The purpose of this study is to determine the effects of variations in cardiac output upon the mean systolic left ventricular-brachial artery gradient in patients with aortic stenosis. The magnitude of this gradient varies with valve size, flow across the valve and possibly heart rate. The effect of these parameters has been investigated in patients with mitral stenosis. Since exertional dyspnea, angina and syncope are common in physiologically significant aortic stenosis, determination of the exercise aortic gradient is of considerable interest in evaluation of the mechanism of these symptoms. In principle, exercise gradient changes may result from alterations in left ventricular systolic pressure, brachial artery systolic pressure, or both factors.

**SECTION ON CARDIOVASCULAR DISEASES**

The Effect of Exercise upon the Mean Systolic Left Ventricular-Brachial Artery Gradient in Aortic Stenosis*

PHILIP SAMET, M.D., F.C.C.P., WILLIAM H. BERNSTEIN, M.D., and ROBERT S. LITWAK, M.D., F.C.C.P.

Miami Beach, Florida

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age (Yr.)</th>
<th>B.S.A. (M.²)</th>
<th>Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>G. And.</td>
<td>50</td>
<td>1.86</td>
<td>Rh. H.D. E.H. A.S. N.S.R. II C.</td>
</tr>
<tr>
<td>G. Woo.</td>
<td>37</td>
<td>1.81</td>
<td>Rh. H.D. E.H. A.S. N.S.R. III C.</td>
</tr>
<tr>
<td>S. Ber.</td>
<td>53</td>
<td>1.41</td>
<td>Rh. H.D. E.H. M.S. A.S. A.F. II C.</td>
</tr>
</tbody>
</table>

**TABLE 2—CARDIAC OUTPUT DATA DURING COMBINED HEART CATHETERIZATION**

<table>
<thead>
<tr>
<th>Patient</th>
<th>Vent. Rate (/Min.)</th>
<th>Cardiac Index (L./Min./M.²)</th>
<th>Stroke Vol. (ml.)</th>
<th>Oxygen Consumption (Ml./Min./M.²)</th>
<th>R</th>
<th>A.V.D.M. (Vol. %)</th>
<th>Saha percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>G. And.</td>
<td>Ra</td>
<td>68</td>
<td>2.94</td>
<td>80</td>
<td>.78</td>
<td>5.2</td>
<td>94</td>
</tr>
<tr>
<td></td>
<td>Ea</td>
<td>89</td>
<td>3.82</td>
<td>80</td>
<td>.99</td>
<td>8.8</td>
<td>96</td>
</tr>
<tr>
<td>G. Woo.</td>
<td>R</td>
<td>84</td>
<td>2.91</td>
<td>63</td>
<td>.87</td>
<td>5.6</td>
<td>93</td>
</tr>
<tr>
<td></td>
<td>E</td>
<td>101</td>
<td>4.18</td>
<td>75</td>
<td>.90</td>
<td>5.5</td>
<td>93</td>
</tr>
<tr>
<td>G. Smi.</td>
<td>R</td>
<td>68</td>
<td>3.93</td>
<td>103</td>
<td>.87</td>
<td>3.8</td>
<td>94</td>
</tr>
<tr>
<td></td>
<td>E</td>
<td>80</td>
<td>4.16</td>
<td>93</td>
<td>.68</td>
<td>6.4</td>
<td>96</td>
</tr>
<tr>
<td>S. Ber.</td>
<td>Ra</td>
<td>67</td>
<td>2.20</td>
<td>48</td>
<td>.97</td>
<td>4.6</td>
<td>98</td>
</tr>
<tr>
<td></td>
<td>Ea</td>
<td>88</td>
<td>2.91</td>
<td>47</td>
<td>1.02</td>
<td>7.6</td>
<td>97</td>
</tr>
</tbody>
</table>

a. Obtained during right heart catheterization only.

*From the Cardio-Pulmonary Laboratory and the Department of Medicine, Mount Sinai Hospital, Miami Beach, and the Departments of Medicine and Surgery, University of Miami School of Medicine, Coral Gables.
Methods and Materials

The physical characteristics and diagnoses in the four patients are given below (Table 1). Right heart catheterization, brachial artery cannulation and posterior percutaneous left atrial puncture were performed as previously described. Data were obtained at rest and during exercise in the course of combined right and left heart catheterization. Cardiac output was determined by the Fick principle.

The left ventricular-brachial artery gradient was calculated via planimetric integration of the systolic pressure difference between the left ventricle and the brachial artery during exercise.

FIGURE 1: Left ventricular and brachial artery pressures and systolic gradients in G. And. The gradient increases about 15 mm. Hg during exercise.
ventricular and brachial artery pressure curves, recorded from the same base-line at identical strain gauge sensitivities. At least six beats were studied for each gradient determination. Theoretically, determination of the left ventricular-aortic mean systolic gradient is preferable. In actual practice, however, the ventricular-brachial artery systolic gradient is only about 10 per cent less than the simultaneously determined ventricular-aortic systolic gradient.

**Results**

The cardiac output and pressure data are presented in Table 2, and Figs. 1 to 4.

