Hypertension in aortic valve disease and its response to valve replacement

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Summary: We have investigated the prevalence of hypertension and the response of blood pressure to operation in 87 patients with lone aortic valve disease who underwent aortic valve replacement.

In patients with aortic stenosis alone 26% were hypertensive pre-operatively (age and sex adjusted blood pressure > 160 systolic and or > 95 mmHg diastolic) and 24% were hypertensive post-operatively. In those with aortic regurgitation alone, hypertension was present in 65% before and 57% after valve replacement using the same criterion. For combined stenosis and regurgitation, the prevalence was 54% and 62%, respectively.

The post-operative increase in systolic pressure in patients with aortic stenosis occurred mainly in those with a history of left ventricular failure. In those with aortic regurgitation or combined stenosis with regurgitation, diastolic pressure rose after valve replacement resulting in a prevalence of diastolic hypertension of 44% and 35%, respectively. Blood pressure changes were not predicted by the type of valve inserted nor its size.

Our data show that despite severe symptomatic aortic valve disease, systolic hypertension was common in aortic stenosis and diastolic hypertension was found in aortic regurgitation. This underlines the importance of blood pressure monitoring in patients following aortic valve replacement.

Introduction

All forms of aortic valve disease are known to be associated with abnormalities of blood pressure. Paul Wood’s textbook describes the increased pulse pressure with raised systolic and low diastolic pressures in patients with aortic regurgitation (AR) and the reduced pulse pressure characteristic of aortic stenosis (AS).¹ Thus AS systolic hypertension might be expected to be uncommon and in AR a raised diastolic pressure should not be encountered. However, we have been misled by a patient with severe lone AS who had severe hypertension.² Furthermore, the murmur of aortic regurgitation is found in a proportion of patients with diastolic hypertension³ and although this regurgitation was usually minor, progression necessitating aortic valve replacement (AVR) has been recorded.⁴ Transient increases in blood pressure are well documented immediately following cardiac surgery and in patients with AS raised blood pressure has been reported in about 10% of cases in the immediate post-operative period.⁵ There are, however, few long-term data on the effects of AVR.⁶ ⁷

The association between hypertension and aortic valve disease is not widely recognized. This prompted us to examine the prevalence of hypertension in patients who underwent cardiac catheterization for severe aortic stenosis and/or regurgitation and to investigate blood pressure changes resulting from aortic valve replacement.

Patients and methods

The records from the catheter laboratory of our district general hospital were examined retrospectively for a 10 year period to identify all patients with lone aortic valve disease without involvement of other cardiac valves. The present analysis was confined to those cases who subsequently underwent AVR. Two patients who died within 6 months of operation and 5 who developed paraprosthetic aortic valve leaks were excluded from the study. Data on cardiac symptoms, physical signs and the need for diuretic and/or antihypertensive drugs were recorded. For this analysis, only measurements of blood pressure obtained during the last outpatient clinic visit within the 6 months prior to cardiac catheterization and at follow-up between 6–12 months after AVR were analysed as these are

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Accepted: 9 October 1991
the blood pressure readings upon which clinical decisions are made. If more than one measurement was made the average values were used for analysis. Throughout, measurements of semi-recumbent systolic and diastolic phase IV (muffling of sounds), blood pressures were recorded mainly by one observer using standard mercury sphygmomanometers.

Patients with heart failure continued to receive their diuretic treatment as indicated and underwent cardiac catheterization only when they were improved and stable. At left heart catheterization, the peak systolic gradient across the aortic valve, the left ventricular end-diastolic pressure (LVEDP) and ascending aortic pressures were measured. Cardiac output (CO) was calculated by the direct Fick method and total peripheral resistance (TPR) derived from the CO and the mean intra-arterial blood pressure.

Patients were classified as having AS alone, AR alone or combined AS with AR. The degree of aortic regurgitation was quantified using a grading system based on left ventricular (LV) opacification during aortography. The criteria for lone AS were a peak systolic gradient of more than 30 mmHg across the aortic valve with zero or grade one aortic regurgitation. The severity of AS was confirmed by using Gorlin’s formula for aortic valve orifice area. Lone AR was defined as grade 2 to 4 aortic regurgitation with less than a 30 mmHg pressure gradient across the aortic valve. Combined AS and AR was defined as an aortic valve gradient of greater than 30 mmHg and aortic regurgitation of grade two or more.

In view of the differences in age and sex of the patients studied and the increase in age of up to 16 months during follow-up, blood pressure readings were adjusted for age and sex by the method of Pickering. This method was used because his data were, as in the present study, obtained using phase IV diastolic pressures in an outpatient survey where men and women were examined separately. Actual and adjusted readings (to the age of 55 years) are presented.

