortic regurgitation. Among subjects 80

TABLE 2

Number of regurgitant valves by age group

<table>
<thead>
<tr>
<th>Regurgitation</th>
<th>40–49 (n = 33)</th>
<th>50–59 (n = 35)</th>
<th>60–69 (n = 36)</th>
<th>70–79 (n = 37)</th>
<th>80+ (n = 35)</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>32 (97%)</td>
<td>30 (86%)</td>
<td>11 (31%)</td>
<td>2 (5%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>One valve</td>
<td>1 (3%)</td>
<td>4 (11%)</td>
<td>12 (33%)</td>
<td>7 (19%)</td>
<td>4 (11%)</td>
</tr>
<tr>
<td>Two valves</td>
<td>0 (0%)</td>
<td>1 (3%)</td>
<td>9 (25%)</td>
<td>8 (22%)</td>
<td>8 (23%)</td>
</tr>
<tr>
<td>Three valves</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>4 (11%)</td>
<td>11 (30%)</td>
<td>12 (34%)</td>
</tr>
<tr>
<td>Four valves</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>9 (24%)</td>
<td>11 (31%)</td>
</tr>
</tbody>
</table>
years old and older, aortic regurgitation was present in 89%. Right-sided valvular regurgitation was observed in more than a half of the subjects 70 or more years old.

**Semiquantification of valvular regurgitation.** All mitral, aortic, and pulmonary regurgitation observed was trivial to mild and was thought to have no clinical significance. Most of the tricuspid regurgitation observed was also trivial to mild, but occasionally moderate tricuspid regurgitation was noted.

**Discussion**

The results of this investigation reveal that valvular regurgitation, as detected by pulsed Doppler echocardiography, increases progressively with age in apparently healthy subjects and is almost uniformly observed in subjects in their eighties. Multivalvular regurgitation was seen in more than 70% of our study population 70 or more years old, and aortic regurgitation was observed in 89% of subjects 80 years old and older.

The high prevalence of valvular regurgitation in the aged might be related to myxomatous degeneration of valves and their supporting structures. Grossly, the atrioventricular valves become thicker and more opaque with advancing age. Similar changes may occur in the semilunar valves. The grade of these

**TABLE 3**

<table>
<thead>
<tr>
<th>Specific valves involved in each age group</th>
<th>Age (yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>40–49 (n = 33)</td>
</tr>
<tr>
<td>MR = mitral regurgitation; AR = aortic regurgitation; TR = tricuspid regurgitation; PR = pulmonary regurgitation.</td>
<td></td>
</tr>
</tbody>
</table>

FIGURE 1. Doppler flow signals in a subject with regurgitation of all four — mitral (upper left), tricuspid (lower left), aortic (upper right), and pulmonary (lower right) — valves.
changes is in part genetically determined, and in part age related. Long-standing mechanical stress may also play a role in producing regurgitation. The left-sided valves (aortic and mitral) are, of course, exposed to high pressures and may therefore undergo degenerative changes earlier than right-sided valves. In our study, aortic regurgitation was most frequently seen, and mitral regurgitation was the second most frequent in subjects of advanced age. In subjects with left-sided valvular regurgitation, however, the effect of mild hypertension cannot be completely excluded, especially in outpatients in this study.

Pulsed Doppler echocardiography has proven to be a highly accurate and objective noninvasive technique for detecting valvular regurgitation. However, correlation of Doppler-measured turbulent flow with auscultatory findings is extremely poor. Murmurs are vibrations in an audible frequency range induced by turbulent flow, while the Doppler shifts represent minute changes in the frequency range also induced by flow dynamics. Therefore, it is possible for the turbulence resulting from small amounts of regurgitant flow to be insufficient in magnitude to induce audible vibrations. This appears to be the reason for the discrepancy between auscultatory and Doppler findings noted in our subjects.

The clinical implication of our findings of silent regurgitation detected by the Doppler technique is principally the avoidance of iatrogenic heart disease. Our study reveals a high prevalence of hemodynamically insignificant degrees of regurgitation often involving several valves in the aged. When valvular regurgitation is recognized by pulsed Doppler echocardiography, other clinical and laboratory evidence of heart disease should be carefully evaluated to avoid overdiagnosis, since the degree of regurgitation may in fact be insignificant.

The recently developed Doppler color flow mapping system could allow rapid identification and semiquantitation of valvular regurgitation. When this system is used, however, a prevalence of valvular regurgitation similar to that in this study should be expected in the aged because sensitivity and specificity of the system are equivalent to those of the pulsed Doppler technique.

Finally, this kind of study should be done with a prospective cohort of individuals who are normal by physical examination, echocardiography, and Doppler techniques. Therefore, a further follow-up study is needed to provide final conclusions.

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References
Age-related valvular regurgitation: a study by pulsed Doppler echocardiography.
T Akasaka, J Yoshikawa, K Yoshida, F Okumachi, K Koizumi, K Shiratori, S Takao, M Shakudo and H Kato

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