The control left ventricular-brachial artery mean systolic gradients in G. And. ranged from 74 to 79 mm. Hg. During exercise the gradient increased to 95 mm. Hg and fell to 77 during recovery (Fig. 1). Cardiac output data during right heart catheterization alone earlier during the

**FIGURE 2:** Similar data in G. Woo. The gradient changes during exercise are minimal. Left ventricular end-diastolic pressures rise sharply in the course of exercise.
same catheterization revealed an exercise factor of 480. That is, the cardiac output during exercise increased 480 ml. for each 100 ml. increment in oxygen consumption. The normal range is 600-1000 ml. per 100 ml. increment in oxygen utilization. Systolic left ventricular pressure rose from control levels of 220 mm. Hg to exercise levels of about 245 mm. Hg. Left ventricular end-diastolic pressure was slightly elevated at rest and rose to more abnormal levels during exercise.

The control gradients in G. Woo. ranged from 76 to 88 mm. Hg (Fig. 2). There was no change during exercise. During early recovery the gradient was 92 mm. Hg. The exercise factor during combined right and left heart catheterization was 970 ml. Left ventricular systolic pressure rose slightly during exercise; left ventricular end-diastolic pressure rose markedly during exercise to 46 mm. Hg. Pulmonary edema did not develop during exercise despite this gross elevation in left ventricular end-diastolic pressure.

![Graph showing heart catheterization values](image)

**FIGURE 3:** Left heart catheterization values in G. Smi. A mild increase in left ventricular-brachial artery systolic gradient is noted during exercise.
The control gradients in G. Smi. (Fig. 3) ranged from 134 to 143 mm. Hg. During exercise the gradient rose to 158 mm. Hg, but returned to control levels during recovery. Left ventricular systolic pressures were about 285 at rest and rose slightly to 300 during exercise. No change was noted in left ventricular end-diastolic pressure during exercise. The exercise factor totaled 200 ml.

Severe aortic stenosis was present in the first three subjects. In the fourth, S. Ber. (Fig. 4) the predominant lesion was mitral stenosis; the aortic stenotic lesion was of little physiologic import. The control aortic

![Figure 4: Catheterization data in S. Ber. The percentage exercise increment in left ventricular-brachial artery systolic gradient is far less than that of the diastolic left atrial-left ventricular gradient.](http://journal.publications.chestnet.org/pdfaccess.ashx?url=/data/journals/chest/21363/)
systolic gradients ranged from 8 to 12 mm. Hg. No significant increase was noted during exercise. In contrast, the mitral diastolic gradient more than doubled during exercise. Left ventricular systolic pressure rose slightly during exercise; left ventricular end-diastolic pressure was unchanged. Left atrial mean pressure rose significantly during exercise. The exercise factor, during the preceding right heart catheterization alone, was slightly subnormal, 580 ml.

Discussion

The magnitude of the mean systolic left ventricular-brachial artery gradient may vary under the influence of a number of factors. Increase in blood flow during exercise had surprisingly little effect upon the magnitude of the systolic aortic gradient. This observation was noted even when the increase in output and stroke volume during exercise were significant, as in G. Woo. These data are in marked contrast to the large exercise increase in mean diastolic mitral gradient previously noted in patients with mitral stenosis even when the exercise cardiac output and stroke volume increases were small.

Other studies have, however, indicated that alterations in heart rate and or left ventricular filling will affect the aortic systolic gradient. For example in Fig. 5, the aortic systolic gradient is minimal or absent in the course of ventricular premature beats. The post-premature beat gradient is, on the other hand, considerably larger.
FIGURE 7: The increase in systolic gradient consequent to acetylcholine infusion and systemic arterial hypotension is readily noted in the same patient as in Fig. 6.

than the control gradient. Best to best variation in the aortic systolic gradient may be noted during atrial fibrillation.

Left ventricular pulsus alternans also results in alteration of the magnitude of the aortic systolic gradient. Variations in systemic arterial pressure result in changes in aortic systolic gradient (Figs. 6 and 7). Right and left heart pressures are recorded simultaneously in a patient with aortic and mitral stenosis. The moderate aortic gradient noted prior to intracardiac acetylcholine infusion increased sharply during acetylcholine infusion with the development of systemic arterial hypotension and the presumed decrease in peripheral vascular resistance.

The explanation for the minimal rise of the aortic systolic gradient during exercise despite sizeable elevations of cardiac output and oxygen consumption remains uncertain, but the data are in sharp contrast to the behavior of the mitral diastolic gradient under similar exercise conditions.

SUMMARY

Measurements of the mean systolic left ventricular-brachial artery gradient and cardiac output at rest and during exercise in four subjects with aortic stenosis were made in the course of combined right and left heart catheterization. Only minimal elevations were noted in the aortic systolic gradient during exercise despite significant flow increases in three of the four patients.

RESUMEN

La medición el medio gradiente sistólico ventricular izquierdo-arteria braquial y el rendimiento cardíaco durante el ejercicio y el reposo en cuatro sujetos con estenosis aórtica se hizo en el curso de la cateterización cardíaca combinada izquierda y derecha. Solo elevaciones mínimas se notaron en el gradiente sistólico durante el ejercicio a pesar de aumento significante del flujo en tres de los cuatro enfermos.

ZUSAMMENFASSUNG


REFERENCES