Statistical analysis was performed using Student’s t-tests for paired data, Chi-squared with Yates’ correction for discontinuity to compare frequencies and Pearson’s r for correlation coefficients.

Results

Of the 87 consecutive patients in the study, 38 had AS, 26 had AS/AR and 23 AR alone. The clinical features and investigative findings are shown in Table I. The cardiac catheter could not be passed into the left ventricle in 2 patients with AS. The mean aortic valve orifice area in the 28 patients with AS who had their CO calculated was 0.38 cm² (range 0.2–0.52) which confirmed severe stenosis.

Pre-operatively antihypertensive drugs were used in one patient although 20 were receiving loop diuretics which may have reduced their blood pressure. After valve replacement, 3 patients were given antihypertensive drugs of whom 2 had AR and one had AS with AR. Nine patients continued to take loop diuretics.

Mean blood pressure levels before and after surgery are shown in Table II. These data show that, pre-operatively, raised systolic blood pressures were present in 3 cases (8%) with AS alone, the diastolic hypertension was seen in 9 cases (24%). In patients with AR alone, systolic hypertension was, as expected, common being seen in 15 patients (65%). However, diastolic hypertension was also seen in 2 cases (9%). In patients with combined AS and AR, systolic hypertension was seen in 12 cases (46%) and diastolic hypertension was present in 3 (11%).

The WHO criteria for hypertension which are based on systolic and/or diastolic blood pressures were met by 10 (26%) patients with AS alone, 15 (65%) with AR alone and 14 (54%) with combined AS and AR. Of the cases with AS alone, 4 had intra-arterial systolic pressures of 160 mmHg or more, and one had a diastolic pressure of 95 mmHg. In patients with AR alone, intra-arterial systolic pressures were 160 mmHg or more in 10 cases although none had diastolic hypertension. In patients with combined AS and AR, intra-arterial systolic pressures were 160 mmHg or more in 3 cases but again none had diastolic hypertension.

After aortic valve replacement, there was no significant change in mean systolic or diastolic blood pressures in patients with AS alone (Figure 1). Systolic hypertension was now found in 9 patients (24%) of whom 2 had had raised systolic pressures prior to surgery. In patients with AR alone, average systolic blood pressures were reduced significantly in response to surgery and as expected there was a highly significant rise in average diastolic pressures (P < 0.001). Ten of these patients (43%) now exhibited diastolic hypertension. Patients with combined AS and AR showed a significant rise in diastolic (P < 0.05) but not systolic blood pressure in response to AVR and 16 cases (62%) now had hypertension by WHO criteria.

Amongst those meeting WHO criteria pre-operatively, 40% of AS patients remained hypertensive post-operatively compared to 54% of AR cases and 58% in the AS/AR group. In those without pre-operative hypertension, 21% of AS patients became hypertensive post-surgery compared to 40% of AR cases and 14% in the AS/AR group.

No differences in blood pressure, or change in blood pressure after AVR were found in patients with and/or without angina or syncopal attacks.
Table 1 Pre-operative clinical and investigation characteristics of patients with aortic stenosis, regurgitation or combined valve disease

<table>
<thead>
<tr>
<th></th>
<th>Aortic stenosis</th>
<th>Aortic regurgitation</th>
<th>Stenosis and regurgitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patients</td>
<td>38</td>
<td>23</td>
<td>26</td>
</tr>
<tr>
<td>Male/female</td>
<td>22/16</td>
<td>18/5</td>
<td>21/5</td>
</tr>
<tr>
<td>Mean age (years) at operation</td>
<td>57 (9)</td>
<td>53 (11)</td>
<td>43 (10)</td>
</tr>
<tr>
<td>Symptoms (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Angina</td>
<td>63</td>
<td>39</td>
<td>58</td>
</tr>
<tr>
<td>Exertional dyspnoea</td>
<td>76</td>
<td>78</td>
<td>100</td>
</tr>
<tr>
<td>Syncope</td>
<td>11</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>Symptomless</td>
<td>5</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>Previous left ventricular failure (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean ECG size (mm) (SV1 or 2 + RV5 or 6)</td>
<td>48 (17)</td>
<td>55 (13)</td>
<td>54 (19)</td>
</tr>
<tr>
<td>Mean aortic valve peak systolic gradient (mmHg)</td>
<td>100 (25)</td>
<td>6 (4)</td>
<td>67 (32)</td>
</tr>
<tr>
<td>Mean left ventricular end diastolic pressure (mmHg)</td>
<td>69–180</td>
<td>0–10</td>
<td>30–138</td>
</tr>
<tr>
<td>Mean cardiac output (l/min)</td>
<td>5 (1.6)</td>
<td>5 (1.6)</td>
<td>4.2 (1.3)</td>
</tr>
<tr>
<td>Mean total peripheral resistance (mmHg/min/l)</td>
<td>19 (5)</td>
<td>18 (7)</td>
<td>23 (8)</td>
</tr>
</tbody>
</table>

Figures in parentheses are standard deviations.

The rise in corrected systolic pressure following valve replacement in AS patients was confined to those with previous left ventricular failure (125 to 143 mmHg, \( P < 0.001; n = 28 \)). In those without failure systolic pressures were little changed (141 to 147 mmHg; \( n = 10 \)). In AS patients with prior left heart failure, the diastolic pressures were non-significantly reduced following AVR (84 to 80 mmHg) and were unchanged in those without heart failure (90 mmHg). In patients with AR, systolic pressure dropped and diastolic rose in response to surgery in both those with and without left ventricular failure. Most cases with combined AS and AR had cardiac failure prior to surgery.

Minor grades of aortic regurgitation associated with aortic stenosis did not influence systolic or diastolic pressure changes. Neither were they different in those given Bjork–Shiley (\( n = 58 \)) or Starr–Edwards prosthetic valves (\( n = 27 \)) in any disease category. The remaining 2 patients had homograft valves. No correlation emerged between valve size and pre- or post-operative blood pressure. As expected, those with AR required larger valves.

In patients with aortic stenosis a positive correlation was observed between the cardiac output and the height of the diastolic pressure (\( r = 0.54, \)

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**Figure 1** Individual systolic (●) and diastolic (○) age-corrected blood pressures measured in the outpatient clinic before and at least 6 months after aortic valve replacement for aortic stenosis, aortic regurgitation and combined stenosis and regurgitation. Horizontal bars represent the means. The fall in average systolic blood pressure following surgery in patients with aortic regurgitation was statistically significant (\( P < 0.05 \)) as was the rise in diastolic blood pressure in cases with aortic regurgitation alone (\( P < 0.01 \)) and combined stenosis and regurgitation (\( P < 0.05 \)).
Table II  Mean and (standard deviation) of blood pressure (mmHg) before and after aortic valve replacement and the percentages for cases in excess of various levels of blood pressure

<table>
<thead>
<tr>
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<tr>
<td>Number of patients</td>
<td>38</td>
<td>23</td>
<td>26</td>
</tr>
<tr>
<td>Pre-operative blood pressure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systolic</td>
<td>128 (21)</td>
<td>168 (34)</td>
<td>150 (31)</td>
</tr>
<tr>
<td>Diastolic</td>
<td>85 (12)</td>
<td>62 (19)</td>
<td>77 (16)</td>
</tr>
<tr>
<td>Systolic A</td>
<td>130 (23)</td>
<td>177 (37)</td>
<td>162 (49)</td>
</tr>
<tr>
<td>Diastolic A</td>
<td>85 (13)</td>
<td>63 (19)</td>
<td>77 (20)</td>
</tr>
<tr>
<td>% systolic A &gt; 160 mmHg</td>
<td>8</td>
<td>65</td>
<td>46</td>
</tr>
<tr>
<td>% diastolic A &gt; 95 mmHg</td>
<td>24</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>% A &gt; 160 and/or 95 mmHg</td>
<td>26</td>
<td>65</td>
<td>54</td>
</tr>
<tr>
<td>Post-operative blood pressure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systolic</td>
<td>142 (24)</td>
<td>155 (26)</td>
<td>145 (26)</td>
</tr>
<tr>
<td>Diastolic</td>
<td>82 (11)</td>
<td>89 (12)</td>
<td>84 (15)</td>
</tr>
<tr>
<td>Systolic A</td>
<td>144 (25)</td>
<td>161 (24)</td>
<td>156 (34)</td>
</tr>
<tr>
<td>Diastolic A</td>
<td>83 (12)</td>
<td>92 (13)</td>
<td>87 (16)</td>
</tr>
<tr>
<td>% systolic A &gt; 160 mmHg</td>
<td>24</td>
<td>44</td>
<td>54</td>
</tr>
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<td>54</td>
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<td>% A &gt; 160 and/or 95 mmHg</td>
<td>24</td>
<td>57</td>
<td>62</td>
</tr>
</tbody>
</table>

Suffix A indicates pressures adjusted to age 55 years by the method of Pickering. A systolic blood pressure >160 and/or a diastolic pressure of 95 mmHg or more is the WHO criterion for hypertension.

$P<0.01$) but not the systolic blood pressure. The systolic and diastolic pressures were not related to the gradient across the aortic valve, valve orifice area, LVEDP or TPR.

In aortic regurgitation, diastolic pressures were positively correlated with LVEDP ($r=0.45$, $P<0.05$) and the LVEDP correlated with the cardiac output ($r=0.54$, $P<0.05$). In patients with combined AS and AR, systolic pressure was negatively related to aortic valve gradient ($r=-0.57$, $P<0.01$) but unrelated to TPR, CO or LVEDP.

The aetiology of aortic valve disease in relation to the type of lesion was as follows; those classified as of degenerative aetiology all had tricuspid aortic valves with variable leaflet thickening, distortion, degeneration and calcification. The other rarer causes of AR included Reiter’s disease (1), Marfan’s syndrome (1), syphilis (1), chronic aortic dissection (1) and subacute bacterial endocarditis in previously normal valves (4).

Discussion

These data show that even in the presence of severe symptomatic aortic valve disease, both systolic and diastolic hypertension are common. Others have reported that 10% of their patients requiring AVR for calcific AS were receiving treatment for hypertension.\(^\text{11}\) Due to limited numbers it is difficult to be sure if the prevalence of hypertension was unduly common or if the two diseases simply co-existed. The true prevalence of hypertension might be higher since some patients pressures may have been lowered by depressed left ventricular function or diuretic therapy. However, the aetiology of aortic valve stenosis could be the key to a genuine association. The underlying pathology of AS in middle age is most commonly congenital bicuspid valves whilst senile degenerative calcification of tricuspid aortic valves predominates in the elderly.\(^\text{12,13}\) Both valvular and vascular degeneration, with decreased large artery compliance and increasing systolic blood pressure, might therefore co-exist and accelerate the degeneration in both sclerotic tricuspid and congenitally bicuspid aortic valves. In addition, the increased peripheral arteriolar resistance which occurs in hypertension could lead to dilatation of the aortic root and produce regurgitant flow which might then accelerate aortic valve degeneration. Aortic root dilatation has been associated with myxoid degeneration of the aortic cusps.\(^\text{14}\) However, the similar aetiology of the valve disease but different blood pressures seen here in those with AS and AS with AR suggests that the haemodynamic disturbances caused by the valve disease itself may be responsible for the blood pressure changes seen after AVR. In AS, patients with prior heart failure showed significant increases in systolic and reductions in
diastolic pressure. Left ventricular contractility is impaired in aortic valve disease with heart failure and following AVR this often returns to normal so that subsequent improved ventricular ejection could then explain rises in systolic pressure.15–17

Hypertension immediately following cardiac surgery appears to be mediated via cardiac reflexes and sympathetic nervous system, although the renin–angiotensin system and circulating vasopressin levels have been implicated.18–20 Hypertension following repair of aortic coarctation is associated with reduced arterial compliance, abnormalities of baroreceptor function and abnormal vascular reactivity consistent with a myogenic abnormality.21–23 It is not known if these mechanisms are responsible for the long-term elevations in blood pressure seen in AVD.

The highest age-adjusted blood pressures following AVR were seen in patients with either AR or AS with AR. Although the aetiology of these two types of valve malfunction was different, widened preoperative pulse pressure is a common factor. An in vitro arterial wall model suggests that elastic and collagen fibres are damaged more rapidly by pulsatile than continuous stress.24 In AR, high peak wall stress and maximal rate of change of the large arteries would produce increased cyclic stress over a long period which could result in arterial hypertension. Peak aortic flow velocity is higher in patients with combined AS and AR than in those with AR alone and this may offset the effects of cyclic stress. The high velocity blood jet creates a 'Venturi' effect which reduces the aortic wall lateral pressure as the pulse wave develops. Whilst a similar effect is seen in AS, the ejected systolic volume is smaller and aortic pressure rises more slowly. This may explain the differences in postoperative blood pressure in patients with AS compared with AR and AS with AR.

Elevation of blood pressure in patients with aortic valve disease is common, and may remain after AVR. Hypertension has its own associated morbidity and mortality and may also accelerate deterioration of homograft valves although it is unlikely to affect mechanical valves. These data emphasize the value of routine blood pressure monitoring at follow-up in patients undergoing aortic valve replacement. Our data suggest that ejection systolic murmurs in hypertensive patients may occasionally be associated with significant aortic stenosis and aortic regurgitation may be seen in patients with raised diastolic blood pressures.

Acknowledgements

We wish to thank Ms Fay Cox for secretarial assistance and Mrs Dilys Thomas for preparing the illustration.

References


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doi: 10.1136/pgmj.68.797.180

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